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Strengthening Radiation Protection of Workers – Twenty Years of Progress and the Way Forward

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Abstracts and Posters

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SESSION 1:

REVIEW OF STANDARDS AND RECOMMENDATIONS ON OCCUPATIONAL RADIATION PROTECTION AT THE INTERNATIONAL, REGIONAL, AND NATIONAL LEVELS: PROGRESS OVER THE PAST TWENTY YEARS AND EXISTING CHALLENGES

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Regulatory Control for the Occupational Radiation Protection

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Industrial Radiological Applications at Jordan Energy and Minerals Regulatory Commission

The establishment of a regulatory framework for the occupational radiation protection is one of the main responsibilities of the Energy and Minerals Regulatory Commission (EMRC) as a regulatory body in Jordan. EMRC has hosted several missions from the International Atomic Energy Agency, in particular the Integrated Regulatory Review Service Mission (IRRS), this mission recommended to improve the regulatory control over occupational exposures through the establishment and enforcement of regulatory requirements. EMRC has established specific requirements for the occupational exposure in line with the IAEA safety standards and international best practices. The paper that will be prepared in this regard will present the most important challenges faced by the Commission in the context of occupational exposures, regulatory requirements that have been established for the protection of radiation workers, the regulatory activities to ensure the compliance of facilities with the regulatory requirements, responsibilities of the licensees and registrants in planned exposure situations related to the occupational protection and description of occupational protection systems in industrial radiation facilities.

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Implications of the ICRU 95 Quantities for Swiss Personal Dosimetry Services: A Status Quo**

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The main objective of the revision of operational quantities for personal dosimetry as introduced in the ICRU Report 95 was to use more realistic human phantoms in the calculations of conversion factors between quantities, and hence to allow for more appropriate personal dose estimates, Hp, and skin dose estimates, Dlocal skin. The simplified geometries used in the past had led to over- or underestimates of the operational quantities Hp(10) and Hp(0.07) defined by the ICRU Report 51, in the low and high photon energy ranges (< 50 keV and > 3 MeV respectively). In practice, this means that dosimeters optimised for the ICRU Report 51's quantities will exhibit an over-response at photon energies <50 keV (predominantly used in medical applications) in terms of the ICRU Report 95's quantities, if no change in design or evaluation algorithm is adopted.
The objective of this work is to assess the photon response of the dosimetry systems used across Switzerland in terms of the operational quantities for external radiation exposure personal dose, Hp, and personal absorbed dose in local skin, Dlocal skin, defined in the ICRU Report 95. The responses of the dosimetry systems (angle and energy response) in terms of the new ICRU Report 95 quantities are calculated by combining their measured responses in terms of the ICRU Report 51 quantities and the conversion coefficients from air kerma to Hp and Dlocal skin, as done by Otto (2019), Hoeldmoser et al. (2020) and Bossin et al. (2022).
The dosimetry systems investigated include thermoluminescence (TL) systems based on LiF:Mg,Ti, Li2B4O7:Mn,Si, Li2B4O7:Cu and CaSO4:Tm, a BeO-based optically stimulated luminescence (OSL) system, a radiophotoluminescence (RPL) system based on Ag+-doped phosphate glass, and a direct-ion-storage (DIS) system. Therefore, the results are representative of the situation that many individual dosimetry services are facing following the changes introduced by the ICRU Report 95, and helps to evaluate the challenges ahead.

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Regulatory Requirements Regarding Occupational Exposure**

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Radiation Safety Directorate

The regulatory body established and enforces requirements to ensure that protection and safety is optimized, and the regulatory body enforces compliance with dose limits for occupational exposure through its authority provided in the legislation for inspection and enforcement.
The regulatory body established and enforces requirements for the monitoring and recording of occupational exposures in planned exposure situations.
There are established requirements for the licensees to be responsible for the protection of workers against occupational exposure and to ensure that protection and safety is optimized and that the dose limits for occupational exposure are not exceeded.
Dose limits are prescribed in the Regulation on the limits of exposure.
Regarding the potential exposure, in accordance with the Law, person may be exposed to ionizing radiation under different conditions, i.e. occupational exposure, public exposure and medical exposure. The provisions of the Law shall also apply to potential exposure, and emergency exposure Regulation on occupational exposure prescribes measurement of individual monitoring and ambient monitoring. In accordance with the provisions of this regulation, when the occupationally exposed individual in a legal entity, works at several working places with different ionizing radiation sources, this individual shall be obliged to use the same personal dosimeter. When the occupationally exposed individual works with ionizing radiation sources in two or more legal entities, each of these legal entities should provide him with separate personal dosimeter.
The degree of external exposure to ionizing radiation of occupationally exposed individuals when carrying out activities with ionizing radiation sources or other work activities where the use of personal dosimeters for individual monitoring is inappropriate, or the reading of the personal dosimeter is prevented for any reason, shall be estimated on the basis of the results from the monitoring of the working environment or of the results acquired in respect of another adequate occupationally ex- posed individual.
The investigation level shall be determined by the legal person for the practice with ionizing radiation sources that it carries out, and this level should not exceed the value corresponding to 3/10 of the monthly value of the dose in accordance with the annual value of the dose prescribed by the regulations on ionizing radiation protection and radiation safety.
There are requirements in the legislation regarding female workers, as necessary, for protection of the embryo or fetus and breastfed infants. There are also requirements regarding special arrangements for protection and safety for persons under 18 years of age who are undergoing training.
Also persons under the age of 16 years shall not be subject to occupational exposure, as well as special arrangements for protection and safety for persons under 18 years of age who are undergoing training are in Article 16 of the Law on ionizing radiation protection and radiation safety.

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Enhancement of National Regulatory Requirements for Occupational Radiation Protection based on Gap Analysis of International Standards and Challenges

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PNRA Regulations on Radiation Protection-PAK/904 Rev.0 were issued in 2004 and were based on International Basic Safety Standards for Protection against Ionizing Radiation and for Safety of Radiation Sources (BSS-115). Regulations-PAK/904 describe the regulatory requirements for occupational radiation protection that are applicable to all nuclear and radiation facilities in Pakistan. The International Commission on Radiological Protection published the recommendations for radiation protection and safety of sources (ICRP 103) in 2007. Subsequently, the IAEA revised BSS-115 and published General Safety Requirements (GSR Part 3) in 2014. PNRA initiated the process of revision of PNRA Regulations -PAK/904, Rev-0 in 2016 on the basis GSR Part 3 and issued revised Regulation- PAK/904, Rev-1 in 2020. GSR Part 3 introduces the concept of three types of exposure situations i.e. planned, existing and emergency exposure situations [1] and GSR Part 3 classifies radon expo- sure into occupational and public exposure. According to UNSCEAR Report 2008, the world average dose due to background radiation is 2.4mSv that is mainly due to radon [2]. The ICRP 103 expresses reference level as activity i.e. 1500 Bq/m3 for workplaces and 600 Bq/m3 for homes [3], whereas, GSR Part 3 recommends the activity levels of 1000 Bq/m3 for an occupational exposure, and 300 Bq/m3 for the public exposure. The new and revised requirements in Regulations PAK-904 includes; establishment of dose constraints for occupational exposure, calibration of radiation monitors from authorized service providers, establishment of radiation protection program and control of occupational exposure in remediation of areas with residual radioactive material [4]. Moreover, the revised Regulations-PAK/904 also include new values of dose limits for the lens of eye (i.e. 20mSv/y) based on GSR Part 3 and ICRP publication 118 and values of reference levels for radon to control occupational exposure at workplaces.

This paper describes, evolution of the regulatory requirements on radiation protection during the last two decades, gap analysis of BSS-115 and GSR Part 3, revision process of PNRA Regulations-PAK/904 and includes discussion on challenges in implementation of new requirements for existing exposure situations (such as assessment of exposure due to radon at workplaces etc.).

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Belarus Experience of applying the Dose Constraint for Occupationally Exposed Workers in National Regulations*, **

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By now the DC concept for occupational exposure has been widely used in various exposure situations, however, the comprehensive review of its practical implementation allows speaking that in many cases the used DC does not resemble DC as defined by the ICRP.
In the Republic of Belarus, the commitment of the source operator (employer for use) and the State Sanitary Supervision (hereinafter referred to as Gossannadzor) to establish DC for occupational exposure within frame of optimization of protection and safety is prescribed in the radiation hygienic regulations, effective from January 2012. Further a new Law of the Republic of Belarus “On radiation safety” put in force on June 18, 2020 updated the requirement on legislative level and authorized the Ministry of Health (hereinafter referred to as MoH) to set up the procedure for establishing and application of DC in the radiation protection system. In pursuance of the Law, the MoH developed and approved two documents, both based on ICRP and IAEA recommendations with due account to national regulatory experience.
The report is intended to contribute to the experience of introducing the concept of DC for occupationally exposed workers to the national regulatory framework for radiation protection and safety.

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The Role of Regulatory Body (FANR) in Strengthening Radiation Protection by controlling Occupational Radiation Exposure and Enhancing Training in Medical and Industrial Field

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FANR

The implementation of radiation safety regulations particularly in occupational exposure for both medical and industrial fields raises challenges for all regulators, health authorities, and users. In view of this, Federal Authority for Nuclear Regulation (FANR), the regulatory body in the UAE, issued series of regulations and guides since its establishment year in 2009. FANR adopted inter- national radiation safety regulations to ensure protection of public, radiation workers, patients and environment. It successfully completed number of IAEA peer review missions including the IRRS mission twice in 2011 and in 2015 and ORPAS mission during the past ten years. Since 2009, FANR started introducing licensees to regulations, regulatory guides, and license conditions, following a consistent graded approach in regulatory functions (authorization, review and assessment, inspection and enforcement). The goal of this paper is to demonstrate how FANR utilizes certain regulatory tools to achieve control of occupational exposures and how mandatory radiation safety training for workers assist to improve radiation safety culture in the UAE. In addition to, facing COVID -19 challenges and limiting the over exposure cases. This is implemented by establishing electronic national dose registry, development of national radiation safety training strategy associated with a range of training modules, national qualifications and list of temporary Qualified Experts in the UAE. The availability of regulation, regulatory control and obligate requirements of radiation safety training over all licensees lead to best understanding and implementing of occupational radiation exposure requirements.

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Some Inconsistencies in The Present System of Radiation Protection Quantities

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The system of radiation protection quantities has been developing for years, beginning with the introduction of the roentgen to assess the exposure to X-rays and gamma rays at the end of the 1920s. In the beginning, there was no clear distinction between the unit and the quantity and between what we now refer to as stochastic and deterministic effects. The unit roentgen was redefined several times and later attributed to the quantity of exposure. Since this quantity was limited to the quantification of only photons, later on, a universal quantity - absorbed dose - was introduced as a fundamental physical radiation quantity. Based on the dose, such radiation protection quantities as dose equivalent, equivalent dose, effective dose, and relevant operational quantities have been defined. During the years, the system of radiation protection quantities has been modified many times to reflect stochastic effects better, while not so much attention was paid to the quantification of deterministic effects. Problems appeared with multiple quantities used simultaneously and the continuous attempt to improve the relationship between physical quantities and biological effects. This situation resulted in too many quantities used today, many of which cannot be measured or monitored directly.
The paper discusses inconsistencies arising from too many different quantities currently used in radiation protection. Some problems related to the concept of the effective dose and equivalent dose on the one side, and the RBE-weighted dose on the other side, are outlined. Special attention is paid to the use of these quantities to assess the risk caused by the stochastic and deterministic effects taking into account specific conditions in the case of internal exposure and exposure due to high energy radiation. Some suggestions aimed at reducing the number of the present radiation protection quantities are presented.

SESSION 2:

MONITORING AND DOSE ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURES

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Gamma and Neutron Spatial Distribution Doses in Radioactive Waste Storage Facility

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Monitoring and dose assessment of external radiation for a radioactive waste storage facility in the Malaysian Nuclear Agency (Nuklear Malaysia) is part of Class G license requirement under the Malaysian Atomic Licensing Energy Board (AELB). The objectives of this paper are to obtain the distribution of radiation dose, create a dose database and generate a dose map in the waste storage facility after the rearrangement of waste packages and DSRS performed in 2021. The radiation dose measurement is important to fulfil the radiation protection program to ensure the safety of the workers. The result shows that the ALARA concept alongside time, distance and shielding principles shall be adopted to ensure the dose for the workers is kept below the dose limit regulated by AELB which is 20 mSv/year for radiation workers. This study is important for the improvement of the safe operation of Nuklear Malaysia as the national radioactive waste management organization.

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Local Radiation Dosimetry of Workers Method using Optically Stimulated Pulsed Luminescence and Monte Carlo Simulation**

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Background: This is the first study that has been done in Morocco with the aim of optimizing protection of workers in diagnostic radiology, by using Monte Carlo simulation and Optically Stimulated Luminescence (OSL).
Methods: Measurements have been performed OSL detectors to determine the dose received by workers.
Results: There was no statistically significant difference between dose simulated by GATE and those measured using the OSL ($P < 0.01$).
Conclusion: Monte Carlo simulation responses were suitable and could provide an accurate alternative for dose determination with non-uniform primary x-ray beams.

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Monitoring and Dose Assessment of Occupational Radiation Protection Exposures – The Nigerian Perspective*

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Planned, emergency, and existing exposure situations resulting in occupational exposure, requiring appropriate optimization of protection for doses reduction [1]. Effective monitoring of radiation workers involving use of ionizing radiation by NNRA has improved Radiation Protection in Nigeria [2]. The NNRA assesses external exposures of workers through DSPs from 2012 to 2020, with deployment of dosimeters. The AEDs of radiation workers from practices ranges (0.31-2.48)mSv/yr for 2012, (0.3 – 1.44) mSv/yr for 2013, (0.14 – 2.34) mSv/yr for 2014, (0.23 – 2.42) mSv/yr for 2015 and (0.04 – 2.07) mSv/yr for 2016, (0.08-1.64) mSv/yr for 2017, (0.05-2.34) mSv/yr for 2018, (0.38-1.28) mSv/yr for 2019 and (0.06-0.79) mSv/yr for 2020, while average AED ranges between (0.28 to 1.24) mSv/yr from 2012 to 2020 with overall average of 0.81 mSv/yr for 9 years under review, which are all presented in Table 1, Figures 1&2. The evaluated AED were found below of 20 mSv/yr limits, which by implication shows no radiological hazards to workers in Nigeria [3,4].
Keywords: Radiation Protection, Occupational dose, radiation exposures, effective dose

PRACTICES /YEAR (mSv)	ED 2012	ED 2013	ED 2014	ED 2015	ED 2016	ED 2017	ED 2018	ED 2019	ED 2020
Ind. Rad.	0.57	0.54	0.5	1.1	0.78	1.14	1.61	1.28	0.34
Nuc. Guage	1.26	0.71	0.25	0.64	1.15	0.63	1.39	0.89	0.79
Well Logging	0.34	0.3	0.14	2.42	0.85	Nil	1.43	0.5	0.19
GIF	0.95	0.86	Nil	1.45	2.07	1.64	1.9	0.38	Nil
Diag. Rad	1.1	0.47	1.64	1.41	0.58	0.6	0.34	Nil	0.17
Radiotherapy	1.22	0.35	0.55	0.92	0.41	0.08	Nil	0.5	0.06
Nuc. Med	Nil	Nil	Nil	1.84	0.04	Nil	2.34	1.17	0.16
Res. Reactor	2.48	1.44	2.34	1.11	1.86	1.33	1.18	1.27	0.79
Activities	0.31	0.4	0.36	0.23	0.15	0.42	0.05	0.47	0.21
Range	0.31-2.48	0.3-1.44	0.14-2.34	0.23-2.42	0.04-2.07	0.08-1.64	0.05-2.34	0.38-1.28	0.06-0.79
Average AED	**1.03**	**0.63**	**0.64**	**1.24**	**0.88**	**0.65**	**1.14**	**0.72**	**0.30**

Table 1: AED of all practices for 2012 to 2020

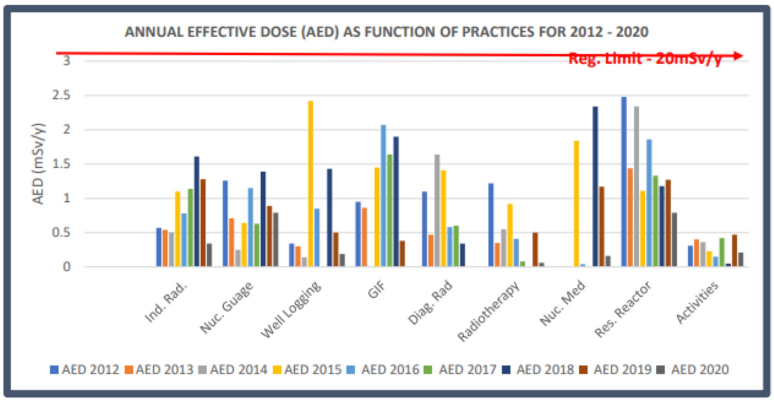

Figure 1: AED of practices for 2012 to 2020

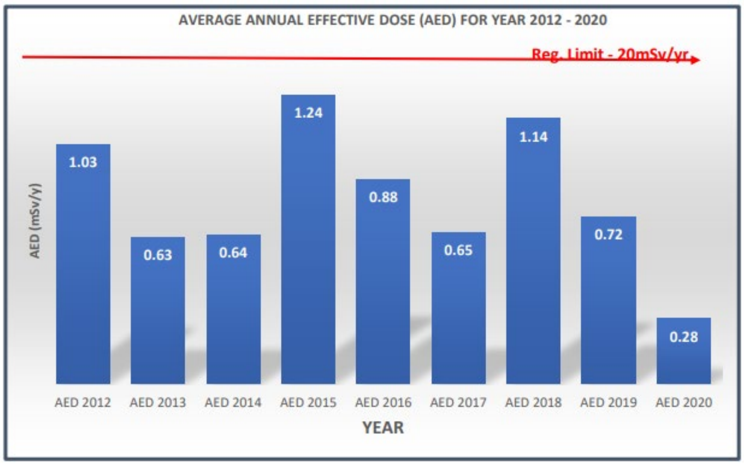

Figure 2: Comparism of AED for 2012 to 2020

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- AED - Annual Effective Doses; NNRA - Nigerian Nuclear Regulatory Authority; DSPs - Dosimetry Service Providers

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The Report of Annual Occupational Dose at King Chulalongkorn Memorial Hospital

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Background and Objective: As the tertiary hospital, King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand, has been providing extensive radiation diagnostic and thera- peutic services. The aim of this study was to monitor and assess the occupational radiation exposure in the department of radiology.
Methods: For the total of 580 radiation workers, the optical stimulated luminescence dosimeters (OSL) from Bureau of Radiation and Medical Device (Bangkok, Thailand) were employed to monitor the Hp(10), Hp(3), and Hp(0.07) for effective dose, equivalent dose of lens of eye, and skin, respectively. These personal doses were collected from October, 2020 to September, 2021. The workers were separated into the group of diagnostic, nuclear medicine, radiation oncology, and radiation worker in other departments with the number of 298, 33, 129, and 120, respectively.
Results and discussion: With the OSL minimum dose report of 0.1 mSv per reading, 103 from 580 workers received the doses lager than this value, at least one recording, were stated. For diagnostic group, about 10 percent of worker in this group received maximum occupational dose range up to 1.03 mSv per month. The maximum annual occupational dose was recorded from technologist who worked in Interventional unit with the value of 8.41, 8.80 and 8.96 mSv for Hp(10), Hp(3), and Hp(0.07), respectively. For nuclear medicine group, 26 from 33 workers had the maximum occupational dose range up to 0.5 mSv per month. The maximum annual effective dose, equivalent dose of lens of eye, and skin were equal at 1.47 mSv from one technologist. For radiation oncology group, the optical stimulated luminescence neutron dosimeter (OSLN) was used to expand the field of neutron measurement due to the operation of five 10 MV and one 15 MV linear accelerators and one proton therapy system. There were 14 from 129 workers received the maximum doses range up to 0.17 mSv per month. The maximum annual occupational dose of this group was about 1.15 mSv for each of Hp(10), Hp(3), and Hp(0.07). For radiation worker in other departments group, the maxi- mum effective dose from gastrointestinal nurse was 1.29 mSv per month which contributed to the annual occupational dose of Hp(10), Hp(3), and Hp(0.07) as 5.73, 5.73, and 5.57 mSv, respectively. The reasonable reason was found in the investigation without potential emergency situations. The descending order of the annual occupational dose was diagnostic (interventional unit), radiation worker in other departments, nuclear medicine, and radiation oncology.
Conclusion: The annual occupational dose within the occupational dose limit was reported. We enduring the radiation protection training and education in our hospital. The radiation safety officers (RSO) have been monitoring and assessing the radiation exposure for both occupational and public.

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Occupational Radiation Protection in Mali: Case Study of Dose Limit Exceedings**

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In Mali, Occupational Radiation Protection was relaunched in 2005 after many years of interruption. Since then the service has been continueously delivered with no interruption. This result was achieved due to IAEA decision at that time to provide the Regulatory Body (since there was no private service provider) with the necessary training and equipment: TLD reader (HAR- SHAW 4500) and accessories (TLD cards, external irradiator, nitrogene generator, etc.). Then in 2010, the Government of MALI, provided AMARAP (the RB) with a new TLD Reader (HAR- SHAW 6600plus) and more TLD cards. About 650 radiation workers are (or were) monitored either individually or collectivly on a quarterly basis (montly for radiotherapy department).
Some regulations have been adopted by the government Mali (Decree N°06-488 /P-RM of 23rd November 2006 replaced by the Decree n°2014-0931/P-RM of 31st December 2014) which cover the subject of occupational radiation protection. And there are some provisions about how regulations require the implementation of radiation protection programs by end-users as well as provisions about requirements for the authorization of technical services (service providers) related to occupational exposure.
Up to now some workers are monitoring for external exposure and effective dose (Hp(10)). There is neither extremity dosimetry nor internal dosimetry yet. One staff member participated in the 2nd International Conference on ORP, held in Vienna in December 2014 with a contributed paper intittled "Occupational Radiation Protection in Medicine in Mali".
Since this 2nd conference, in our laboratory, we have developped internal procedures which include some dose reference levels such as: Recording Levels (any dose obtained after subtraction of travel dose) and Investigation Levels. But dose limits not to be exceeded are given by regulations (decree of 2014) which are compliant GSR-Part3.
However, we noticed:

- one case of investigation levels being exceeded, and
- two cases of average dose limits being exceeded in facilities working of sectors.

The aim of this paper is:

- to chare the levels of recorded doses,
- to chare our experience of how we dealt with these situations: actions taken by the RB and by the end-users,
- and to seek for advice on what would had been the best way to proceed.

1. Cases of high doses: According to our procedures, our Investigation Levels are:
2. for Hp(10): 6 mSv quarterly and 2 mSv monthly;
3. for Hp(0,07): 25 mSv quarterly and monthly.

According to our regulations, for adult workers, doses limits are:

- an average effective dose of 20 mSv per year over five consecutive years (100 mSv in five years) and a maximum of 50 mSv in a single year;
- an average equivalent dose to the eye lens of 20 mSv per year over five consecutive years (100 mSv in five years) and a maximum of 50 mSv in a single year;
- an equivalent dose of 500 mSv per year to the extremities. But we noticed:

- One facility with Hp(10) twice higher than the investigation level
- Two facilities with Hp(10) over 20 times annual

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Implemantation of Dosimetric Biology for Certification According to ISO 15189 Standard

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IRSN medicine laboratory is currently waiting for the label from the French accreditation Committee (COFRAC), belonging to International Laboratory Accreditation Cooperation. Indeed, it is mandatory in France to get the certification through EN ISO 15189 standard for laboratory medicine.
Biological dosimetry is a method to quantify the exposure and to perform a dose assessment following a suspected radiation exposure. For this purpose, a specific cytogenetic analysis is required. A sample of blood from the victim is needed in order to culture the lymphocytes and isolate the mitotic metaphase chromosomes.
The dicentric chromosome is a damaged chromosome. It results from the misrepair of breaks in two different chromosomes. It carries two centromeres instead of one centromere in normal chromosomes. These cytogenetic anomalies are almost pathognomonic for acute radiation exposure upper than 100mGy. They are counted by a trained Biologist with a dedicated microscope linked with a specific software.
The confidence interval of the dose received by the victim is then estimated via dose-response calibration curves.
In France, biological dosimetry is part of the laboratory medicine exams. Performing biological dosimetry is highly regulated, therefore accreditation is mandatory.

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Assessment of Whole-Body and Collective Dose of Occupational Radiation Exposure in a Gamma Irradiation Facility (2009-2018)

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Individuals working in both radiological and nuclear facilities are often exposed to sources of ionizing radiation resulting in some level of occupational hazards. Appropriate levels of radiation protection of workers are essential for the safe and justified use of radiation, radioactive material and nuclear energy. Occupational exposure to radiation workers in a Gamma Irradiation Facility has been analysed for a 10 year period between 2009 and 2018. The data from 2009-2018 were used to compute the average annual effective and the annual collective dose. The results show that the total deep dose, Hp(10), received by the radiation workers for the ten year period ranged between
10.21 mSv to 16.05 mSv with a mean of 13.97 mSv. It also showed that the average annual effective dose ranged between 0.65±0.04 mSv to 1.98±0.30 mSv with a mean of 1.51±0.42 mSv. The Collective dose ranged between 10.92 man.Sv to 33.66 man.Sv with a mean of 23.76±8.32 man.Sv. This shows that the risk due to radiation exposure of the workers is within the recommended and regulatory limits.

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Development of Automated Air Monitoring System for Airborne Radioiodine: The Way to reduce Occupational Exposure for Nuclear Medicine Workers

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Iodine-131 (131I) is the most common therapeutic radiopharmaceutical used in nuclear medicine. However, 131I can be converted to a volatile form (also called "airborne radioiodine") which can cause a potential internal exposure to the radiation workers via inhalation process. Consequently, monitoring of airborne radioiodine is recommended by IAEA (International Atomic Energy Agency) and ICRP (International Commission on Radiation Protection). In practical, the monitoring processes are included the sampling of air with adsorption media using charcoal cartridge. Then, the cartridge is transferred to measure in the calibrated radiation detector. Consequently, these processes take time, and the result is not in real-time. Therefore, the aim of this work was to design and develop the automated air monitoring system for airborne radioiodine in nuclear medicine. In this work, the 3-inch sodium iodide activated with thallium (NaI(Tl)) scintillation detector with single channel analyzer (SCA) was used to detect the airborne radioiodine collected from the charcoal cartridge. To calibrate the counting system, the in-house standard was fabricated using standardized 131I from the Secondary Standard Dosimetry Laboratory (SSDL) of the Office of Atoms for Peace (OAP). The automate system was assembled as well as the in-house software was developed for system operation. After mechanical evaluation, the equipment was tested at the Division of Nuclear Medicine, Faculty of Medicine Ramathibodi Hospital. During the testing period, the equipment was measured several testing scenarios. The results were satisfactory. However, minor problems were reported for example the high background counts due to improper shielding and software errors. In conclusion, this product can be used to monitor and measure the airborne radioiodine with the automated and real-time result.

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Occupational Integrated Management System of the Brazilian Caldas Uranium Mine Facility**

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This work describes some aspects of the implementation of the radiological protection program developed specifically for the Caldas uranium mine facility. The items described are: the responsibilities of the staff concerning their radiation exposures; a brief description of the sources and practices; the occupational dose levels of the site which are at maximum 0,9 mSv/year due to mining material exposure and up to 8 mSv/year due to exposure to the external radioactive material stored in Cal- das facility; the occupational controls and monitoring programs; and the occupational radiological protection training program.

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Occupational Dose Assessment for Workers Involved in the Management of Radioactive Waste Generated from Remediation of Adaya Site**

Author: Nabeel Al-Tameemi

Adaya site is one of the radioactively contaminated sites in Iraq that require remediation. Adaya site has been selected in 1991 as a temporary burial location for destroyed machines and equipment in Al-Jazeera site for conceal from international monitoring. The Adaya burial site lies on the eastern slope of a mountain ridge located about 27 km west of Al-Mosul city and about 23 km south of the Al-Jesira uranium refinement facility, where most of the buried contents originated. The damaged equipment and cemented rubbles generated from destruction of Al-Jazeera site have been buried in hurried manner in deep geological cracks, covered by soil. Most of the dumped materials and equipments are contaminated by yellowcake (ammonium diuranate (ADU)), UO2, and UO3.
Soil samples were collected according to a predetermined pattern based on such factors as accessibility and the features of the site. Forty-eight soil samples have been collected for radiometric analysis, as being representative of the entire site. Collected samples were packaged, labeled with the location code, date and time of sampling, sealed in a plastic bag and shipped to the analytical laboratory for analysis. At the laboratory, the samples were dried, weighted, and counted using a high purity germanium detector with multichannel analyzer to provide radionuclide-specific results.
Two computer codes were used for evaluating the potential radiological impact of radioactive waste management operations:
- SAFRAN (Safety Assessment Framework) version 2 (2020) is used for estimating radiation doses to workers involved in sorting, compaction, packaging and storage of radioactive waste arising from Adaya site remediation.
- TSD-Dose Version 2.22 (1998) computer program developed by Argonne National Laboratory is used for estimating radiation doses to facility workers from some waste-handling operations for the radioactive waste generated from anticipated remediation activities for Adaya site. The operational activities modeled using TSD-Dose included: transport of the generated radioactive waste to the storage facility, receiving and sampling of the waste.
It is apparent from the radioanalytical data that 234mPa and 235U contamination levels in identified hot spots vary considerably within wide range in the surface soil and there is a high deviation to the mean observed level due to non-uniform surface soil contamination. The radiometric analysis results identify 13 and 7 soil samples (of 48 samples) containing 234mPa and 235U radioactivity levels, respectively, significantly above the remaining areas, i.e. hot spots or non-homogenous contamination. The potential radiation doses to personnel involved in radioactive waste management activities during normal conditions vary depending on the tasks they perform. Results of the dose assessment using SAFRAN and TSD-Dose indicated that no worker would receive a radiation dose of more than 2 mSv/y for the entire quantity of radioactive waste. The total dose estimates to the workers as a consequence of radioactive waste management activities (2 mSv/y) are well within regulatory limit (20 mSv/y), indicating that it is highly unlikely that the receiving, sampling, sorting, packaging, transportation and storage of the produced radioactive waste resulted in significant radiological health impacts to the waste management workers.

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Assessment of Occupational Radiation Dose Exposure in One of the Referral Hospitals in Kenya*, **

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The objective of this study was to assess the occupational radiation dose data of the radiation workers in the radiotherapy and radiology departments for a period of two years, 2019/2020 and 202/2021. The dose reports were evaluated to identify the dose distribution of each identified sub-group, total number of monitored radiation workers, annual whole body dose (Hp(10)). The radiation workers were divided into the subgroups: Radiologists, Radiation Oncologists, Physicists, Radiographers and Radiation Therapy Technicians. The TLD system used by the hospital comprises of Harshaw 8800 Dosimetry Reader and LiF:Mg,Ti (TLD 100) dosimeters from Thermofisher Scientific. The maximum effective dose recorded was 18.05 mSv and 1.79 mSv in period 2019/2020 and 2020/2021, respectively. This is within the stipulated recommended whole body dose limit by the International Commission for Radiological Protection (ICRP).

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Monitoring the Lens of the Eye and Extremity of Radiation Workers in Bangladesh**

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The use of ionizing radiation in the nuclear medicine and cardiology departments are increasing in Bangladesh. Nuclear medicine workers are getting higher radiation dose comparing to other workers in medical procedures because nuclear medicine workers used to handle unsealed radioactive sources. Extremities for example fingers of the hands of radiation workers in nuclear medicine is usually exposed to higher radiation comparing to other parts of the body because it is unshielded and close to the source. In 2011 ICRP recommendation, dose limit for lens of the eye of radiation workers has been significantly reduced from 150 mSv/yr to 20 mSv/yr, averaged on five consecutive years, with provision that any single year maximum dose 50 mSv. Cardiologists are also getting high dose in lens of the eye because they need to stand close to the patient and patient is the main source of the scattered radiation. 45 radiation workers working in five large nuclear medicine departments of Bangladesh were monitored using ring TL dosimeters for consecutive two years. Each worker was worn two ring TL dosimeters at left- and right-hand fingers and the monitoring period was varied from 01-03 months. Lens of the eye equivalent doses of 14 radiation workers working in 3 interventional cardiology departments in large hospitals of Dhaka city were monitored using headbands for one year. The calculated left and right hands doses were varied from 1.609-105.071 mSv/yr and 1.587-81.176 mSv/yr respectively. It is observed that radiation worker working in isotope dispensing rooms, gamma camera rooms and thyroid laboratories are exposed more radiation than those working in other laboratories. The equivalent dose for lens of the eye of Cath Lab workers were ranged from 0.938-85.714 mSv/yr. Cardiologists were received higher equivalent dose comparing to the radiographers and nurses. Nuclear Medicine and Cardiology departments Staff should be more conscious on radiation protection as per national regulations and international recommendations for minimizing radiation exposure. Periodic training on radiation protection & safety to be arranged in order to implement the ALARA principle.

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An Application and Improvement Study of CR-39 Personal Neutron Dosimeter

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As a passive neutron personal dosimeter, CR-39 solid state nuclear track detector is convenient, cheap, insensitive to gamma and beta rays and has strong anti-interference ability and better response to fast neutrons. A method of neutron dose measurement with CR-39 solid state nuclear track detector is established, consisting of detector preprocessing, neutron irradiation, chemical etching and track reading. A performance experiments are carried out on the CR-39 detector according to the international standard ISO21909-1. The results show that the CR-39 solid state nuclear track detector has good repeatability, batch homogeneity, dose linearity, time stability and environmental stability. By adopting the method of adding the polyethylene and boron converter to CR-39 detector, the optimization design is carried out to improve the energy response of fast neutrons and expand the energy detection range. A set of personal neutron dose measurement methods based on the CR- 39 solid track detector has been established by using Monte-Carlo method. To conform the personal neutron dose measurement method, an experimental comparison study is made by using the CR-39 to measure the neutron dose in standard Am-Be, Cf, D2O moderated Cf neutron source radiation field, which the neutron dose distributions were well known. The comparison result shows the deviation of the neutron exposure dose obtained by this measurement method from the actual exposure does not exceed 12%, which has high feasibility and accuracy.

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Research Status and Development of Neutron Detector**

Author: Hengchun Zhao

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With the development of nuclear industry, neutron detection has been playing a more and more important role in radiation protection of workers. Scintillator detector, semiconductor detector and gas ionization detector are the most commonly used neutron detectors. Gas ionization detector has the characteristics of irradiation resistance, simple preparation and convenient use. Scintillation detector has the characteristics of high detection efficiency and high sensitivity. Semiconductor detectors are characterized by high energy resolution and small size. Due to the shortage of 3He, scientists are actively carrying out new detectors including boron-coated straw tube neutron and lithium-doped scintillators to replace 3He neutron detector. These new detectors will further advance radiation protection of workers.

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A Method of Tracking Workers Contaminated with Radioactive Materials by Visual Recognition Based on YOLO3

Author: Chongyang Wang

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Workers can be unintentionally contaminated with radioactive materials when they work in radioactive environment. To detect this situation in time, a method is proposed to real-time detect and track workers with radioactive substances under stable background radiation conditions. In this method, visual recognition based on YOLO3 was used to recognize and track the source carrier, obtain the path information of the carrier by which the source-detector distance can be calculated. A cylindrical 3in.×3in. NaI(Tl) detector was used to monitor the variation of counting rate. According to the inverse ratio of the counting rate to the square of the distance, it is theoretically possible to attribute the source to a single person by comparing the variation rate of the counting rate with the variation rate of the square of the person-detector distance. This paper used Locality In-between Polylines (LIP) to measure the similarity of the curves generated by the variation of counting rate and the square of distance over time1. To make the coincidence between the counting rate and the distance more accurate, it is necessary to remove the background counting rate. In addition, the deviations due to scattering and detector geometry shape must be considered. Through the test and simulation of specific application sites, the empirical formula of the variation of these deviations with distance can be fitted. It was proved that the correlation degree between the variation of counting rate and the variation of distance can be significantly improved by modifying measured counting rate. There are always workers whose path information is similar to the source carrier, multiple workers with high similarity will be identified simultaneously, even though some of them are not contaminated, then we can use other more precise methods to detect the actual carrier. It was proved that contaminated workers can be accurately detected by the above method.

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Design and Development of Gamma Camera based on LaBr3 (Ce) Crystal Coupled SiPM Array

Author: Yan Li

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The location of radioactive material is critical for the radiation protection of workers in the field of nuclear industry. During the overhaul of the nuclear power plant or the decommissioning detection of the nuclear facility, since the distribution of the radioactive material in the pipeline is not known in advance, it is necessary to use the detection technology for determining the location information of the radioactive source. Radiographic imaging technology is a new technology in the field of nuclear radiation detection. It can detect radioactive substances in the field of view from a long distance and give a two-dimensional distribution image that cooperate with an optical camera to intuitively indicate the location of hot spots. In radiographic imaging technology, coded aperture imaging technology are the current mainstream imaging technologies, which have been successfully applied in the fields of nuclear security, nuclear industry, and nuclear medicine. Because of its good angular resolution, strong anti-interference ability, and high efficiency, the coded aperture imaging system has advantages in applications with high dose rates such as the nuclear industry. In order to meet the needs of the nuclear industry for imaging systems with high dose rate, high energy resolution, miniaturization, and strong anti-interference capability, a coded aperture imaging (CAI) system based on LaBr3(Ce) crystal-coupled SiPM arrays is proposed in this paper.

The CAI system includes four parts: the coded aperture collimator, the position sensitive detector, the data acquisition system, and the terminal display. The modified uniformly redundant array (MURA) aperture was selected due to its significant improvements to SNR of the reconstructed images compared with randomly distributed arrays. tungsten-nickel-copper alloy with 99% tungsten content was selected to make the aperture with an 7×7 loop nesting MURA pattern to modulate the incident particles. the size of a single pixel is 7mm×7mm×7mm. The detector part is composed of 8×8 LaBr3(Ce) crystal strips which the size of a single pixel is 6.4mm×6.4mm×20mm. The photoelectric conversion device uses ARRAYC-60035-64P array SiPM produced by Onsemi Company, which is composed of 8×8 C-60035 pixel SiPM. The LaBr3(Ce) crystal array is coupled with the SiPM array through silicone grease to form a detector module. The data acquisition system uses IDEAL's ROSMAP-MP, which can simultaneously acquire 64-channel analog signals. After completing the entire coded aperture imaging system, we performed a series of tests of detector performance and imaging performance. The average energy resolution of 64 crystal strip pixels is 4.96%, of which the best and worst energy resolution is 3.92% and 5.91%, respectively. The projection map of (Am-241, Cs-137, Co-60) detectors was decoded and reconstructed using the direct convolution algorithm, and the results were all accurately reconstructed the position of the radioactive source. The test results show that the coded aperture gamma imaging system can clearly image radioactive sources and has the ability to image radioactive substances on site.

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Silicon PIN-photodiode and CsI(Tl) Scintillator in Application to a Portable Dosimeter**

Author: Yu Wang

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ICRP has recommended an equivalent dose limit for the eye-lens be 20mSv per year, averaged over defined periods of 5 years, with no single year exceeding 50mSv. The reduction of the limit for occupational exposure for the eye-lens has significant implication in view of the application to planned exposure situations for the different areas of occupational exposure and needs adequate approaches for eye protection and eye dose monitoring.

A portable dosimeter for personal dose equivalent Hp(3) measurements based on silicon PIN-photodiode coupled to CsI(Tl) scintillator was designed and tested in this paper. The composition structure of the dosimeter is shown in the figure below. Silicon semiconductor detectors are mainly operated in current or pulse mode to collect the charge produced by radiation interactions. Current mode was selected for this dosimeter. A transresistive, non-polarized amplification current-to-voltage conversion stage was designed and built to amplify the PIN diode signal. The electronics is based on a Texas Instruments operational amplifier and provides a closed loop gain of 108 at zero frequency. The output voltage is directly proportional to the photocurrent generated in the photodiode by radiation interactions. A Monte Carlo simulation of the detector was performed with the GEANT4 code in order to model and fully understand, in particular, the impact of the sensor casing on the low energy response of the device.

The Hp(3) dosimeter was tested in a reference radiation field of narrow spectrum X-ray and 137Cs nuclide sources with an ISO standard plate phantom. The conventional values Hp(3) on the test point of the reference radiation fields were calculated using the air kerma Kair and the conversion coefficients Hp(3,ɑ) recommended by ICRP 116 recommendation. The Kair can be measured by standard ionization chamber dosimeter. Then the conventional true value Hp(3) on test point was provided and compared with dosimeter measured values. Dose rate measurement accuracy is better than 40% in range 10μSv/h-10mSv/h due to the special preamplifier circuit with low input bias current. The batch-to-batch reproducibility of different batches of diodes and scintillators was also experimentally investigated, showing a linear correlation between PIN-photodiode readout and the conventional true value Hp(3) of the reference radiation field. Therefore, this portable dosimeter based on silicon PIN-photodiode and CsI(Tl) scintillator appears promising for the eye-lens dose monitoring.

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Design and Performance Test of an Eye Lens Dosimeter C-lens

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Recently, with the dose limit of eye lens reduced, a series of problems in research, monitoring, protection and evaluation, have gradually attracted attention. The dosimeter of the eye lens plays an important and foundational role in this circle. This paper mainly focuses on an eye lens dosimeter named C-lens.

Firstly, the type of eye-lens dosimeter, one single LiF:Mg,Cu,P elements with a plastic shell, was chosen. Secondly, with MC simulation method, the energy response and angular response of the dosimeter were optimized and improved by adjusting the thickness, material and shell shape of the dosimeter. Then, the prototype and final dosimeter was completed by 3D printing and injection molding respectively. Finally, the radiation performance of C-lens was tested in a radiation metrology station, which is an IAEA Sub-standard Lab.

The results show that the non-linear response was less than 6% within 0.01 to 100mSv, relative energy response (normalized to 661keV) for photons was between 0.80 and 1.25 in the range of 20.3 to 1250 keV, and the relative deviations of angular response (normalized to 0°) was less than 4%when the incident angle was less than 60.

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Application of Microwave Communication in Individual Dose Monitoring and Collective Dose Optimization

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Occupational radiation exposure occurs in many nuclear-related applications. The daily operation and maintenance of nuclear facilities is the main contribution of plant workers, including the use and maintenance of nuclear medicine equipment, the monitoring and inspection of the environment and working conditions inside and outside the factory, Maintenance and replacement of equipment and fuel on the island during the overhaul, status monitoring of dose hot spots, etc. However, since most of the current dose rate meters and detectors in the factory do not have microwave communication functions, the staff can only record manually or use the localized storage function of the instruments And the radio walkie-talkie will transfer and save the collected data. Using meters with microwave communication modules to remotely transmit the information collected by these devices (including the current serial number of the device, placement location, time information and dose information), it can effectively replace many manual data recording and transmission functions, and realize personal dose monitoring At the same time, it can effectively reduce the collective dose.

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Study on Detection Efficiency Response of Standing Whole-Body Counter Based on Multi-Size Voxel Phantoms

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Background
The standing whole-body counters are widely used for in-vivo measurements, such as ORTEC-StandFAST, CANBERRA-FASTSCAN, CIRP-StandWBC. They are mainly designed to quickly and accurately measure internal contamination of radionuclides with medium and high photon energy. The physical phantoms such as BOMAB, IGOR, sBCAM have been used for whole-body counting calibrations. However, these simplified phantoms cannot fully represent all the characteristics of the human body, furthermore, the phantom parameters are based on the reference human body, which cannot represent workers with different body shapes and sizes. To date, there is a lack of understanding about the detection efficiency response as a function of phantom sizes and photon energy.

Methods
The Monte Carlo method was used to simulate and analyze the detection efficiency response of standing whole-body counter to multi-size voxel phantoms. The whole-body counter is ORTEC-StandFAST II. The multi-size voxel phantoms are Chinese adult male individualized voxel phantoms, with a height range of 155cm~185cm and a weight range of 42kg~103kg; The photon energy range is 80kev~1836kev. In this paper, the body build index (BBI,) is introduced to analyze the influence of human body size on the detection efficiency response of whole-body counter. [Results] Compared with the detection efficiency of the calibration phantom, the relative deviation range of the detection efficiency response of the whole-body counter to other sized voxel phantoms is -20.15%~33.03%. A function was also found that related detection efficiency to BBI and photon energy. Based on this function, The deviation of detection efficiency between the calculated value based on this function and the simulated value is within -4.41%~8.15%.

Conclusion
This paper presents a study on the detection efficiency of standing whole-body counter obtained from Monte Carlo simulations of multi-size voxel phantoms. The results show that the detection efficiency of whole-body counter largely depends on the phantom size, and the function can be used to modify the efficiency calibration results for a given individual, which can effectively improve the measurement accuracy of the whole-body counter.

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Analysis on Characteristics of Occupational Radiation Source Items during Ap1000 Unit Overhaul

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According to the physical characteristics of Chinese adult male reference person (170cm, 70kg), the digital model of Chinese adult male reference person (CRAM) was surface-sourced and simply modified, and then segmented by horizontal slicing. The lower side of the seventh cervical vertebra C07 has been selected as the segmentation baseline, which was segmented upward and downward respectively, with the layer thickness of 2.5cm and 3cm. This model contained layered arms and legs. After repairing the sliced digital mode, FDM 3D printing rapid prototyping was performed on organs of each layer, including whole-body bones (excluding metacarpal bones and fingers / phalanges bones), skin, brain, eye crystals, left and right lungs, heart, liver, large and small intestines, left and right kidneys, etc. With these rapid forming layer cutting organs as the mold type, the silicone outer mold and glass fiber reinforced plastic sleeve mold were turned out respectively, and more than 200 sets of various molds were produced. Finally, the radiation tissue equivalent materials were used for layered pouring. The palms, soles, fingers, and toes of the model only contained soft tissues without bones. Different organs were stained with different stains. Each layer of the model was drilled by a CNC machine, with hole diameter of 5 mm and hole spacing of 2.5 cm and 3 cm.
Four self-developed radiation tissue equivalent materials were used in this model: soft tissue (muscle tissue with 10% fat), lung, cartilage and hard bone. The soft tissue and lung materials were based on polyurethane (TPU), and the bone materials were based on epoxy resin (E). Compared with ICRP-23 standard model, ICRU-46 standard model and tissue equivalent gas, the relative deviation of density and effective atomic number of soft tissue materials is less than 10%, and the relative deviation of electron density is less than 2%. Compared with the results of the line fading coefficients calculated by the relevant recommended values in ICRP-23, the deviation of the line fading coefficients is less than 5% for the 241Am γ rays of 59.54KeV and 17.61KeV.

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Impact of the New ICRU Operational Dose Quantities EURADOS Evaluation and Recommendations**

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As part of its strategic research agenda, the European Radiation Dosimetry Group, EURADOS (www.eurados.org), contributes to the development and understanding of fundamental dose concepts, such as operational quantities. Accordingly, EURADOS has carried out a project to evaluate the impact of the new ICRU operational quantities and to make recommendations for their application. The EURADOS report analyzes the impact that the new quantities will have on: radiation protection practice; calibration and reference fields; European and national regulation; international standards; and, especially, dosemeter and instrument design. The conclusions are that, while there are some advantages to adopting the new quantities, it is likely that the costs of adapting instruments and dosemeters will be significant. These costs will arise either from necessary alterations to design or from need to r4eplace obsolete types. For these reasons the period of adoption of the new quantities will be protracted.

The definitions of the new quantities are more closely aligned with those of the protection quantities effective dose and equivalent dose. The same calculational, anthropomorphic phantoms have been used, together with full-transport numerical calculations. New operational quantities for extremity, skin and eye lens dosimetry are based on absorbed dose, thereby anticipating developments in the protection quantities.

The new quantities cover a wider range of radiations and energies than before. For medical interventional procedures, the current overestimates compared to effective dose will be removed. The definitions of the new operational quantities are better aligned with those of the protection quantities and no longer depend on arbitrary constructs such as the ICRU sphere.

One drawback concerns the use of full-transport calculations. For photons in particular, in any practical situation, primary radiation beams will be contaminated with secondary charged particles – in this case, electrons. Calibration and type-testing laboratories can only ensure common conditions by ensuring charged-particle equilibrium (CPE). CPE conditions are closely linked to use of the kerma approximation for calculating conversion coefficients. Therefore ICRU have included alternative coefficients, calculated using the kerma approximation, in their report. It is these kerma-approximation coefficients that will be used in the vast majority of photon dosimetry.

Our report includes extensive analysis of the response of existing dosemeters and instruments in terms of the new quantities. The costs of adapting to the new quantities are likely to be significant, although further work is needed to establish the costs more precisely. Other impacts, for example in terms of updating international standards, are broadly as expected. The adaptation can be phased over a period of years, although in view of the instrument and dosemeter costs, this period could be decades and planning should begin at an early stage. We also comment on other aspects: for example, we recommend that, despite the apparent reduction in doses that will occur for medical diagnostic / interventional procedures, radiation protection measures should not be relaxed because the values of the protection quantities will not change.

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Development of a New Skull Phantom for Calibrating in Vivo Measurements of Pb-210

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The internal exposure dose estimation formula is E=I·e(g), where I is the intake, and e(g) is the dose coefficient. Therefore, the intake I directly determines the committed effective dose, and the main purpose of internal exposure monitoring is to obtain the value of the intake I by measuring the retention. In order to improve the accuracy of the intake I, a more effective measure is to calibrate the counter to improve the measurement accuracy of the retention. In this paper, a new anthropometric skull phantom has made for skull counter calibration, and carried out calibration of the skull counter. The phantoms' head circumference of is 56.18cm, the total head height is 23.31cm, the maximum head breadth is 15.76cm, and the maximum head length is 19.23cm. conforms to the reference Chinese male . The phantom consists of bone substitute and soft tissue substitute, the soft tissue substitute is polyurethane, and the hard bone substitute is a mixture of epoxy resin and calcium carbonate. At 46.5keV, the relative deviations between the mass attenuation coefficients of the two tissue equivalent materials and the reference values in the ICRP23 report are 0.86% and -2.98%, respectively. The relative deviation of the mass attenuation coefficient of brain tissue and soft tissue at 46.5KeV is 5.03%, so soft tissue substitute can be used instead of brain tissue. The phantom was made by pouring. The mold is made by 3D printing.

In order to restore the bone-seeking nuclide distribution, the paper decided to use the point source to simulate the surface source by evenly distributing it on the skull surface. The solution of the radioactive source is dropped on the filter paper, and then the filter paper is cut and attached to the corresponding position of the skull, and the skull is suspended in the head mold. After the positioning is completed, soft substitute is poured and the radioactive source is sealed. The radioactivity of the Pb-210 is 4203Bq. The skull counter uses an electrically cooled HPGE. The measurement was carried out in a low-background laboratory. In order to ensure the consistency of multiple measurements, a limit device was designed for the phantom. The detector plane was close to the scalp during measurement. By 3 replicate measurements, the average detection efficiency was 0.00501 cph/Bq.

In this paper, an anthropometric skull phantom that conforms to the reference Chinese male is designed and manufactured. Using this model, the efficiency of the skull counter can be calibrated, so as to provide support for the accurate acquisition of Pb-210 retention.

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Personal Online Dosimetry using Computational Methods: The PODIUM Project and the Future of Active Dosimetry**

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Individual monitoring of workers exposed to external ionizing radiation is essential to allow application of the ALARA principle and follow up of the official dose limits. However, large uncertainties still exist in personal dosimetry, especially for neutrons and for inhomogeneous fields. Also, many practical problems exist for personal dosimetry, with many dosemeters getting lost and the reluctance of many workers to wear one or more dosemeters.
The objective of the PODIUM project is to improve personal dosimetry by an innovative approach: the development of an online dosimetry application based on computer simulations without the use of physical dosemeters. Operational quantities, protection quantities and radiosensitive organ doses (e.g. eye lens, brain, heart, extremities) will be calculated based on the use of modern technology such as personal tracking devices, flexible individualized phantoms and scanning of geometry set-up. When combined with fast simulation codes, the aim is to perform personal dosimetry in real-time.
Parallel to this, a different approach was planned with pre-calculated fluence to dose conversion coefficients for phantoms of different statures and postures.
We applied and validated the methodology for two situations where improvements in dosimetry are urgently needed: neutron workplaces and interventional radiology. An online application in which we calculate individually the level of occupational exposure is developed. For that purpose, the spatio-temporal radiation field, including its energy and angular distribution, needs to be known. We use input from dose monitors in the neutron workplace and radiation dose structured reports (RDSR) from the x-ray machine used in interventional radiology and we capture real movements of exposed workers and transfer this to the calculation application.
This paper will describe the achievements of the PODIUM projects in this new approach for personal dosimetry. We will show the results from the validation and test measurements in different hospitals, and in 2 workplace fields with significant neutron exposure.
The availability of the proposed online personal dosimetry application shall overcome the problems that arise from the use of current passive and active dosemeters. Such limitations include the uncertainty in assessing neutron and photon doses when part of the body is shielded, the delay in calculating the doses and the situation where workers position dosemeters incorrectly. In addition, it will increase awareness of radiation protection among workers and will improve the application of the ALARA principle.

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Assessment of the nuclear medicine personnel occupational exposure to radioiodine in Thailand**

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In Thailand, the diagnostic and treatment of hypothyroidism and thyroid cancer using radiopharmaceutical with iodine-131 (I-131) is widely performed. The utilization of large quantities of I-131 in nuclear medicine has been recorded and regulated by the Office of Atoms for Peace, Thailand. Although workplace safety regulations have been established, a review of reported data of routine handling of the radionuclide could result in a significant risk of occupational exposure of the workers chronically intake and intact to unsealed radioiodine. To ensure safety uses of the radiopharmaceutical to be aligned with national regulation and international standards, the radiation biology group under the regulatory support division of the Office of Atoms for Peace performed dose assessment for nuclear medicine personnel and radiation workers in Thailand. By measuring and evaluating the radiation dose of nuclear medicine practitioners using internal dosimetry tools including direct thyroid measurement and aerosol sample analysis, thus, ensuring the safety of I-131 exposure enters the body of nuclear medicine operators. Additionally, this raises awareness of the relevant stakeholders to understand the importance of routine monitoring iodine-131 content and ultimately use it to improve work or analyse the cause of radiation exposure.
To determine the safety of using iodine-131 Nuclear Medicine Agency The worker is required to measure and assess the radiation dose from within the body according to the criteria specified in the IAEA Safety Standards Series No.RS-G-1.2 and the Nuclear Energy for Peace Act, No.2, B.E. 2016. This work will present methods and results from 4 year-monitoring and dose assessment for the nuclear medicine personnel and radiation workers in Thailand and how these results were communicated to relevant stakeholders and applied in the workplace to improve occupational radiation protection safety.

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Accredited Proficiency Testing and Calibrations at the Service of Radiation Protection**

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The Council Directive 2013/59/EURATOM[1] points out the importance of periodical calibrations, quality assurance as well as the recognition of radiation protection services and experts. Already in 2009, the RP 160[2] gave the basis for procedures and criteria for mutual recognition of approved dosimetry services in Europe. Nevertheless, in Italy, the European Directive has been implemented only in 2020[3], subsequently this recognition process has just started. Specifically, for radon measurement providers, some indications were given about the requirements for the service recognition, including the compliance with the ISO 17025[4] standard.
In this context, the Laboratory of Radiation Metrology (LMR) of the Politecnico di Milano has organized its activities to offer accredited proficiency testing (PT) schemes, compliant with the standard ISO 17043[5] and calibration services for radiation protection practitioners.
The LMR hosts two calibration centers: the ionizing radiation laboratory (X and gamma beam facilities) and the radon laboratory.
The ionizing radiation laboratory, accredited since February 1999, performs calibrations using the reference radiation qualities specified in the ISO 4037-1[5] standard for the following dosimetry quantities: kerma in air, rate of kerma in air, equivalent personal dose, rate of equivalent personal dose, equivalent of environmental dose and rate of equivalent environmental dose.
The radon laboratory is equipped with a 2 m^3 radon chamber, built according to IEC 61577-4[6], that allows carrying out active instrument calibrations and exposures of passive devices. The radon laboratory was accredited in March 2021.
The increasing number of individual monitoring services (IMS) and radon monitoring services (RMS) demands not only for calibration facilities but also for proficiency testing providers (PTP).
Hence, to connect the calibration activity with the increasing request of inter-laboratory comparisons, the LMR undertook the ISO 17043 accreditation process to become a PTP both for external dosimetry and passive radon detectors. The accreditation for the personal and area dosimetry scheme was obtained in November 2021, and in 2022 the first accredited PT for extremities dosemeters is taking place.
Meanwhile, the pilot inter-laboratory comparison for radon passive devices started in summer 2021 and is expected to end in April 2022 with the publication of the final report. Consequently, in spring 2022, the LMR will be examined to get the accreditation extension also for this PT scheme.

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Radiation Monitoring System at the Enterprises of Uranium Mining by ISL Method**

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Uranium in the Republic of Kazakhstan is mined by the enterprises of NAC Kazatomprom JSC by in-situ leaching method. The sources of radiation-hazardous factors are natural uranium, which occurs at all stages of the technological chain. External exposure occurs largely in areas where uranium is concentrated in a large volume, during the transportation of uranium. Long lived radionuclide dust can be contained in occupational dust, mainly in areas where there is a dry circulation. Sources of radon and its decay products appear together with uranium when it is extracted from the earth interior, and since the pumping of pregnant solutions goes through pipelines to technological equipment. In addition, sources of internal exposure can be radioactively contaminated materials if handled incorrectly.

Radiation monitoring
The schedule of radiation monitoring is developed taking into account the technological chain, the places of radiation-hazardous factors, as well as the degree of their impact on personnel and the environment. As a rule, radon and its decay products is monitored in the shop of processing of pregnant solutions in automatic mode displaying the information on the board, the power of gamma radiation in the workplace is determined from daily measurements at the main workplaces to quarterly measurements in the territory around production sites.
Radiation monitoring equipment
The radiation monitoring equipment used must be certified for use on the territory of the Republic of Kazakhstan, in accordance with the legislation, it passes annual verification by a certified organization, as well as calibration before starting work in accordance with the manufacturer's recommendations.

Qualification of personnel
In accordance with the legislation, mandatory training is carried out for all personnel involved in working with ionizing radiation sources. Separate requirements are imposed on employees of the units that carry out and are responsible for radiation monitoring. All employees of such units have professional training, the employees appointed responsible for radiation control are certified by the authorized state body in the field of atomic energy use. Certification is carried out once every three years.

Dosimetric control
TLDs are used to determine the dose of external exposure. They are used by all workers. For individual works, when an excess in the dose of external exposure may occur, when evaluating newly introduced production capacities, or when eliminating radiation accidents, the use of direct-indicating electronic personal dosimeters is provided. The dose of internal exposure is determined based on radiation monitoring data and the time spent by personnel at specific sites.
The uranium content in bioassays is analysed at ISL enterprises. However, legally, at the moment, the data from the analysis of bioassays are not the source of calculating the dose of internal radiation, but allow us to assess the control measures applied.

Continuous improvement
The level of radiation exposure at ISL enterprises is consistently low, the level of the average radiation dose is about 1.5 mSv/year, taking into account natural background. Measures are being taken to increase the competencies of personnel, as well as the use of scientific developments that reduce the radiation impact on personnel.

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High Dose Records in Thailand – Problems and Ways Forward to Solutions

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Thailand has been using ionizing radiation for more 120 years, beginning with the use of x-ray in 1898. However, dose limits for occupational exposure were not established in a Thai regulation until 1961, after the enactment of the Atomic Energy for Peace Act of 1961. The current dose limits are prescribed in the Ministerial Regulation on Radiation Safety of 2018, issued under the Nuclear Energy for Peace Act of 2016. Even with the regulated dose limits, recent dose records still show that occupational exposure for several practices is very close to, or sometime exceeding, dose limits. These high dose records do not reasonably correspond to the nature of activities being performed. Therefore, for the first time in Thailand, a project on high dose records has been initiated to find out the root cause of this high dose records problem. The project is also aimed to determine dose constraints specific to occupational exposure of major practices. The paper will present how the dose survey of occupational exposure is conducted in this project, and how this project will possibly offer solutions to this high dose records problem in Thailand.

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Practical Implications of the New Dose Limit to the Lens of the Eye in Inhomogeneous Radiation Fields**

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1 Dosimetry department
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Due to statement and recommendation of ICRP [1], a lower dose limit regarding equivalent dose to the lens of the eye was introduced in both IAEA and EU Basic Safety Standards. The limit was lowered from 150 mSv/year to 20 mSv/year. Considering this new dose limit the Swedish nuclear facilities identified a need to monitor worker´s eye lens doses in order to ensure compliance.

Nuclear facilities in Sweden, in cooperation, identified specific work tasks where extra monitoring of the eye was needed. These were situations where the eye is more exposed than the rest of the body due to inhomogeneous radiation fields.

During 2018-19 Forsmark NPP identified several different work tasks and it is an ongoing work and we still monitor several work tasks.

For measurement of equivalent dose to the eye Forsmark NPP uses dosimeters from Public Health England Personal Dosimetry Service (PHE PDS).

The results from 2018 and 2020 [2][3][4] in this study, show that for certain work categories, at boiling water reactors, the equivalent dose to eye lens can exceed the effective whole body dose, measured by passive TL-dosimeter, by up to 50 %. Thus can dose to the eye lens be limiting when ensuring compliance with dose limits. Results for work on Control Rod Drive Mechanisms (CRDM) showed a high tendency for a higher dose to the eye than the effective whole body dose. For other work groups there was little or no difference between the eye dose compared to effective whole body dose. This shows that it is important to continue identifying risk tasks in the facility and investigate different work forces in risk of higher dose to the lens of the eye than the effective whole body dose.

- During 2020 396 measurements equivalent dose to the eye lens, Hp(3) at FKA, [4].
- In total 251 measurements dose ≥ 0,5 mSv, [4].
- In total 193 measurements dose showed Hp(3) > Hp(10), [4].

The results indicate that nuclear facilities need to monitor workers, especially itinerant workers. For correct measurements and analysis, it is important to continue to identify risk tasks in the facility, assign dosimeters to the right individuals and make sure workers wear the dosimeter in a correct manner.

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Characteristics of a PADC-based Neutron Dosimetry System developed at PSI**

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Several systems for neutron dosimetry using PADC (CR-39) detectors are commercially available and widely applied for personal dosimetry. These systems, however, generally rely on undisclosed algorithms and predefined detector types which limits the research applications or the ability to evaluate different detector materials with the same system.
To read out different PADC materials in the same reader, apply custom-made converters or specific track filtering techniques, a new neutron dosimetry system was developed at the Paul Scherrer Institute (PSI).
The objective of this work is to show the current status and characteristics of the system, which automatically identifies and scans 100 PADC detectors per frame using motorized stages and a microscope setup with a CCD camera. The system autofocuses on the detector surface through parameters obtained from a combination of grayscale analyses and fast Fourier transformations of the images.
A sequence of GPU-based morphological operations are applied to each image to identify elements appearing like neutron-induced tracks, which are coarsely filtered depending on the track parameters. Further track parameters are computed during the post-processing where the tracks in 6-10 calibration and background detectors are analyzed to create reference distributions of track parameters. Based on these reference distributions, a track resemblance value is evaluated for each element extracted from the detector images, and the element is eventually rejected or accepted as a track. Hence, as the dose algorithm relies on the unique set of reference track parameter distributions, it is independent of a specific detector material, converter, or etching procedure.
The new neutron dosimetry system at PSI is able to scan different PADC detector types, separate the track densities detected below converters, and evaluate the dose of commercially available detector materials.

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Dose Assessment of Occupationally Exposed Workers in Montenegro: An Overview**

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The aim of this study is to estimate the effective doses to workers occupationally exposed to ionizing radiation in Montenegro. Montenegro is a small, developing country with 660 000 population, the use of radiation sources being limited to common medical applications and a few industrial ones, with estimated 620 occupationally exposed individuals. 98 persons belong to Category A (controlled persons). Centre for Eco-toxicological Research in Podgorica, acting as a technical support organization to regulatory authorities, is the first and only institution in the country performing personal dosimetry service (since2007). To assess doses two methods were applied:

(1) the measurement of the ambient equivalent dose, H*(10)using ionization chambers routinely utilized during workplace monitoring; and (2) the measurement of the personal equivalent dose, Hp(10), using thermoluminescent dosemeters routinely utilized during individual monitoring. Annual doses are given for a period of five consecutive years (2014-2020). The highest annual value of the personal equivalent dose, Hp (10), was found with a practitioned in anghiography department, amounting to 8.3 mSv. The results show that estimated doses are well below annual dose limits of 20 mSv for the occupational exposure.

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Eye Lens Dose, Seven-Year Period Monitoring Results: The Greek Experience**

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Following the recommendation of the International Commission on Radiation Protection (ICRP) and European directive 59/2013 as transposed into the Greek legislation in 2018, the annual dose limit for the lens of the eye was reduced from 150 mSv/year to 20 mSv/year. Moreover, according to the regulations, one of the conditions to consider an exposed worker as Category A is to receive an equivalent dose greater than 15 mSv per year for the lens of the eye.

Meanwhile, the dosimetry department started pilot studies in 2014 to identify exposed workers, mainly in the medical sector, who were liable to receive exposure higher than the level of 15 mSv per year. The distribution of eye lens dosemeters started to be performed in routine basis. During the past 7 years, 170 persons are routine monitored using eye lens dosemeters. The majority, 85% are medical doctors, 9% nursing staff, 5% technicians, and 2% others. Regarding the workplaces 67% of them work in interventional cardiology, 21% in interventional radiology and 12% in radiology, nuclear medicine, and other fluoroscopically guided interventional procedures.

Considering the results of the measurements and in order to assist the authorized parties in the development of the radiation protection programme for the exposed workers, especially with regard to the part of monitoring of the lens of the eye, EEAE has published simple guidelines in the form of a flow chart in order to address the issue of monitoring, the estimation of the equivalent dose and the use of protective shielding.

In the current work, a first analysis of the results for the exposure of the lens of the eye is presented based on the occupational categories. The results helped the regulatory authority address the relevant issues in the published guidelines. An outline of the guidelines is also presented.

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New Reference Field for Testing Radiation Protection Dosemeters in Pulsed High-Energy Photon Radiation and the Link to the New European Metrology Network for Radiation Protection**

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Radiation facilities need to meet the legal and normative requirements for radiation protection. This applies also to modern accelerator facilities used in science, technology, and medicine. The radiation protection safety of such accelerators is currently ensured by dosimetric measurements with area dosemeters. However, the dosemeter's suitability for these high-energy and pulsed radiation fields is usually not tested according to the state-of-the-art in science and technology due to the lack of suitable reference fields. In order to address this, PTB aims to establish a new reference radiation field allowing for measurements traceable to national standards within a project funded by the German Federal Office for Radiation Protection (BfS)[(1)]. This field can be used for tests, development and verification of existing or novel dosimetry systems.

Type-testing is usually performed with energies up to 7 MeV in continuous radiation fields. As the response of radiation protection dosemeters can be affected by pulsed radiation, e.g. due to dead time effects, the international standards for testing dosemeters in pulsed fields of ionizing radiation (ISO/TS 18090-1 and IEC TS 63050) were established. However, a reference field similar to the fields typically expected behind (weak) shieldings of medical accelerators is non-existent. Within the German project "Establishment and characterisation of a reference field for ensuring radiation protection at accelerator facilities in medicine and research and for testing and calibrating of corresponding measuring instruments" [(1)] such a reference field has been established. Within this characterized pulsed photon reference field, dose rates occurring behind (insufficient) shielding of medical and research accelerator facilities can be realized. The field is based on a commercial medical linear accelerator at PTB. It is generated behind a 2 m-thick concrete wall with a composition typical used for radiation shielding.

The absence of a suitable reference field as described above has been a noticeable gap in the metrology infrastructure, both nationally and internationally. During a workshop within the EMPIR project 19NET03 supportBSS[(2)] this absence was also identified as a gap in the European metrology infrastructure. International awareness to the existing deficiency of radiation protection dosemeters in pulsed fields of ionizing radiation has also been raised. These gaps will be introduced into the new strategic research agenda (SRA) of the European Metrology Network for Radiation Protection approved by the General Assembly of EURAMET in June 2021[(3)].

In this presentation, results from the characterization of a new suitable reference field will be shown. This includes ambient dose rate measurements using a traceably-calibrated secondary standard ionization chamber as well as photon spectra determined using a passive few-channel spectrometer and Monte Carlo simulations. Information about the European Metrology Network for Radiation Protection will also be included.

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[2] The project 19NET03 supportBSS has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. 19NET03 support BSS denotes the EMPIR project reference.

[3] https://www.euramet.org/european-metrology-networks/radiation-protection/

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Design and Performance Test of an Eye Lens Dosimeter C-lens

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Recently, with the dose limit of eye lens reduced, a series of problems in research, monitoring, protection and evaluation, have gradually attracted attention. The dosimeter of the eye lens plays an important and foundational role in this circle. This paper mainly focuses on an eye lens dosimeter named C-lens.

Firstly, the type of eye-lens dosimeter, one single LiF:Mg,Cu,P elements with a plastic shell, was chosen. Secondly, with MC simulation method, the energy response and angular response of the dosimeter were optimized and improved by adjusting the thickness, material and shell shape of the dosimeter. Then, the prototype and final dosimeter was completed by 3D printing and injection molding respectively. Finally, the radiation performance of C-lens was tested in a radiation metrology station, which is an IAEA Sub-standard Lab.

The results show that the non-linear response was less than 6% within 0.01 to 100mSv, relative energy response (normalized to 661keV) for photons was between 0.80 and 1.25 in the range of 20.3 to 1250 keV, and the relative deviations of angular response (normalized to 0°) was less than 4%when the incident angle was less than 60°.

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Computational Anthropometric Pregnant Female Phantom Library for Fetal Dose Assessment in Occupational Radiation Exposures

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Due to the high radio-sensitivity of the fetus, the accurate estimation of fetal organ dose and its radiation risk assessment are crucial for radiation protection for pregnant females in occupational radiation exposures. Computational phantoms have been widely used in radiation dosimetry while their reliability strongly depends on the anatomical description and physiological characterization of represented subjects. In this work, we aim to build the first phantom library for pregnant females and fetuses for more reliable and accurate radiation dosimetry for pregnant workers.
Materials and Methods: Computed tomography (CT) images of the abdominal and pelvic regions of 46 pregnant females were segmented by experienced medical physicists. The segmented tissues/organs include the body contour, skeleton, uterus, liver, kidney, intestine, stomach, lung, bladder, gall bladder, spleen and pancreas for maternal body, and placenta, amniotic fluid, fetal body, fetal brain and fetal skeletons for the conceptus. The Non-Uniform Rational B-Splines (NURBS) surface of each identified region was constructed manually in 3D modeling software. The Hounsfield unit (HU) values of each identified organs were measured in the CT images and converted into the tissue density. The organ volume was further adjusted according to the reference measurements for developing fetus recommended by World Health Organization (WHO) and International Commission on Radiological Protection (ICRP). A series of anatomical parameters, including femur length (FL), humerus length (HL), biparietal diameter (BPD), abdominal circumference (FAC) and head circumference (HC), were measured and compared with WHO recommendations.
Results: The first phantom library for pregnant workers was established while the anatomical parameters of each model consist with the selected individuals with gestational age varying from 8-weeks to 35-weeks.
Conclusions: The constructed anthropometric computational models are consistent with those of the corresponding individuals. The resulting virtual pregnant females can be used in radiation dosimetry studies to improve the reliability of fetal organ dose and radiation risk assessment. The easiness of deformation and displacement of NURBS surface also makes the studies of understanding the effect of maternal postures, fetal postures and positions on radiation dose calculations convenient.

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Radiation Dose Assessment at the Secondary Standard Dosimetry Laboratory (SSDL) of the Ghana Atomic Energy Commission during Irradiation**

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In Ghana, the responsibility for providing adequate protection of workers against radiations rests with the employer. It also behooves the worker to take all reasonable measures, for example by avoiding unnecessary exposure, to keep his/her own radiation exposure and that of others to the minimum consistent with their duties. Monitoring of working conditions and individual monitoring forms the main components of any radiation protection programme. Most often workplace monitoring is ignored because workers are confident that the type and activity of sources use do not pose any danger, once laid down procedures are followed. This denies the workplace of monitoring data that can be used in emergency situations to estimate doses. The researchers used a Canberra survey meter calibrated for H*(10) to measure the ambient dose equivalent rate distribution within the Ghana Secondary Standards Dosimetry Laboratory (SSDL) in Ghana and subsequently determined the effective annual doses under varying conditions in the laboratory. The highest ambient dose recorded was whilst the source was irradiating, is 8.04 µSv/h. The highest annual effective dose determined is 9.8543 mSv which is 19.7% of the recommended limit of 50 mSv. The distribution of radiation levels in the SSDL is determined to be acceptably safe and satisfactory. Radiation Protection Institute should set up a unit that will coordinate workplace monitoring in the institute. This is necessary because the SSDL is sandwiched by other laboratories, offices and boardroom.

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Monitoring and Dose Assessment of Occupational Radiation Exposure for Zimbabwean Workers: A Decade of Experience**

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Radiation Protection Authority of Zimbabwe

In the past 10 years Zimbabwe has seen an increase in technology that uses radiation sources and related devices, and this has resulted in the need for a robust occupational radiation protection infrastructure. The Radiation Protection Authority of Zimbabwe (RPAZ) boasts of 2 state-of-the-art reader systems namely the Landauer Semi Manual InLight OSL (Optically Stimulated Luminescence) Reader and an automatic Harshaw 6600 Plus TLD (Thermoluminescent Dosimeter) reader. The TLD reader system uses the LiF (MgTi) crystal, TLD-100 and the OSL reader system uses Al2O3:C crystal, InLight OSL for external exposure monitoring of operational quantities Hp (10) and Hp (0.07). Both systems have an embedded algorithm for evaluation of doses.The regulator registered around 500 workers in the first year of individual monitoring work in 2011 and tremendously grew over the years with the current figure standing at 4000 plus registered workers. The register includes workers from the industrial, medical applications and research applications as shown in the table below.

Table 1: Number of workers registered for individual monitoring since 2011 Year Number of Registered Workers Industrial Medical Research
2011 519 102 7
2013 1553 753 27
2015 1806 1207 39
2017 1986 1353 42
2019 2043 1506 44
2021 2585 1570 51

The regulatory body has over time increased its efforts to ensure adequate occupational radiation protection requirements are in place for all users of radiation generating devices and equipment to provide assurance for health and safety for workers. The IAEA (International Atomic Energy Agency) has been offering immense support to the regulatory body individual monitoring laboratory quality assurance programmes through training and the Regional Intercomparison exercises which have been participated in since 2013 up to the year 2021.
Since the gazetting of the NORM (Naturally Occurring Radioactive Material) regulations in 2011, a plan is in place for dose assessment for NORM workers using information from the ongoing baseline studies and characterization of NORM Industries. In line with that, RPAZ (Radiation Protection Authority of Zimbabwe) team started participating in trainings offered by the IAEA to map a way forward as far as worker protection is concerned for NORM industries and Radon exposure measurements and assessments.
In conclusion, because of the immense support from the government of Zimbabwe, the IAEA and other interested parties, the occupational radiation safety regime in Zimbabwe has improved in the past 10 years and is expected to be on an upward trend in the future ahead.

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Assessment of Eye Lens Doses of Interventional Radiology and Interventional Cardiology Workers in the Period of 2016-2020*, **

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Radiation Protection Centre

In 2011 the International Commission on Radiological Protection (ICRP) published a statement on tissue reactions(1) and has recommended reducing an equivalent dose limit for the lens of the eye from 150 mSv per year to 20 mSv per year, averaged over defined periods of five years, with no annual dose in a single year exceeding 50 mSv(2, 3). In 2014 reduced annual occupational equivalent dose limit to the lens of the eye was adopted in the IAEA Safety Standards(4). This new provision was adopted in Lithuanian legislation in 2015. The new dose limit has become very important for interventional radiology (IR) and interventional cardiology (IC) workers because this category of workers receives the highest occupational exposure compared to other medical staff.
Routine monitoring and equivalent dose assessment of the dose to the lens of the eye should be undertaken if the provisional estimation indicates that the annual equivalent dose to the lens of the eye could exceed a dose of the order of 5 mSv(2). The dose to the lens of the eye can be assessed by measuring personal dose equivalent Hp(3) with the eye lens dosimeter at the level of the eye or Hp(10) with the whole body dosemeter above the lead collar. Routine monitoring using the eye lens dosemeter should be undertaken if the provisional estimation indicates that the annual equivalent dose to the lens of the eye could exceed a dose of the order of 15 mSv. The monitoring period should be reduced to one month as well.
Based on international studies (5, 6, 7, 8) the recommendations for the assessment of the equivalent dose to the lens of the eye were developed and approved in Lithuania in 2016. According to these recommendations, eleven Lithuanian hospitals assessed the doses of the lens of the eye and annually submitted them to the National Dose Registry. In the period of 2016–2020, the average annual equivalent doses of the lens of the eye were 2.2-4.6 mSv for IR and IC physicians and 0.6-1.3 mSv for IR and IC nurses. The maximum annual equivalent dose of the lens of the eye was 18.5 mSv for IR physician and 8.1 mSv for IR technologist. In the period of 2016–2020, the maximum annual equivalent doses of the lens of the eye for IR and IC physicians at 11 Lithuanian hospitals are presented in Figure 1.
The results of this study showed that the new limit of the lens of the eye for IR and IC workers was not exceeded. The maximum annual equivalent dose of the lens of the eye in 2020 was about 40 percent lower than in 2016. This shows that operators follow the principle of optimization and adequately ensure radiation protection of IR and IC workers.

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Participation of Latin American Nuclear Medicine Centres in a Strategy to support Individual On-site Monitoring of Internal Exposure to I-131**

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Nuclear Regulatory Authority (ARN)

The Internal Dosimetry Group of REPROLAM (Latin American and Caribbean Network for the Optimization of Occupational Radiation Protection), framed in the RLA 9085 IAEA project for the 2020-2022 period, devised a strategy for the on-site control of internal exposure to I-131 in nuclear medicine Centres (NMCs) to be implemented by end users, with the objective of bringing awareness to the participants about the need to implement a surveillance program of the internal exposition associated to NCMs workers who handle volatile solutions of I-131 on a routinely basis. The basis of that objective is the fact significant amounts of I-131 are handled in NMCs and its occupational intake is not properly monitored most of the times. This strategy included a virtual training and an interactive guide. Participants were provided with a set of instructions to allow the responsible physician, nuclear medicine technician, medical physicist or other suitable professional, to apply the available detection systems in their centre in order to investigate if the potential intake of I-131 will result in an effective committed dose ≥ 1 mSv / year for workers. This set of instructions was presented as a guidance. It was also proposed to the NMCs the possibility to participate in a pilot plan in order to apply the guidance and to know the magnitude order of the dose for internal exposure to I-131 of occupationally exposed workers. This support plan was developed by a committee of the Internal Dosimetry Group and it includes: advisory for the calibration of gamma cameras and I-131 detector probes, assistance for the implementation of the routine monitoring by the NMCs staff and a follow-up tool to assess the routine monitoring results. Great interest was proven from the NMCs to participate on this pilot plan, and currently, there are around 80 NMCs enrolled from Argentina, Bolivia, Brazil, Chili, Colombia, Costa Rica, Cuba, Ecuador, Honduras, Mexico, Nicaragua, Paraguay, Peru, Uruguay, Venezuela and Spain. Finally, this paper presents the perspectives and progress of the proposed strategy, applied within a regional scope.

Keywords: RLA 9085 IAEA project, individual monitoring, internal exposure, I-131.

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Monitoring and Dose Assessment of Occupational Exposure in Nepal*, **

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The use of ionizing radiation is ubiquitous in the field of medicine, industry, agriculture etc, however the hazardous aspects of those radiations should be addressed during their use. In Nepal, the use of ionizing radiation is mainly focused on medical sectors and the equipment in use include X-Ray machine, Computerized Tomography (CT), Cobalt-60 therapy, linear accelerator (LINAC), fluoroscopy, mammography, nuclear medicine facilities, high dose rate brachytherapy sources, etc. However, the status of individual monitoring for the implementation of radiation protection has not been satisfactory here. With the radiation related law in place in the country recently in 2020, the radiation protection related issue can be expected to intensify in near future. An initiation on the radiation protection of individuals has been carried out at Nepal Academy of Science and Technology (NAST) with the establishment of Individual Monitoring Service (IMS) laboratory at Physical Science Unit of NAST. This laboratory has been established in Dec. 2015 in collaboration with Ministry of Education, Science and Technology, Government of Nepal and IAEA under the technical cooperation project NEP9001 "Developing and Establishing National Infrastructures for Radiation Safety". The IMS laboratory currently hosts a 6600 plus Harshaw TLD reader along with 1050 TLD-100 cards. The reader is calibrated annually by exposing calibration cards to known dose at SSDL, Nuclear Malaysia/ IAEA. The individual monitoring service is being provided to almost 800 radiation professionals from more than 100 health institutions of the country. The monitoring period is of three months. The year wise expansion of dosimetry service of NAST since its establishment has been shown in the Figure 1. The dosimetry service has gained serious attention from the stakeholders with numerous request received for personal dosimetry. The IMS however currently is not able to address the entire received request due to limited resources. The IMS laboratory plans to expand dosimetry network all over Nepal in near future.

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Dose Assessment of Occupational Radiation Exposure of Radiation Workers Working at Different Radiation Facilities in Pakistan

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Pakistan Nuclear Regulatory Authority

The purpose of this study is to evaluate the effective implementation of PNRA Regulations and adoption of protective and safety measures by assessing radiation doses received by radiation workers working in different radiation facilities of Pakistan. In this study the occupational radiation doses of radiation workers from different radiation facilities were measured and analyzed for the period 2016—2020. Radiation workers were divided into two categories according to their work i.e. Nuclear Medical Center (NMC) and Industrial Radiography. The dose monitoring period varies from one month to three months depending on the potential of exposure. The radiation doses were assessed using thermo-luminescent dosimeter TLD-100 and were read through Harshaw Automatic TLD Reader 6600Plus. The average annual doses of radiation workers of NMC were 1.72 ± 0.65 mSv and Industrial Radiography were 2.06 ± 0.35 mSv respectively. These results show that radiation doses received by radiation workers are far below the radiation dose limit as described in Regulations on Radiations Protection-PAK/904 (Rev.1) This assessment provided confidence on the effective implementation of PNRA Regulations such as inspection of radiation facilities and fulfillment of regulatory requirement; awareness of radiation workers about the associated radiation hazards and use of adequate protective & safety measures at these facilities accordingly.

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Experimental Study of Exposure Situations at Shielded and Unshielded Medical Cyclotron Facilities in Pakistan

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This experimental study presents an evaluation of the exposure situation on shielded (PET Trace 800) and unshielded (IBA 18/9) cyclotrons installed in Pakistan. The cyclotrons are used for the production of 18F through 18O(p,n) reaction with the energetic protons (˜18 MeV). The production process results the emission of energetic neutrons with an average energy in the range of 2-4 MeV. Different experimental studies were conducted to assess the neutron field inside and outside medical cyclotron vault, identify radioactive byproducts in the components of medical cyclotrons, evaluate the design of the PET cyclotron facilities.
Activation in the components of cyclotrons was assessed with the help of portable HPGe detector. Micro-trans-SPEC HPGe Detector was installed around the cyclotrons and spectra were acquired, at different distances and times, to identify the radioactive by-product in the components [1].
Design of the PET Cyclotron facilities was assessed on the basis of IAEA guidelines [2] that workers should not be exposed to radiation level of greater than 2.5 μSv/h and dose rate in the controlled area should not be greater than 25 μSv/h. It was observed that the facilities are well designed and radiation exposures in these areas are well below the acceptable limits [3].
On the basis of these observations, recommendations to ensure radiation safety practices in shielding, operation, QC, repair & maintenance and management of radioactive waste at medical cyclotron facilities were proposed. The appropriate actions on the recommendations will result optimization in radiation exposures and personnel doses.

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Monitoring and Analysis of Working Area Dose Rate in Radioactive Waste Installation and Interim Storage for Spent Fuel*

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A radiation monitoring system of working area that continuously measures the dose rate gamma in the room of nuclear and radioactive facilities is an important tool for presenting dose rate information to workers or authorities for radiological protection during normal operations and radiological accidents. We have developed the system in such a way in radioactive and nuclear installation that it consists of 8 NaI(Tl) probe based devices for monitoring dose rate levels in the rooms of Radioactive Waste Installation (RWI) and 5 NaI(Tl) probe in the Interim Storage for Spent Fuel (ISSF). It has been operating since 2020. In this study, a description of the system and the analysis of measured data is presented. Data analysis for the last two years shows that the average dose rate is between 0.15 µSv/h-2.52 µSv/h, which is still lower than the limit for gamma radiation levels in the working area. If total effective working hours is equal 2000 hours per annual, this value is corresponding to 0.3 mSv-5.04 mSv per annual (less than 20 mSv/a for radiation workers). Time series analysis of the monitoring data shows a good agreement between the increase dose rate in the working area and the presence of the dose rate due to detector testing, also when there is loading activity of receiving disused sealed radioactive sources into containers. These results show that the system is also effective for an early warning system in cases of radiological emergencies.

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Investigation of Eye Lens Dose Operational Quantity Hp(3) in Kilovoltage Energies*

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The use of radiation in medical imaging has been increasing during the past decades. Based on the new annual dose limit recommended by the ICRP, eye lens dosimetry should be considered important in occupational monitoring. In this study, the important challenges in eye lens dosimetry were investigated using Monte Carlo simulation. For this purpose, the human eye was completely simulated using MCNP Monte Carlo code, the sensitive part of the lens, i.e. the germinative zone was also considered in the simulations. To investigate the effect of the lens depth on the dose delivered to the lens, different eye anatomies like normal, myopia, hyperopia were simulated. The scattered X-ray spectrum received by the eye of the staff, after scattering from the patient was obtained, and the dose from the scattered photons in different parts of the eye lens was calculated. For measurement of Hp(3), 3mm of tissue-equivalent material is usually suggested to be used for covering the dosimeter. The X-ray attenuation of different thicknesses of tissue and plexiglass was compared in order to find the thickness of plexiglass which is equivalent to 3mm eye tissue. Finally, the results of the simulations show that the previously-suggested protocols for the measurement of Hp(3) can be used with small uncertainties. The result indicates that the dose received by the lens is not much affected by the thickness and the depth of the lens. In the next step, the effect of cylindrical, and slab phantom for calibration was investigated. The percentage differences between the lens dose for normal, myopia, and hyperopia eyes are less than 2%. Therefore, it was concluded that the different eye anatomy has no significant effect on the lens dose. The cylindrical phantom was suggested for calibration, instead of the slab phantom. 3mm plexiglass was equivalent to 3mm eye tissue, therefore the 3mm plexiglass was suggested to cover the personal dosimeter.

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Challenges of the Eye Lens Dosimetry using Thermoluminescence Dosimetry*

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Eye lens cataract is one of the earliest biological effects of radiation since the discovery of X-rays. According to the 2011 update of the International Commission on Radiological Protection (ICRP), the dose to the eye lens in occupational exposure in planned exposure was reduced significantly compared to the previous dose limit (1,2). Therefore, measurement of lens dose has been the subject of different investigations during the last decade. In this study, the common method used in our department, for the measurement of Hp (3) operational quantity using thermoluminescence dosimeters, has been verified. In this investigation, the effect of TLD location, and the thickness of material covering the dosimeters was investigated. For this purpose, two phantoms were used, one of them was on the bed to provide the scattering condition as the patient, and the second Phantom, the Alderson Rando phantom was located at the position of the cardiologists in angiography. Several TLD-100 cubical chips were installed at different places on the face of the phantom, like eyebrows, cheeks, forehead, and temples. Currently, the Hp(3) monitoring methods suggest that the dosimeters should be located at the edge of the eye, near the temples. However, the results of our investigation showed that this place may introduce significant uncertainties to the measurement. Based on our measurements, the best locations with the results near the central part of the eye is on both eyebrows, or on the cheek. The results also indicate that 3mm plexiglass should cover the TLD, the dosimetry experiences about 10% uncertainty for 80 kVp X-rays scattered from the patient phantom, and reaching the staff eye. Finally, the currently used protocol used in our department was revised, and based on the new protocol, TLDs are inserted inside cubical plexiglass containers, and put on the middle of right, and left eyebrows in order to reduce the uncertainties in eye dosimetry.

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Occupational Dose Assessment for Radiation Workers at Centre for Energy Research and Training, Zaria, Nigeria*, **

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Centre for Energy Research and Training

As part of the measures to ensure the radiation protection of technical staff, CERT have saddle the responsibility of Dosimetry monitoring of its radiation workers on quarterly bases even before the commissioning of NIRR-1. Assessment of the annual effective dose of radiation workers for 14 years was carried out. The result shows that the doses were below the acceptable limit as per compared with the standard organizations (ICRP, IAEA and NNRA.)

Introduction
Centre for Energy Research Training (CERT), Ahmadu Bello University Zaria is nuclear research institute established in 1984 for training and research in nuclear technology. It has many nuclear facilities including Research Reactor (NIRR-1), Am-Be Source, Neutron Generator, XRF, Liquid Scintillation counter (LSC) Gross Alpha-Beta and Radioactive Waste Management Facility (RWMF) among others.
NIRR-1 is an MNSR research reactor which achieved its first criticality on 3rd February 2004 and in 2018, NIRR-1 was converted from HEU to LEU. All the technical staff at the Centre were monitored using thermoluminescent dosimeter (TLD) as per required by the Nigerian Regulatory Authority of Nigeria (NNRA) and IAEA.

Materials and Methods
TLD Badges were used to monitor the personnel dose at CERT. the Badges are calibrated bi-annually at Secondary Standard Dosimetry Laboratory (SSDL) of Nigeria, Ibadan. Harshaw TLD Reader (Model 4500) was used to read the Badges.
All the radiation workers are issued personal bar-coded whole-body thermoluminescent dosimeters (TLD-100). The workers are monitored on quarterly basis. Analysis of the annual effective dose for 14years was carried out from commissioning to decommissioning of the reactor with HEU fuel rods.

Results and Discussion
The annual doses received by the workers from2004 to 2017 were in the range: (0.21-3.13), (0.85-4.77), (0.69-6.08), (0,19-5.36), (0.18-4.43), (no data), (1.04-3.53), (0.47-6.12), (1.36-6.58), (0.66-3.58), (0.21-3.62), (0.20-3.62), (0.2-4.86) and (0.32-2.40)mSv respectively. For the 14 years of operations with highly enriched uranium (HEU) fuel rods there was no incidence of an occupational dose exceeding the annual regulatory limit of 20mSv/yr. This indicates a proper implementation of the radiation protection protocol in compliance with regulatory bodies (ICRP, IAEA and NNRA).

Conclusion and Acknowledgement
This study is mainly conducted to assess the effective dose of radiation workers at CERT. the effective dose was found to be below the prescribed dose limit as per requirement of the Nigerian Nuclear Regulatory Authority (NNRA). Though the effective dose is below the limit, there is still the need to improve on the necessary to reduce the dose received by workers as low as possible (ALARA).

I wish to acknowledge the assistance and guidance provided by IAEA in terms of Radiation Protection facilities, Training of CERT staff and Radiation Dosimetry.

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Development and Validation of an Internal Dosimetric Analyser to Assist Confirmatory, Routine and Special Radiobioassay**

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International Atomic Energy Agency (IAEA)

The IAEA Radiation Safety Technical Services Laboratory has developed an Internal Dosimetric Analyser (IDA) software tool to facilitate the access to dosimetric data and perform calculations related to individual monitoring for intakes of radionuclides and occupational radiation protection. Direct (or in-vivo) and indirect (or in-vitro) radiobioassay methods have been developed to detect radionuclides of interest in tissues or organs of the human body or in excreta. IDA serves to correlate measurement data from confirmatory, routine and special internal monitoring with data obtained from the Occupational Intakes of Radionuclides (OIR) series of recommendations published by the International Commission on Radiological Protection (ICRP) [1−4]. The software tool was designed with an intuitive user interface using Microsoft Excel and was written using the programming language Visual Basic for Applications (VBA). The objective of IDA is to keep the internal dosimetry data in the background and allow the dosimetrist to make the necessary calculations so as to be able to decide, given the bioassay method and monitoring period: (i) whether the method and period are appropriate for confirmatory or routine monitoring; (ii) whether the method and monitoring period allow the recording level to be detected; (iii) whether previous intakes are interfering with the current measurement; and (iv) how uncertainties in the measurement affect the dose assessment. IDA can present additional information such as the minimum detectable dose as a function of the time after intake, derived recording levels for radionuclide mixtures, committed effective dose calculations for data from air monitoring and the ISO 27048 procedure for the assessment of doses based on bioassay measurements [5]. Isodose curves are shown that allow a quick estimate of the committed effective dose when the time of the intake is known. IDA was successfully validated for functionality according to the requirements of ISO/IEC 17025.

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2021 IAEA Regional Intercomparison Exercise on Individual Monitoring for External Exposure in Africa*, **

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The organization of this regional intercomparison exercise on individual monitoring in Africa region was implemented under the framework of IAEA Technical Cooperation Project RAF9068. The SSDL of CNRP of Morocco hosted this intercomparison exercise (irradiation of dosimeters sent by participating dosimetry service and evaluation of final results). Results of this intercomparison exercise were discussed during the virtual meeting held on 13-15 December 2021, Vienne – Austria.
In this meeting Intercomparison results for each country checked and validated with special interest on consistency, accuracy (trumpet curve criteria compliance); influence of background radiation; unexceptionally too high or too low values; & typographic errors. Results were analysed country by country to identify specific issues or otherwise in each case.
Introduction: When the exercise was announced, twenty-three (23) countries sent their application form to participate to the intercomparison exercise. Participants were asked to send 36 dosimeters used routinely and to give details on the dosimeter reference point.
The final number of participants who sent their dosimeters for irradiation was eighteen (18) and dosimetry systems were twenty (20).
Participants who sent their results were seventeen (17). One country used two readers: Automatic and manual OSL systems. The dosimetry systems to be evaluated are twenty (20). (11 TLD and 09 OSL).
The participants were instructed to follow normal routine procedures during the assessment of the dosimeters and to send the results of the dosimeter readings to the hosting SSDL for evaluation.
In this exercise, two quantities Hp (10) and Hp (0.07) have been evaluated and this intercomparison was designed to be a blind test for all participants who reported their results without knowing the reference dose values.
The SSDL established the irradiation plan and announced the intercomparison in February 2021. After completing the application procedures, the participants sent their dosimeters, in accordance with the instructions, to the SSDL. The laboratory irradiated the dosimeters according to the irradiation plan. The dosimeters were sent back to the participants. Each participant was instructed to follow normal routine procedures as far as possible.
The participants sent the results of dosimeters readings to the organizer (SSDL CNRP) for evaluation during the period August – 20 November 2021.
The performance limits (i.e. trumpet curves) were calculated and represented in the participant's graphs using H0 = 0.1 mSv for Hp (10) and Hp (0.07), as stated in ISO 14146 [4].
Results of this intercomparison exercise were discussed during the virtual meeting held on 13-15 December 2021, Vienne – Austria.
The final individual results were sent to each participant in December 2021.
Conclusión: The results show that some participants have a very satisfactory performance and that a number of services could improve the quality of their systems by improving the calibration of their systems. With the aid of the intercomparison results the participants can show compliance within their quality management system, compare their results with those from other participants and develop action plans for improvement of their system.

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Current Status of Individual Dosimetric Monitoring in Senegal**

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In Senegal, workers exposed to ionizing radiation are increasing every year; hence the importance of an accessible dosimetric monitoring system. Only about fifty workers are monitored by foreign dosimetry laboratories. To facilitate access to dosimetric monitoring of workers exposed to ionizing radiation in SENEGAL, the Autorité sénegalaise de Radioprotection et de Sûreté nucléaire (ARSN) has set up, since November 2014, an external dosimetry laboratory using the Landauer's OSL microstar reader. Based on OSL technology, the emitted light by the OSL detector after stimulation by light emitting diodes is proportional to its exposed irradiation dose.

The aim of the present work is to study and describe the current situation of individual dose exposition of 700 workers in both the medical sector (radiodiagnostic, fluoroscopy, Computed Tomography, radiotherapy) and industrial sector (NDT, well logging industries, mining).

The analysis of the external exposure by field of activity have also been studied. Results have shown that the average annual effective dose is 0.46 mSv in the medical sector (80% of the total monitored) and 1.1 mSv in the industrial sector (20% of the total monitored).

This study contributes to the existing works to promote a more comprehensive personal monitoring service for OEWs. Continued analysis of occupational doses should be an integral component of institutional radiation safety programs in SENEGAL.

Keywords: Doses, occupational exposed workers, OSL, ionizing radiation

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Monitoring and Dose Assessment of Liquid Waste Sources

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Australian Nuclear Science and Technology Organisation (ANSTO)

The amount of liquid radioactive waste produced and stored around the world is increasing. As such, the development and implementation of waste treatment options are progressively becoming essential requirements for the approval and acceptance of future nuclear facilities built around the world. Liquid waste typically presents as a mixture with complex physical, chemical, and radiological properties. Dose assessments, though challenging to develop, are essential in order to facilitate waste characterisation programmes, and for the design, development, and operation of waste treatment technologies. In addition, freshly produced wastes typically have high concentrations of radioisotopes (such as fission and activation products), and associated dose rates, which makes such material difficult to access for a direct dose measurement. In such case, theoretical dose assessments become an essential tool in the development program to characterise nuclear waste.
ANSTO Synroc have been developing Synroc waste treatment technologies for over 30 years and have built substantial expertise in radioactive waste characterisation, including dose assessments and monitoring. In this paper the approach that is used by ANSTO Synroc to conduct dose rate assessments and monitoring of liquid waste sources will be discussed. The focus of the presentation will be the Intermediate Level Liquid Waste (ILLW) by-product from ANSTO's Mo-99 radiopharmaceutical production. This waste stream will be treated at ANSTO using its own proprietary Synroc technology to produce a wasteform suitable for geological disposal. In order to develop a design basis for the Synroc facility to operate safely, dose assessments are required for all stages of the treatment process, including waste sampling and characterisation, Synroc processing, transport, and storage of the final wasteform. Initial assessment of a neat ILLW sample is performed based upon available theoretical data and allows to establish risk acceptance criteria for the skin dose and inhalation during unsealed liquid handling. This information is used to facilitate further sampling and direct dose measurement, as well as chemical and radiological waste characterisation. Real measurements are used to verify that the doses are within the accepted design basis. Once properties of the waste are established, controls can be developed to minimise planned and emergency exposure for all stages of the Synroc process. Since the ILLW contains numerous fission and activation products of high specific activity, decaying the waste in an appropriate manner is also an important design and operational safety decision to minimise beta dose and this will be addressed in this paper.

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Optimizing the Individual Monitoring Service in Sri Lanka by Minimizing the Background Radiation Dose Effect**

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Personal Monitoring Service Laboratory (PMSL) of Sri Lanka Atomic Energy Board (SLAEB) solely provides the external individual radiation monitoring service for the radiation workers in Sri Lanka. More than 2300 radiation workers from 187 radiation facilities are monitored. Out of 187 institutes, 164 are medical, 02 are agricultural, 15 are industrial, 03 are research and 03 are educational. Thermo Luminescence Dosimeters with two elements (TLD-100) composed of LiF: Mg, Ti are used for monitoring the personal dose equivalent, whole body dose (Hp (10)) and skin dose (Hp (0.07)). The effective whole body radiation doses are reported with 22% uncertainty for use of single TLD and 12% when using two TLDs. TLDs are read by using Harshaw TLD reader Model 6600+. Background radiation dose is subtracted to obtain the occupational radiation exposure. A separate TLD card is used to measure the background radiation dose which varies significantly due to geographical anomalies. Baseline environmental radiation monitoring program provides average radiation dose rates obtained from 355 different locations of Sri Lanka, which ranges from 27 nSv/hr to 1125 nSv/hr.

This study investigated the effect of using an average Per Day, Background Radiation Dose (PDBRD) to estimate the periodic background radiation dose in situations of background TLD card is lost, damaged, not returned to the laboratory or an abnormal background radiation dose is read out. This methodology was adopted hence incorrect background radiation doses would result a false loss or an enhancement to the occupational radiation doses. PDBRD was calculated by dividing the background radiation dose by the number of days for the entire monitoring period. The periodic background radiation dose was estimated by multiplying the institute's average PDBRD by number of days. Average per day dose database for each institute was updated with reading from background TLD card at the end of each monitoring period. PDBRDs with three sigma deviation (μ±3SD) from the average were excluded from the database.

It was observed that average PDBRD has ranged between 0.07±0.04 μSv/day to 8.6±0.05 μSv/day and 90% of the observations were fallen between 1.2 μSv/day to 2.8 μSv/day. Average PDBRD of the most institutes were approximately 2.3 μSv/day. SDs for most institutes remain very low but a few institutes were shown significantly higher SDs.

Using an average PDBRD when background TLD card is not available, was found to be a better alternative to minimize the effect. However, it could still result incorrect dose estimations. To improve the accuracy of the occupational radiation doses, it is highly recommended to place the background TLD card at a radiation free area and return it back to PMSL together with other TLDs. Radiation protection officers are instructed by PMSL to store all the TLD cards with the background TLD card when they are not in use to effectively avoid the background radiation dose effect.

Keywords: Thermo Luminescence Dosimeter, Occupational radiation exposure, Background Radiation dose, Estimated per day background radiation exposure, Radiation workers.

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Assessment of Occupational Radiation Exposure in Industrial Radiography in Kenya: Case Study of Two Non-Destructive Testing Companies*,**

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The objective of this study was to assess the effectiveness of radiation protection program of companies involved in industrial radiography. Our study target two selected companies that participated in carrying out quality control tests of oil pipeline that was under construction in Kenya and completed in 2018. A total of 7 radiation workers were monitored using OSL technology. In 2018, both companies carried out their activity in four months.
In that year, the maximum individual dose in one month for company A was found to be was found to be 6.93 mSv and Company B was 2.95 mSv. Both figures are higher than the monthly dose constraint recommended by the regulatory authority of 1.67 mSv. Even though the annual whole body dose for each worker didn't exceed the recommended limit by ICRP, there is need of improvement in radiation protection programmes and safety culture in industrial radiography sector in the country

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Contamination Problem of Workers handling with 177Lu-labeled Radiopharmaceuticals*

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Introduction
The 177Lu emits mainly electrons up to a maximum energy of 498 keV and photons with energies of 113 keV and 208 keV, which can effectively irradiate the skin on the hands of radiopharmaceutists in the preparation of these radiopharmaceuticals for patients. Finger-mounted monitors (finger dosimeters) with a thermoluminescent dosimeter (TLD) are used to control the skin irradiation on the hands of radiopharmaceuticals. Finger dosimeters are commonly equipped with a TL detector that detects both photons and electrons with a sensitive layer thickness of 0.9 mm. Due to the relatively low energy of the electrons emitted by 177Lu, it is recommended to use a TLD with a thin sensitive layer 0.05 mm thick, which has the same response to the radiation dose from both electrons and photons emitted by 177Lu.
To test the effectiveness of radiation protection measures for NM therapeutic sites using 177Lu-labeled radiopharmaceuticals, the presentation proposes a method of testing them and a procedure to ensure effective investigation of excessive worker exposure by the required supervisory body based on legal dosimetry of the worker's finger or whole body dosimeter.
Methods
Continuous measures require:
- introduction of a method of selective indicative gamma and beta irradiation of the skin of the hands with a pair of TLDs with different sensitivities of gamma and beta radiation,
- mapping by selective indicative gamma irradiation and beta irradiation of the skin on the hands using TLD placement at standard sites on a hand according to the ORAMED project [1], in routine manipulations with therapeutic doses of 177Lu-labeled radiopharmaceuticals,
- a method of contamination measurement with a collimated gamma spectrometer to determine the position of the maximum local contamination of the glove and to estimate the value of the area activity.

Results
A model experiment with contaminated work gloves handling a 177Lu-labeled radiopharmaceutical. Table 1 shows the responses of dual ring monitors placed on the left hand and the results of gamma spectrometric model measurement of contaminated work gloves at the thumb and forefinger sites, as shown in Figure 1.
A dual monitor placed on the tip of the index finger shows that contamination there causes local irradiation of the skin, which is caused mainly by electrons (approx. 100% according to tab.1). In this case, the MCP-7 TLD, which is still commonly used in conventional finger monitors, registers five times less actual skin irradiation (1208/258 - ratio of values shown in tab.1).

Conclusion
A new method for a comprehensive examination of excessive skin irradiation on the hands of workers handling 177Lu-labeled radiopharmaceuticals has been proposed. Method allows also the assessment of other exposure circumstances, such as personal responsibility of the worker for excessive irradiation or deficiency in organizational and technological measures of radiation protection in the workplace.
Acknowledgments: The paper was partially supported by the project SGS18/100/OHK4/1T/17

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Personnel Dose Assessment during Commissioning of the First Hospital-Based PET Radiopharmaceutical Cyclotron in Greece**

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The role of FDG in PET imaging is well established in the diagnosis and management of cancer patients. Small footprint cyclotrons that can be installed on-site are becoming popular worldwide and are an efficient solution for medium-size facilities. The dose-on-Demand Biomarker Generator (BG-75) was installed at Metaxa Cancer Hospital, Piraeus, Greece, in May 2021 and is the first hospital-based PET radiopharmaceutical cyclotron in the country. The system consists of an accelerator used in conjunction with a Chemistry Production Module (CPM). In the commissioning process, it was necessary to establish the expected external dose to personnel; internal exposure is not expected under normal conditions. Personnel includes operators (technologists), a radiochemist, and medical physicists. Among these groups, the highest exposure is expected in the operators' group. All personnel have been assigned TLD whole body and extremity dosimeters and have completed relevant radiation safety training. Also, operating training was provided by the cyclotron installation engineer. Personnel dose was estimated using two methods: survey meter measurements in various locations combined with the time spent in each location, and direct measurement using electronic personal dosimeters. It is estimated that approximately 8 patients (˜4 cyclotron runs) will be performed every workday (5 days/week, 50 weeks/year). All gamma radiation readings outside the cyclotron vault were at background levels. Neutron readings were at background levels except for the reading in the hot lab, where 0.1 μSv/h was recorded close to the wall, which is still a negligible contribution to personnel dose. Inside the cyclotron vault, the highest recorded readings were 18 μSv/h for both gammas and neutrons close to the target; at one meter, the values were 5 μSv/h and 4 μSv/h, respectively. The estimated whole-body dose for 60 min runs for the two methods are
1.75 μSv (exposure rate method) and 2.44 μSv (personal dosimeter method). The respective extremity dose estimates are 65 μSv (exposure rate method) and 25 μSv (personal dosimeter method). The annual expected whole-body dose per operator is 0.6 mSv, and the respective extremity dose is 16 mSv. The annual expected whole body and extremity dose for the radiochemist is 0.3 mSv and 25 mSv, respectively. The respective annual dose estimates for the medical physicists are < 1 mSv. The expected doses for technologists/operators, radiochemists, and medical physicists are expected to be well below the regulatory limits and local ALARA levels. With experience and a robust ALARA program, personnel exposure could be further reduced.

SESSION 3:

RADIATION EFFECTS, HEALTH RISKS OF OCCUPATIONAL EXPOSURE AND WORKER'S HEALTH SURVEILLANCE

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Computed Tomography and Occupational Radiation Exposure of the "Mayak" Workers: CT Register**

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Exposure to diagnostic radiation from computed tomography (CT) scans is an additional source of potential radiation risk for nuclear workers. To ensure their adequate protection, it is necessary to control the radiation burden resulted from diagnostic CT exposures. A radiation-epidemiological register of CT-exposed persons has been created for this purpose.
The "CT Register" currently includes 14,624 patients of both sexes and all ages, including 25% of "Mayak" nuclear workers, who underwent CT examinations in 5 hospitals in Southern Urals between 1993 and 2019. Information on CT scans performed, patient diagnosis, vital status and cause of death, cancer morbidity and other factors is available in the Register to provide a retrospective epidemiological analyzes of late effects of radiation exposure and assess the contribution of CT exposure to the potential radiogenic risk among occupationally exposed workers.
The study will help to review of international standards and recommendations on occupational radiation protection.

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National Health Surveillance Procedures according to Iraqi Radiation Law and IAEA Safety Standards Series No. GSR Part 3

Author: Shaymaa AL-Janabi

Working in the field of ionizing radiation involves many risks due to the harmful biological effects of ionizing radiation on the health of workers who are involved. Therefore, radiation protection center (RPC) the regulatory body in Iraq which is responsible of monitoring all activities related to ionizing radiation and responsible of monitoring 6200 workers in radiation field including health surveillance through blood examinations to provides safety for them in this field before and during their work according to GSR part 3 articles 3.108 and 3.109 and Protection of Ionizing Radiation Law No. 99 of 1980, article 12/5th which states that (the source owner should Ensure all workers in radiation field performing the initial and periodic fitness medical examination, according to the instructions and at his own expense). Accordingly, one of the conditions set by RPC for granting license to work in radiation field is to conduct an initial medical examination mentioned in the primary medical examination form prepared by RPC which includes skin, ophthalmological, blood tests and semen analysis report, to ensure their suitability for work and their ability to tackle the assigned tasks. RPC also conducts periodic health surveillance for workers for the duration of their work in radiation field who have been granted licenses by forcing them to do blood tests per year as mentioned in the periodic medical form prepared by RPC. Both initial and periodic medical examinations are being Followed-up by specialized physicians in RPC to ensure workers fitness to continue working in radiation field. Iraqi law no. 99 in 1980 includes the generalization of fitness tests required for radiation workers who want to work in the areas of radiation according to article 4/a of the instructions for the employment of applicants to work in the fields of radiation, which states that: It is not possible to work in radiation fields for those who have the following diseases (cancer, all blood diseases including all kinds of anemia, corneal opacity, cataract, Xeroderma Pigmentosa). Physicians in RPC recommend to exclude those workers from working in radiation field. RPC statistics in 2021 showed that 10 workers were excluded from work in Radiation and Nuclear Medicine Hospital because they had cancer, 6 workers were excluded because they had cataract, 2 workers were excluded because they had thalassemia and one worker excluded because he had Corneal Opacity.

There are certain diseases or minor changes in blood tests do not require excluding workers from work in the field of radiation. For such cases medical treatment and monitoring their medical examination periodically is recommended. a re-examination after a certain period of time is also recommended to ensure their safety from the hazards of ionizing radiation. The RPC maintains medical records such as (pre-employment, initial and periodic medical tests, private and end-of-work) and laboratory test reports (e.g. blood samples, skin, and semen tests for males). It also includes exposure records (e.g. overexposure) and all of these data are confidential. The data of workers in Iraq are kept 30 years after the workers retirement.

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Radiological Characterization of the Radioactivity at Al-Tuwaitha Nuclear Site and Determination of the Radiation Doses for Workers**

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The research aims to assess the radioactivity levels at Al-Tuwaitha nuclear site due to the remnants it contains such as destroyed buildings, facilities, and the previous activities at the site before the gulf-war, 1991. In addition to the decommissioning processes and treatment of the radioactive contamination practiced by the assigned teams from the directorates of the site since 1991 until now. Through the research, different environmental samples (soil, water, air, etc.) will be collected for measurements using different laboratory techniques such as gamma spectroscopy (HPGe), as well as portable devices.
Then, the calculated data will be used to determine the received radiation doses and their impact on workers, people, and the environment. In addition, the results will be used to calculate the Evaluation of Radiological Hazard Effects of Raeq, absorbed dose, and the annual effective dose in (Bq.Kg-1, nGy.h^(-1) and mSv.y^(-1) (respectively, and comparing it with the global recommendation limits
Keywords: Al-Tuwaitha Nuclear site, Radionuclides, HPGe.

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Markers of Neural Degeneration and Regeneration in Blood of Cardiac Catheterization Personals**

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The catheterization laboratory is considered an area where exposure to ionizing radiation (IR) is particularly high during fluoroscopic procedures. Neuro-vascular and cerebro-vascular damage are considered to be induced by IR. Such damage is postulated to be repaired by circulating endothelial and neural circulating progenitor cells originating from the Bone Marrow. The aim of the present study was to evaluate neural damage and rejuvenation capacity among cardiac catheterization (CC) staff. Subjects and Methods: Venous blood samples were obtained from 70 cardiac catheterization staff exposed to x-ray during fluoroscopy procedures at three busy hospitals in Cairo – Egypt vs. 40 controls. Blood was assayed for the amyloid beta peptide, the frequency of micronuclei (FMN), plasma nerve growth factor (NGF) and cell phenotype of circulating neural progenitor cells (NPCs), whose surface markers were identified as the nestin, CD45 and CD34. Amyloid beta peptide was non significantly increased among CC staff compared to controls. The individual three month collective dose information, as measured by thermoluminscent personal dosimeters (TLD), ranged between

2.16 and 14.9 mSv/y. Results: NFG and FMN were significantly higher among CC staff compared to controls. Nestin, CD45 and CD34 were also significantly higher among CC staff compared to the controls. Smoking seemed to have a positive effect on the FMN and SDF-1, while negative on circulating progenitor cells. Conclusion: It is found that among CC staff, the numbers of EPCs had increased indicating an increased capacity for tissue repair. This regenerative process is hindered by smoking, evidenced by increased levels of NFG and decreased numbers of PCs. Further studies are required to prove whether changes in of EPCs' levels can offer a reliable detection marker for radiation exposure.

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A Preliminary Study on the Risk of Lung Cancer from Radon Exposure in Chinese Uranium Miners Based on Poisson Regression

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China Institute for Radiation Protection

Since the 1980s, scholars from various countries have begun to study relative risk of lung cancer caused by radon. The research results show that radon exposure can increase the risk of lung cancer in underground miners. However, due to the limitations of research cohort and calculation software, the excess relative risk coefficient of radiation-induced cancer in China has not been obtained. To obtain and verify the excess relative risk coefficient of radon induced lung cancer in China, this study uses the data of Chinese uranium mines to preliminarily estimate the excess relative risk coefficient of radon induced lung cancer.

In this study, 4851 male miners who worked in a uranium mine in Hunan, China for more than one year from 1958 to 1985 were selected as subjects, and a total of 207251 person years were followed up. Poisson regression was used to fit the risk of lung cancer death caused by radon with time since exposure, attained age and exposure rate.

The results showed that when the average time since exposure was 45 years and the average exposure rate was 0.14wl, the estimated value of excess relative risk coefficient ERR/ 100WLM was 1.73 (95% CI: 0.36; 3.11). For every 10 years since exposure, the relative risk decreased by about 60%, and for every 1wl increase in exposure rate, the relative risk increased by about 30%.

The preliminary estimation of the risk coefficient of lung cancer caused by radon in Chinese uranium miners can provide a scientific basis for the calculation of carcinogenic risk and etiological probability of radon exposure in China's occupational population.

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Revision of the IAEA Manual 2011 based on Data on Radio-sensitivity, Dose-rate Findings Contributing**

Author: Gang Liu

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"Cytogenetic Dosimetry: Applications in Preparedness for and Response to Radiation Emergencies (IAEA,2011)" plays a vital role in radiology. Although IAEA Manual Report 405 for additional details that were left out of the IAEA Manual 2011. The use of the G function, a time dependent function used to modify the dose squared coefficient of the linear quadratic dose response relationship to allow for the effects of dose protection (IAEA, 2011), however, the method mentioned in the paper has some limitations, such as lack of detailed researches to explain the effects of individual differences in radiosensitivity and radiation dose rate on biological dose-response curves, establishing a unified standard curve of biological dose is urgently needed.
What are the new findings?
1. Individual differences of radiosensitivity are very large.
2. At each dose point, "(dicentric chromosome + centric rings) /cell" is proportional to "dose rate", that is, Y=k x +b;
3."(dicentric chromosome + centric rings) /Cell" is a quadratic linear relationship with dose rate, that is, y=a x 2+b x +c.
4. We created a "Unity Standard Curve of Biological Dose Estimation".
Creating a Unity Standard Curve of Biological Dose, under these circumstances, we can form a joint and rapid response to a nuclear and radiological accident.

ABSTRACT
Objectives: In order to achieve the goal of rapid response, effective coped with and protection of life of large-scale radiation events, the establishment of an in vitro unified standard dose-response curve for chromosomal aberration becomes an urgent need.
Methods: Using 60Co radiation (0.27 Gy/min), analysis individual differences in radiation sensitivity; Chromosomal aberrations with different irradiation dose rates were used to establish the biological dose curve and analyze the excess of the "dicentric + ring" caused by the dose rate at each dose point; DAPI-images and Metafer 4 captures metaphase images images and analysis.
Results: Dicentric+ ring /100 Cell was 17.5-43.8, the average is 28.32 ± 6.98. The mean value of Dicentric+ ring /100 Cell was 31.37 in males and 25.27 in females, there are significant differences ($p<0.01$). Irradiation dose is dominant; At each dose point, "(dicentric chromosome + centric rings) /cell" is proportional to "dose rate", that is, Y=k x +b; Within the dose range of 1-5Gy, "(dicentric chromosome + centric rings)/Cell " holds a quadratic linear relationship with dose rate, that is, y=a x 2+b x +c; The DAPI-images might give you more hints than those of conventional Giemsa-stain.
Conclusions: The author recommends revision of the IAEA Manual 2011 based on data on radio-sensitivity, dose-rate findings contributing to a unified dose-response calibration curve, and potential for automation in cytogenetic biodosimetry.

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The Several Issues that it should be paid Attention to the Radiological Workers in the Occupational Health*

Author: Gang Liu

Gansu provincial Center for Disease Control and Prevention

Key points

- Radiation workers have certain radiation damage, and the focus is on those engaged in interventional radiology.
- The detection rate of lens opacity was higher among the radiological workers, but 99.7% of the lens opacity occurs in the peripheral cortex of the eye. Posterior subcapsular opacification of posterior pole of the lens less than 3‰ (The national standard of occupational radiation cataract stipulates). This problem should arouse enough attention of occupational health regulatory authorities.
- The chromosome aberration analysis is an important index in occupational health monitoring of radiological workers.

Background
In the present study, we analyzed radiation injuries to Chinese workers exposed to low- dose radiation. We discuss the relationships between dose and injury.
Methods This study randomly selected 976 radiation workers who underwent occupational health monitoring. The radiation workers were divided into 5 different types of work: radiation diagnosis, radiation therapy, interventional therapy, nuclear medicine, and industrial inspection.
Results The average annual cumulative dose to interventional radiation workers was the highest, i.e., 0.86mSv. The detection rate of lens opacity was 37.00%, but 99.70 per cent of lens opacities occurred in the peripheral cortex. Posterior subcapsular opacification was detected less than 1.00% of the time. The rate of chromosomal aberrations was highest for radiological workers with more than 20 years of service. Annual cumulative dose reached 2.04 mSv, and the monitoring dose for 3 months was as high as 1.62 mSv. Dicentric chromosomes were also detected. The manual packaging and drug delivery nuclear medicine staffs totaled 14 individuals. I-131 was detected in the thyroids of 4 workers (28.57%). The detection rate of thyroid iodine-131 was higher in the hand-packed and administered group than in the automatic administration group.

Conclusion
Radiation workers exposed to low doses of radiation can sustain injuries. Interventional radiology workers receive the highest doses and sustain the most significant effects. This study suggests that chromosome aberration analysis is an important index in occupational health monitoring of radiological workers. Monitoring of internal radiation exposure cannot be ignored for nuclear medicine staff.

SESSION 4:

OCCUPATIONAL EXPOSURE LEVELS AND DOSE REGISTRIES

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Analysis of Individual Dose Monitoring Results of Radiation Workers from 2009 to 2018

Author: Kairui Zhou

Since 2009, the number of medical departments related to nuclear medicine has increased, and the number of radiation workers is also growing rapidly. The progress of occupational protection measures can be studied by counting the changes of annual average dose of nuclear related workers.
According to the Chinese Registry of Radiation Workers (CRRW)' database, the average annual effective dose of workers from 2009 to 2018 was 0.403mSv. In 2018, after statistics of more than 380000 workers, the annual dose of more than 96% of the tested workers was lower than the specified public limit (1mSv). Compared with 2010, the annual average dose decreased by 31% - 69% according to different types of work. Among them, the proportion of personnel engaged in medical related occupations is about 81.6%, and the annual average dose is about 48uSv higher than that of industrial related personnel.
In addition, the annual average dose of personnel engaged in interventional radiation is the highest, which is most likely to exceed the annual dose limit, so additional protective measures need to be taken.

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The Applications of Occupational Dose Data Management System in China and Other Countries

Author: Yuan Xu

Since individual dose monitoring data are the basis for radiation protection evaluation, it's necessary to establish an information management system for dose records of workers who are monitored for occupational exposure to ionizing radiation. Many countries have established their own national dose management systems and provide extreme valuable information on occupational exposure protection for the authority. The applications of occupational dose data management system for in China are summarized, the applications in other countries are also discussed.

Applications in China

In China, some institutions or organizations have established independent dose management system.

National Health Commission established "individual monitoring registry system for radiation workers" in 2009, and then the system was promoted and used in national individual dose monitoring institutions. Since its operation 12 years ago, the system has covered 32 provinces all around China, collecting more than 8.27 million dose records. In December 2018, Ministry of Ecology and Environment of China established the "national radiation occupational exposure information system", it's used to collect individual dose information in nuclear facilities, uranium mining and metallurgy facilities, nuclear technology utilization, nuclear and radiation safety supervision etc.

In addition, the system of China Academy of Engineering Physics (CAEP) has kept the individual dose data since 1974. Almost each nuclear power plant in China has developed its own management system for individual dose information collection, storage, statistical analysis and evaluation.

Applications in other countries

Seven countries of Eu member states - the United Kingdom, France, Germany, Spain, Finland, Sweden and Greece, have established the national individual dose central database to effectively save and maintain individual monitoring records. The database consist the information of workers, employers, monitoring, and occupational classifications, and provide specific information to authorities, employers and radiation workers.

The National Dose Registry (NDR) is the national repository for occupational dose records for Canadian workers. It is administered by Health Canada's Radiation Protection Bureau. It has been continuous operation since 1951 and now contains the records of more than half a million individuals. Australian Radiation Protection and Nuclear Safety Agency (ARPNSA) has established ANRDR (Australian National Radiation Dose Register) since 2011. ANRDR is applied to all radiation industries in Australia to centrally register, store and maintain individual dose records. Radiation workers can track their lifetime individual dose records, including all records from institutions in multiple jurisdictions and during their employment with multiple owners.

Japan Association for Radiation Effects established "Radiation Dose Registration Centre" in 1977, and the Korean National Dose Registry Management System was established in 1984, both systems are used to manage individual dose data of radiation workers nationwide.

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Turkey Occupational Exposure Levels and Dose Registration System**

Author: Cangul Akturk

Nuclear Regulatory Authority

Annual dose limits for employees

- The effective dose limit for radiation workers is 20 mSv on average for five consecutive years and 50 mSv in any given year.
- The annual equivalent dose limit for the hand and foot or skin is 500 mSv, and for the eyepiece it is 150 mSv (1).

Planned irradiation for special cases

- There are irradiations that occur in normal applications and require effective dose exposure over annual dose limits, but in special cases where there are no other methods other than irradiation, these overdoses are carried out with the permission of the Nuclear Regulatory Authority.
- For radiation workers who will be exposed to irradiation in special cases, dose limits are 50 mSv in any given year, an average of 20 mSv per year in 10 consecutive years, and a total of 100 mSv (1). Dose limits for pregnant radiation workers
- The effective dose limits of the pregnant radiation worker are 1 mSv per year, which is the maximum dose that the society can receive.
- Female employees during breastfeeding are not employed in jobs that are at risk of radioactive contamination (1).

International Central Dose Recording System

- Persons working in case of A Class working condition who is likely to receive more than 6 mSv of effective doses per year or equivalent doses of more than three-tenths of the dose limits given for eyepieces, skin, hands and feet) are required to use ''a personal dosimeter''.
- Dosimetry service is provided by organizations deemed appropriate by the Nuclear Regulatory Authority and the results of dosimetric evaluation are processed into ''the International Central Dose Recording System''(1).

Reference levels

The reference levels determined by the Nuclear Regulatory Authority are given below;

a) Recording Level: The dose limits recorded in monthly periods for radiation workers are above 0.2 mSv.
b) Review Level: Equivalent dose requiring further examination, if exceed 2mSv/month.
c) Intervention Level: Equivalent dose requiring intervention if exceeded 50mSv/month (1).

Other Notes for Dose Registration System:

- Doses taken during accidents are separated from doses taken under operating conditions. These doses are processed separately by the dosimetry service to the Central Dose Registration System.
- The dosimetry service provides radiation workers information about their own dose records.
- In the event that the employee leaves the post and starts working elsewhere, employee gives a copy of the dose records to the employee and ensures that the dose records are kept confidential.
- Personal dose records are stored in the Central Dose Registration System not less than 30 years after the end of the work requiring radiation exposure, during the working life in which the employee is exposed to radiation and then until the year the person reaches the age of 75 (2).

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National Dose Registry for Occupational Exposure in Saudi Arabia**

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Nuclear and Radiological Regulatory Commission

In light of the rapidly increasing development of nuclear and radiation applications used in vital areas such as medicine, industry, research, and education, the Kingdom of Saudi Arabia (the Kingdom) approved the Law of Nuclear and Radiological Control (the Law) that established the Nuclear and Radiological Regulatory Commission (NRRC) as the new regulatory body with the goal to strengthen regulatory capacity and capability in the Kingdom. The Law provides a clear direction on the responsibility of the NRRC to protect the workers, the public and the environment for any potential harmful effect of radiation based on the international best practices.

NRRC Regulatory Core Process related to Occupational Exposure
- Basses of Control on Occupational Exposure:
Currently, the NRRC is working toward approving their 20 regulations derived from their legal obligation under the Law to ensure safety, security, and safeguard of nuclear and radiation applications in the Kingdom. Among which, the Radiation Safety Regulation (NRRC-R-01), which aims to set out the general safety requirements in ensuring protection of people, including radiation workers and the environment against the harmful effects of ionizing radiation and for the safety of radiation sources. Additionally, it harmonizes the requirements applicable in the Kingdom with the international best practices in order to achieve the highest standards of safety in activities and facilities that give rise to radiation risks.
The NRRC is responsible for reviewing and assessing the safety and security of each authorized facility or activity in accordance with the stage in the regulatory process. The depth and scope of the review and assessment of the facility or activity by the NRRC shall be commensurate with the radiation risks associated with the facility or activity, in accordance with a graded approach.
The overall goal of the regulatory review is to verify that the facility or activity will not cause an unacceptable adverse impact on human health, safety, security, or on the environment, both now and in the future. NRRC has established two (2) procedures, including their technical guidance for review and assessment as follows:
I. Review and Assessment.
II. Review and Assessment to Support Oversight.
During the review and assessment processes, one of the main aspects of information to be presented for review and assessment by the applicant to the NRRC is the proposed control measures against occupational exposure. The submission shall include responsibilities of employers, authorized person, and workers in ensuring the requirement for occupational exposures can be met by the authorized person.
National Dose Registry
The NRRC-R-01 introduced the national dose limits for the annual exposure, for the average dose over five (5) years, and for pregnant women and defined the internal dose as an additive component to the total dose. All these items require a national dose registration of occupational exposure.

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Individual Monitoring of Exposed Workers - Performance Indicators**

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Greek Atomic Energy Commission (EEAE)

The Personal Dosimetry Department of Greek Atomic Energy Commission (EEAE) coordinates the individual monitoring of exposed workers in Greece since 1991 and maintains the National Dose Registry (NDR) containing data since 1964.
Over the last twenty years, the increasing use of ionizing radiation in medical practices and better access to this technology has led to a rapid increase in the number of exposed workers in the medical sector.
Additionally, during the past two decades, professionals have made significant efforts in the field of optimization for occupational radiation protection, including the application of safe practices and work methods, training of the exposed workers, use of radiation protection means, and finally the strengthening and promotion of all aspects of safety culture.
A big challenge in this framework is the evaluation of the performance of the occupational radiation protection system by using specific, measurable, and quantitative values.
Within a national project for raising awareness related to the use of ionizing radiation, EEAE established a set of such performance indicators making use of the data registered in NDR.
Specific parts of the NDR database were properly combined and used to allow the calculation of measurable indicators over the years. These indicators include among others: Collective dose, mean average dose, percentage of non-returned dosemeters, number of exposed workers with doses above specific values, number of workers who use more than one dosemeter.
In the present work, the trends of these indicators analysed for the different occupational and working categories will be discussed as well as the conclusion that can be drawn by EEAE for the effectiveness of the regulatory work and the areas for improvement.

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Iodine-131 Routine Monitoring Programme in Nuclear Medicine Staff in Uruguay*, **

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The Centre of Nuclear Medicine and Molecular Imaging of the University Hospital (CMNIM) jointly with the Radiochemistry Department of the Faculty of Chemistry settled the Internal Dosimetry Laboratory (IDL) in 2004. Since then, this group has been working uninterruptedly in monitoring potential internal contaminations with 131-Iodine in occupationally exposed personnel (OEP) due to the manipulation of open sources. The IDL performs thyroid measurements fortnightly and free of charge to the Nuclear Medicine Centres of the country both private and public. The Effective Committed Dose E (50) is reported quarterly to the Regulatory Authority. Taking into account that the CMNIM provides more than 260 GBq of Iodine 131 per year, the evolution of the E(50) of technicians, physicians, radiopharmacists and nursing staff since 2008 to date is presented in this work.
The protocol was developed in the framework of the ARCAL RLA/09/049. The methodology consisted in the following steps:

- Calibration of the detection system Captus 3000 (Capintec) NaI (Tl) 2x2'' detector in energy (weekly) and efficiency (yearly).
- Determination of the minimum detectable activity (AMD)
- Determination of counting accuracy.
- Measurement of the OEP neck at 25 cm distance from the detector, 300 seconds, fortnightly.

The effective committed dose estimation E (50) was calculated using the software AIDE 2e considering fast inhalation route, a Retention Fraction m (t): 7.41x10-2 and a Dose Coefficient e (g): 1.1 x10-8 Sv/Bq.
The derivate registration and investigation limits were settled in 1 (yellow) and 5 (red) mSv/year respectively. Figure 1, shows the measurements results of E(50) in the period 2008-2021 in full blue line.
The implementation of the program reached the 46% of the OEP involved in the manipulation of 131I open sources in the Nuclear Medicine area. The method was robust and easy to implement in routine. The IDL participated in three regional intercomparisons promoted by the IAEA achieving excellent results, which confirm the accuracy of the measuring protocols. The E (50) values were always below the registration levels, nevertheless they are submitted to the Regulatory Authority who keeps a national dose registry. Despite the high amounts of Iodine-131 delivered doses, E (50) presents low values indicating good manipulation protocols. This programme is seen as an opportunity of continuous improvement in optimization of the practice and education of the OEP in Nuclear Medicine area.

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Development of National Dose Registry: Malaysia Experience

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Atomic Energy Licensing Board

Regulation 5 of Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 enforced by the Atomic Energy Licensing Board (AELB), require the licensee to ensure that any work involving occupational exposure is adequately supervised and all reasonable steps have been taken to ensure that the radiation protection program, safety procedures, protective measures and safety provisions are observed. In this regard, the licensee is responsible to arrange the assessment of the occupational exposure of workers on the basis of personnel monitoring, where appropriate, using the dosimetry services as approved by AELB. Currently, in Malaysia, there are three occupational dose assessment service providers/ dosimetry service providers i.e. Malaysia Nuclear Agency, Sinaran Utama, and Alypz Sdn. Bhd.
Additionally, Regulation 22(4) of Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 require the licensee to measure the personnel monitoring for external exposure by using one or more approved personnel monitoring devices, carried continuously on the person, which is either Thermoluminescent Dosemeter (TLD), Radiophotoluminescence (RPL) Dosimetry, or Optical Stimulated Luminescence Dosimeter (OSL). When a worker occupationally receives an exposure exceeding 100 mSv, the licensee as employer shall ensure that such worker undergoes a medical examination and investigation by an approved registered medical practitioner.
In May 2017, the International Atomic Energy Agency (IAEA) Occupational Radiation Protection Appraisal Service (ORPAS) Mission to Malaysia was conducted. The ORPAS team consists of nine international experts in occupational radiation protection, including a Team Leader and an IAEA Coordinator. The purpose of the mission was to appraise the regulatory and practical implementation of the occupational radiation protection arrangements in Malaysia. The review compared Malaysia's arrangements for occupational radiation protection against the IAEA Safety Standards, as the international benchmark for protection and safety. The mission was also used to exchange information and experience between the team members and Malaysian counterparts.
One of the elements included in the review is the establishment and operation of a National Dose Registry. The mission has made a recommendation for the national regulatory authority to consider the establishment and operation of a National Dose Registry as a central point for the collection, maintenance, and assessment of dose records for occupationally exposed workers. Therefore, in 2020, AELB as a national regulatory authority in Malaysia has developed an electronic system for National Dose Registry called eDose to collect, maintain, and assess the dose records for occupationally exposed workers.
The development of eDose involved the participation of the Ministry of Science, Technology, and Innovation (MOSTI), Ministry of Health (MoH) and three occupational dose assessment service providers/ dosimetry service providers. This paper will discuss the process of the development of eDose, the consideration that has been taken during the process, the challenges that need to be faced, the implementation limitation, and the sustainability aspect.

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Occupational Exposure Levels and Dose Registries (The Nigerian Experience)**

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Nigerian Nuclear Regulatory Authority

International Conference on Occupational Radiation Protection: Strengthening Radiation Protection of Workers - Twenty Years of Progress and the Way Forward: Occupational Exposure Levels and Dose Registries (The Nigerian Experience) - by Okoye Valentine Ikemefuna
A remarkable distinction between the Public and occupationally exposed individuals alludes to the fact that the latter expectedly undergo personal monitoring that provides a good estimate of radiation dose received in the course of work. Since exposure to ionizing radiation in the workplace transcends exposure to only artificial radiation sources and encompasses exposure to naturally occurring radioactive materials (NORMs) as well as technologically enhanced radioactive materials (Te-NORMs), the demands on occupational radiation protection are getting increasingly complex. Excluding natural background ionizing radiation, any additional exposure from the workplace, if justified, is expected to conform to the "As Low as Reasonably Achievable (ALARA)" principle while taking into account the recommended occupational dose limits and applicable dose constraints. Occupational exposure levels, which cut across planned, emergency, and existing exposure situations, will potentially have different values in the different situations but the common overarching theme is the application of radiation protection optimization principle in all scenarios.
The nexus between an effective dose registry and optimization of radiation protection should be maximally exploited to the benefit of occupationally exposed individuals. Dose registries serve as repositories for dose records of radiation workers and prove to be a useful tool for decision making, research and epidemiological studies; hence its importance cannot be overemphasized. This robust computerized way of recording and maintaining occupational dose records incorporates the capacity to evaluate, analyze and track occupational dose histories in all three exposure situations, proffering feasible solutions for associated long-standing challenges with itinerant workers. Beaming the searchlight on Nigeria and its ever-growing applications of nuclear energy, the Nigerian Nuclear Regulatory Authority (NNRA), with the aid input data supplied by accredited dosimetry service providers, has painstakingly established a secure National Dose register (NDR), which manages occupational effective dose exposure in planned exposure situations in the interim, with bias to external radiation exposure only. This paper highlights the landmarks achieved regarding occupational radiation protection since the advent of Nigeria's NDR (for example; provision of data for UNSCEAR occupational exposure global survey, effective regulatory oversight based on observed trends etc) and proposes future applications of the NDR as a veritable instrument for optimization of occupational radiation protection in authorized practices for all exposure situations as well as the effective use of workplace monitoring of occupational exposure levels for congruence with data supplied from the NDR.

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Current Status on Occupational Dose Management in Malaysian Nuclear Agency**

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Malaysian Nuclear Agency has approximately 400 radiation workers. The Health Physics Group (KFK) of the Radiation Safety Division is assigned and responsible in managing radiation workers' exposure records. Previously, these occupational dose was recorded manually to the individual dose exposure record namely LPTA/A/BM 5 Seksyen B monthly. This LPTA/A/BM 5 Seksyen B will be assessed by regulatory body. As there is time consuming and a chance of human error in manual system, there is a need to change from manual to digital. Currently, the automated system is used in managing the occupational dose. The new system, Radiation Workers Managemengt System (SPPS) is an integrated system of online system in reporting the dose from the laboratory, eSSDL and Personnel Biodata System (Bioweb) that already in placed. As a result, the occupational dose is generated and radiation workers will be notified online in the form LPTA/A/BM 5 Seksyen B. The current system improves management efficiency, saves time and reduces human error.

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Radon in Brazil: Overview according to UNSCEAR Metrics based on Nationally produced Data between 2007-2020

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Among the general public's sense any activity involving radioactive materials is suspiciously foreseen for the potential danger it represents in their imagination. However, to seriously evaluate its requisites and feasibility is needed to measure the impacts and effects the radioactive material handling would generate either for the environment, public and Occupationally Exposed Persons.
Formerly pushed forward by the necessity of gathering data intending to formalize reasoned measures regarding the worldwide proliferation of nuclear experiments, the United Nations General Assembly approved in 1955 the establishment of its Scientific Committee on Effects of Atomic Radiation (UNSCEAR), from which Brazil is a founding member.
Aiming on collecting and producing data about the levels and effects of ionizing radiation, UNSCEAR holds annual meetings where a diverse set of topics on the ionizing radiation usage and Global Surveys' results are presented and discussed.
For achieving its goals, it relies on a distributed network of more than 50 institutions contributing from all around the globe. Brazil is represented by the Brazilian Nuclear Energy Commission (CNEN), and in charge of the Occupational, Medical, Public and Environmental topics stands the Institute of Radiation Protection and Dosimetry (IRD).
The asked data is collected by UNSCEAR once the contributors make the submissions, and after being cataloged and processed are compiled in a publications where it's also possible to find a brief context explaining the development and learned lessons that happened in a certain period of time. The data submissions are accomplished via the upload of fulfilled spreadsheet forms by the National Contact Persons (NCPs) at UNSCEAR's online platform.
The UNSCEAR frequently updates its documentations, and in 2021 it started a new workforce to release a contemporary version of the 2008 Report on the Sources and Effects of Ionizing Radiation. The survey also has the International Labor Organization's and International Atomic Energy Agency's support and its final release is scheduled for 2024, by the end of the current strategic cycle.
This work aims to anticipate the analysis of the Radon's data shared by the Brazilian venture with the UNSCEAR, describing the timespan ranging from 2007-2020.

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Twenty Years of Monitoring of Occupational Exposures to External Radiation Sources in Cuba: Results and Challenges

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In Cuba, the individual monitoring service (IMS) for occupational exposure was introduced at the end of the 80's decade at the same time with the introduction of nuclear technology applications. Since 2000, the External Dosimetry Laboratory (LDE) of the Center for Radiation Protection and Hygiene (CPHR) has been in charge to provide the personal dosimetry service for all the occupationally exposed workers of the country. The LDE has run an IMS based on automatic RADOS TLD system. The service provide dosimeters for whole body, extremities and lens of the eye monitoring, which are calibrated in terms of the operational quantities for personal dosimetry recommended by ICRU. The service also working according technical specifications recommended by IAEA and have been implemented a Quality Management System (QMS) which is accredited to ISO 17025 standard. The paper describes the service arrangements for operation and to accomplish with quality and technical requirements, as well as the main difficulties that affect their performance and operation. In addition, the paper presents a comprehensive overview of the occupational radiation exposure in the country during a twenty years period (2001-2020).

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The Current System of Occupational Exposure Regulation in the Czech Republic*, **

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Current system of occupational exposure regulation after implementation of ICRP 103, IAEA BSS and EU BSS is described. The poster will explain a system of categorization of workers, personal monitoring requirements, regulation of exposures at NORM workplaces as well as radon workplaces. There will be described also a system of outside workers exposures control and regulation. National Central Register of Occupational Exposures (CRPO) is in operation in the Czech Republic more then 20 years. The description of CRPO structure is presented as well as the results of data evaluation. There is about 23 ths active radiation workers registered in CRPO with collective dose 7,8 Sv. The average individual effective dose is 0,35 mSv for all workers and 0,9 mSv for those with doses above MDL. NORM workplaces are categorized in the Czech Republic as planned exposure situation with all relevant requirements for them. Radon workplaces are understood as existing exposure situation and some of relevant requirements for planned exposure situation are applied (see also poster Berčíková et all.)
Paper will give also a short overview of personal dosimeters in use and the system of dosimetric services and their authorization and control in the country. The approach for evaluation of higher doses and excess of the limits is also presented.

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The State System for Monitoring and Evaluation of Occupational Exposure in the Republic of Belarus*, **

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In Belarus the state system for monitoring and accounting of the doses of exposure of workers and members of the public from radiation sources (hereinafter referred to as Dose Accounting System) was created on the basis of the hygiene regulatory requirements and has been constantly improved in response to new developments in the international and national standards, taking into account recommendations of the IAEA Peer Review Missions in Belarus. A new Law of the Republic of Belarus “On radiation safety”, put in force in June 2020, defined that the accounting of exposure doses received by the workers and population should be carried out within the framework of the unified Dose Accounting System in accordance with the procedure established by the Ministry of Health of the Republic of Belarus (hereinafter referred to as MoH). The procedure on the maintenance of the Dose Accounting System was revised and approved by MoH Resolution of 27.11.2020 № 110. However the possibility of upgrading the existing DAS and supplementing the format of the State Dose Register with more wide information is still under discussion. The paper presents the features of the newly upgraded Dose Accounting System in the part related to occupational exposure and outlines the authors’ considerations on its limitations and need for further development.

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Regulatory Control of Occupational Exposure at Radiation Facilities**

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PNRA is maintaining occupational exposure record of radiation workers of radiation facilities in a database at national level. All radiation facilities are required to provide occupational exposure data on annual basis of their workers who are involved in radiation work. Data is also obtained from dosimetry service providers. The database is helpful in evaluating trends in occupational exposures, effectiveness of licensee's radiation protection program, identification of overexposure cases and actions taken by the regulatory body.

As per this database, the annual radiation doses to 96.82 percent of radiation workers remained less than 5 mSv while 3.15 percent of workers received doses between 5-20 mSv. A small fraction of workers i.e., 0.02 percent received doses greater than20 mSv. Under the regulations, the maximum dose in exceptional cases may go up to 50 mSv in any single year provided the average 5 years dose do not exceed 20 mSv. The investigation reports of occupational overexposure cases submitted by the licensee, are reviewed and if needed, the licensees are advised to take necessary corrective actions.

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SESSION 5:

OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL, RESEARCH AND EDUCATION FACILITIES

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Operational Radiation Protection at the Tehran Research Reactor TRR**

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The research reactor TRR is in operation more than 50 years; at the same time the reactor technical condition allows its further safe operation in the case of upgrading of some systems and elements. The basic objective of the reactor modernization implies future utilization complying with the nuclear and radiation safety requirements. The radiation protection system is the subject of such modernization. An overview of the technical and organizational measures aimed on the radiation protection of staff and population at the reactor routine operation is presented. The amount emission rates of Kr and Xe noble gas are measured in TRR. Measuring noble gases is very important in maintaining the health of reactor staff. Long-term experience of the RPS operation has demonstrated its adequacy and efficiency. The reactor operation has negligible influence on environment and cannot be a reason of any negative ecological changes. The amounts of radioactive substances released to the environment form the research reactor and off site radiation dose levels for personnel are under control and in the range.

Keywords: Research reactor, Radiation protection, Staff exposure, radioactive release, Radiation monitoring, noble gas

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Lesson Learned and Challenge to regulate Occupational Exposures for Industrial Workers and Related Industries in Thailand**

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In THAILAND, radioactive material and radiation activities are widely used. This paper shows the lesson learned and challenge concerned radiation exposures in industrial fields. The minimum requirements for licensee during operation gamma irradiation facility were radiological monitoring system, safety or interlock system, operation and emergency procedures, radiological protection, individual dose record for workers and radiological inspection report not included service room area. On that time, the slightly occupational radiation dose for workers by personal radiation dosimeters were found. High radiation levels were detected at resin filter of recirculating water system by Radiation Safety Officer (RSO). Cobalt-60 encouraged for radionuclide after identification by expert team. After verification the source pencil in the pool was cracked. This incident brought the new guideline for safety in gamma irradiation facility. Meanwhile, occupational exposures for radiation workers in radiographic testing fields have been found. In some cases, the workers were not awareness radiation exposures in practice because limitation at workplace and lack of safety culture such as inactive collimators during radiographic testing operation or suitable operational planning before perform work. Especially incomes for workers have been acquired that depended on amount of the film records. Although dose limits for workers and public were stipulated in ministry regulation but dose constraints were not clearly determination. The blinding regulation quantity 4,000 µSv/month for workers were specified. On the other hand, some workers are still expose to radiation dose more than blinding regulation. The implementation of measures and soft power have been establishing to protect the workers continuously perform. Furthermore, the by-product from steel mill plant such as slag and red dust are issues to consider in THAILAND. Because of radioactive contamination in scrap material bring to furnace then contaminated radiation in system and by product. The huge red dust which contaminated radiation have to manage and into the Technologically Enhanced Naturally Occurring Radioactive Material. Whatever all of incidents are challenges related with radiation protection to people and environment.

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Insights into Operational Radiation Protection at PSI*, **

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Paul Scherrer Institute (PSI)

The Paul Scherrer Institute (PSI) consists of a wide range of different facilities such as accelerator facilities, nuclear facilities and radioactive waste treatment. At PSI East site, the facility Hotlab and the Centre for Radiopharmaceutical Sciences are situated where on the one hand highly activated samples are investigated and on the other hand short-lived radionuclides for medical research and patient application are produced. Additionally at PSI West site, a proton accelerator, a spallation source, two electron accelerators and a proton accelerator for medical treatments are operated. Furthermore, four former nuclear installations are dismantled: Three former nuclear research reactors and one incineration plant for radioactive waste material.
This diversity of these facilities with the different experiments and tasks is quite challenging for the operational radiation protection teams.
In this contribution insights into current challenges for operational radiation protection at PSI by focusing on few examples will be given.

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Radiation Protection at Synchrotron Radiation Beamlines-Challenges**

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Synchrotron radiation source (SRS) is a unique photon source of high brightness with a broad energy range extending from infra-red to hard x-ray. SRS is essentially a storage ring in which relativistic electron beam is stored in the vacuum chamber for several hours during which synchrotron radiation is emitted tangential to the circular path of electrons. The radiation is then transported to the experimental station tens of meters away from the source through specially designed beamlines, where experimental investigations are carried out. The radiation environment of a synchrotron beamline consists of (a) gas bremsstrahlung radiation (having a broad energy spectrum extending upto the electron energy, typically upto few GeV) (b) synchrotron radiation (up to few tens of keV) and (c) photo-neutrons. Primary radiation hazard is the gas bremsstrahlung radiation, produced by inelastic scattering of high energy electrons with residual gas molecules inside the vacuum chamber of storage ring [1-3]. The gas bremsstrahlung photons channel to beamline along with the intense synchrotron radiation and produce scattered photons and photo-neutrons on interaction with the beamline components. Thus the radiation scenario in a synchrotron beamline is complex because of mixed radiation field of photons (direct and scattered) and neutrons with broad spectral range and sharp angular distribution. Radiation dosimetry in such radiation environment is very challenging due to limitations in conventional detector system in terms of its energy response, angular distribution of radiation and mixed field. Hence the beamlines are housed in specially shielded hutches to ensure radiation safety of the beamline scientists and users. In the present paper, theoretical and experimental studies for evalaution of gas bremsstrahlung and synchrotron radiation for radiation protection in the beamlines of the synchrotron radiation source, Indus-2 will be discussed (Indus-2 is a 2.5 GeV electron storage ring operational at Raja Ramanna Centre for Advanced Technology, Indore, India for production and utilisation of synchrotron radiation). The challenges in the evaluation of radiation source terms for gas bremsstrahlung radiation and its shielding requirements for ensuring radiation safety will be discussed. In the low energy front, as the conventional personal dosimeters ($CaSO_4$:Dy based) are error prone due to dominance of photoelectric effect, a free air ionization chamber (FAIC) has been designed, developed and characterised in house for accurate dosimetry of intense synchrotron radiation from Indus-2. The design aspects and the characterisation details will be discussed. Additionally the safety procedures, interlocks and monitoring of radiation around the beamlines of Indus-2 and future plans to strengthen radiation safety will be outlined.

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Occupational Radiation Protection of Employees in Industrial Irradiation Facility in Serbia – Risk Analysis*, **

Authors: Ivica Vujcic; Slobodan Masic

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Law on Nuclear Safety and Security of the Republic of Serbia prescribes the Occupational Radiation Protection for all radiation activities in Serbia. The only industrial facility in Serbia for sterilization of medical equipment and food conservation is located within the Vinca Institute of Nuclear Sciences in Belgrade. It is intended primarily for the industrial sterilization of disposable medical equipment. The radioactive source Co-60 is used for irradiation. The radiation risk is defined as a detrimental effect on human health or the likelihood of adverse effects due to exposure to ionizing radiation or any risk that is a direct consequence of exposure to ionizing radiation or the presence of radioactive substances. The paper describes in detail the analysis of all risks that may occur during the operation of the Radiation Unit. All risks in the Radiation Unit can be divided into three categories:

1. Risks in routine use
2. Risks in special operations
3. Accidents

Risks in routine use can be:

a) Risk of irradiation of employees in the irradiation cell

There are three openings where a person could theoretically enter the radiation block:

I) An opening in the ceiling of the cell, provided for the introduction of the container for transporting the source. The weight of the cover plugs (over 3.5 tons) completely prevents accidental opening.

II) Carrier passages. Small pools of water in these passages prevent entry due to forgetfulness or distraction. Behind the small pools, there are footrests. Any pressure on the footrest greater than 10 kg lowers the radiation source to a safe position.

III) The labyrinth entrance door is the only opening normally used to enter the irradiation room. The mechanical system prevents the door from opening when the source is in the working position.

b) Risk of irradiation outside the irradiation block

In all places that can be reached by persons who are not directly related to the operation of the device, the dose rate does not exceed the value of 2μSv/h for a maximum source activity of 1 MCi.

c) Non-nuclear risks

These are the risks associated with the presence of a conveyor and a drive winch for lifting the source. The speed of the conveyor is low, and there is a switch that can stop the movement of the conveyor if necessary, so the risks are minimized.

Risks in special operations:

a) Maintenance-related interventions

For certain maintenance interventions, the security network must be switched to ACCES LIMITED conditions. Under these conditions, any exceeding of the set dose threshold in the cell causes an audible danger signal.

b) Loading and unloading the source carrier

These operations are performed under the ACCESS LIMITED condition. Switching to ACCESS LIMITED allows the plugs to be lifted using a crane located on the roof (Fig.1). The transport container is lowered to the bottom of the pool. The sources are extracted from the container and stacked in the source carrier modules. If the springs in the pool are raised too high during these operations, this is immediately registered via the measuring line as an audible danger signal.

Accidents can be:

a) Cracking concrete protection

A crack in the concrete protection does not pose a great danger. There is a possibility to lower the source to a safe position.

b) Weakening of water protection

Emptying the pool does not cause an increase in the dose outside the facility. It just disables access to the cell. The case of a person entering the pool cannot cause serious consequences from the point of view of radiation if the person remains on the surface of the water.

c) Dropping the source bar from the module

Although this case is almost unbelievable, in such a case the measuring line in the labyrinth reacts and states that the dose rate in the labyrinth is increased above the value of the set threshold. The conveyor stops automatically, and the staff is not exposed to danger.

d) Pool contamination

The cobalt-60 source is encapsulated in a double welded sleeve made of stainless steel. They are manufactured and tested according to standard specifications. Perforation of both layers of steel can cause contamination of the water in the pool. Therefore, water is controlled for the presence of radioactivity. There is practically no danger for the staff in this case.

This paper also describes the risks depending on the radiation zone (active zone, restricted zone, free access zone), as well as decontamination procedures, water and air treatment in the irradiation cell, safe waste management procedure, training and supervision.

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Analysis of Data on Ionizing Radiation Exposure of Employees at the Radiation Facility for Industrial Sterilization*, **

Authors: Ivica Vujcic; Slobodan Masic

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The Program of protection against ionizing radiation, as a part of the Law on Radiation and Nuclear Safety and Security of the Republic of Serbia, prescribes the obligation to establish individual monitoring of exposed workers. In the Radiation Facility for Industrial Sterilization of the Vinca Institute of Nuclear Sciences (Belgrade-Serbia), TLD dosimeters are used for this purpose. Based on them, the absorbed radiation doses received by employees are read once a month.
In the Radiation Facility, Co-60 is used as a source of ionizing radiation. The facility has seven employees: four operators, two dosimetrists, and a head of the Radiation Unit. All of them are obliged to wear personal TLD dosimeters whose values are read once a month. These values show us the exposure of individual employees to the effects of ionizing radiation. The paper analyzes the data on the exposure of employees at the radiation unit in the last 5 years. The values of radiation exposure by workplaces, present in mSv/month, are shown (Table 1). Also, in the plan of the radiation unit, the positions where individual employees mostly stay during their working hours are labeled (Figure 1). Based on these results, the level of risk of each work position can be analyzed.

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Modeling and Assessment of Radioactive Iodine Dispersion inside Egyptian Radioisotope Production Facility

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Air quality is very important topic in radioisotope production facility. It is mandatory for some operators to be available behind hot cell to practice some activities concerning maintenance and operation. One of these tasks is redundant transferring Radioiodine from cell to QC lab and vice versa for measurements. Contam3.2 is a simulation model from NIST (National Institute of Standards and Technology) is used to predict I131 concentration in air in hot cell and area of operator behind the cell in emergency case. Emergency is described by dropping small amount of I131 on cell floor. The model predicts the elapsed time for exhaust system to remove contaminants to dedicated filter and protect operator from inhalation. An emergency statue is also studied in case of opening I131 cell door hole (20 cm) by operators to pick the sample for quality control tests. Pressure interference occurs in this situation permitting some Iodine traces in the area under consideration. Ventilation system is responsible to evacuate and remove all radioactive species to settle it inside dedicated charcoal filters to clean the area and keeps it in permissible safe limits.

Keywords: contaminants, activity, simulation, air concentration, extraction air, Kinetic Reactions.

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Occupational Radiation Dose Assessment of the Radioactive Waste Storage Facility at GAEC

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Occupational radiation dose of staff handling over 200 radioactive sources at the radioactive waste and workplace assessment in Radioactive Waste Management Centre (RWMC) of Ghana Atomic Energy Commission (GAEC) have been undertaken to determine levels of radiation safety. Firstly, five permanent workers were provided with thermoluminescent dosimeters (TLDs) to wear in between the chest and waist for skin and deep dose measurement. Thermoluminescent dosimeters (TLDs) badges were used for six months and the exposed thermoluminescent dosimeters (TLDs) were evaluated with HARSHAW 6600. Ambient equivalent dose rate (µSv/h) was measured using dose rate meter (Canberra Radiagem 2000). Twenty-four control points closed to the source where staff are exposed to ionizing radiation were chosen. The maximum skin dose of Permanent workers was found to be 0.39 mSv of dose limit (25mSv), whiles the body dose was 0.66mSv of dose limit (1mSv). The observed mean value for radiation exposure for the period of September, 2016 to February, 2017 was calculated as 0.15µSv/h. Average ambient equivalent dose rate from radiation survey was lower than 20µSv/h. The result of the decay store (0.9808µSv/h) and at the back of the decay store wall (0.1124 µSv/h), compared to the background radiation dose rate (0.0241µSv/h) confirm the radioactive waste management principle. The radiation dose to occupationally exposed workers obtained in this work was far below The International Atomic Energy Agency (IAEA) standard for radiation worker of 20 mSv/ year and 1 mSv/ year for the public exposure. The study indicated that RWMC staff are exposed to insignificant to ionizing radiation at work and therefore are in safe working environment. It is However, recommended that regular environmental monitoring of radiation level is carried out at the facility to ensure safety of the staff and the public.

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Occupational Exposure from Radiopharmaceuticals and labeled Compounds Production in Cuba

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Over the last twenty-five years, the Centre of Isotopes (CENTIS) of the Republic of Cuba manufactured of a wide range of radioactive products for healthcare, life science research and industrial applications and realized biodistribution and pharmacokinetic studies. These practices generally have not a significant occupational exposure but it is necessary to adopt dose constrains from ALARA principle. The aim of this study is to assess the occupational exposure taking into account the data belonging to the period 1996-2021. Individual monitoring used TLD dosimeters for measurement Hp(10), Hp(0.07) and Hp(3) and bioassays for E(50). The dose constrains by group of workers according to their operations considered experiences from other plants. As a minimum 63% of the monitored workers for E and 80% for Hp(0.07) received lower than 10% of the annual exposure limits. For Hp(3) since 2011 there is 67% of workers with values less than 6mSv. The maximum value registered for collective dose is 98.3 man-mSv y-1, which is less than about 0.49 times the initially projected value. The more exposed groups are Radiopharmacy and Quality Control. The most useful tools for exposure optimization are the use of electronic dosemeters, an additional shielding for the collection of radwastes and shielding for components in hot cells. These measures allow a dose reduction between 10-27%. This research shows an occupational exposure acceptably low.

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Occupational Radiation Protection in Accidental Exposure from the Centre of Isotopes in Cuba

Authors: Fernando Enrique Ayra Pardo; Zayda Amador Balbona

Centre of Isotopes

The aim of this study is to assess the occupational exposure during radiological emergency in the Center of Isotopes of the Cuban Republic, taking into account the data belonging to the period 1997-2021. A total of 240 abnormal occurrences are registered and 80% of them were classified as an alert situation. The permanency of worker in a local with Technetium generator drove the maximum value of E (25.77mSv) in 2000. A later detection of the spill during opening of type A package with a 278GBq of 131I, implied in 2011 the highest registered value 3.6 mSv of E(50). Incident with the maximum contribution to Hp(0.07) took place during the opening a package with 14.8GBq of 90Sr with spill in controlled zone in 2006. Exposures were controlled with TLDs and electronic dosemeters. Bioassays were made in an internal dosimetry laboratory from the Radiation Protection and Hygiene Center.

SESSION 6:

OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR POWER PLANTS AND NUCLEAR FUEL CYCLE FACILITIES

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Development of Quantitative Measurement and analyze Instrument for Continuously Source Items Investigation in NPP

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The collective dose of nuclear power plant workers mainly comes from the outage period of nuclear power plant. The corrosion activation products deposited in the pipelines and the radiation dose field formed are the main sources of occupational exposure of workers in the nuclear facilities, and the changes of their numerical value also reflect the operating state of the NPP unit. Therefore, it is of great significance to monitor the activity and dose rate contribution changes of radionuclides in key pipelines and points in real time, and which is useful to take necessary protective measures for subsequent maintenance work and reducing the collective dose as much as possible.

At present, the nuclear power plant only adopts the dose rate of the maintenance area to implement the corresponding protective measures during the outage period. Some nuclear power plants have implemented the source items investigation during the outage period, and have analyzed the radionuclide activity and dose rate contribution ratio of key pipelines and points in detail. And this work provides a reliable data basis for subsequent source items decontamination and dose reduction. However, during the oxidation operation of the outage period, it is change continuously for the activities of radionuclides at some key points. But there is no relevant instrument to monitor the trend of changes in the radioactivity in the pipeline in real time, which is reserved data blank for the subsequent radiation protection optimization and NPP unit operation evaluation.

In view of the above situation, a portable source term continuous investigation instrument which can quantitative measurement and analyze is developed based on CZT as the core radiation detection device. The core component of the instrument is 10*10*10mm CZT crystal and multi-channel analyzer. And tungsten alloys are used as collimating shields for detectors to expand the dose rate application range of the instrument. According to the different dose rate of the key pipelines, an automatic drive device is used to select the aperture of the collimator. To reduce operator exposure dose, wireless data communication and control module is used between portable devices and tablet computers. The radionuclide activity and dose rate contribution analysis software integrates an automatic spectrum analysis algorithm and a passive efficiency calibration software based on Genat4, which can quickly calculate and analyze the activity and dose rate contribution proportion of key nuclides in the energy spectrum.

The experimental result shows that the energy resolution of the detector for Cs137 is 1.6%, the ranging range is 3cm-10m, the dose rate adaptation range is 1μSv/h-3mSv/h, and the weight is less than 10Kg. The main nuclide activity and dose rate contribution ratio in the pipeline can be analyzed in real time, such as Co58, Co60, Nb95, Ag110m, etc. The device is compact in structure and easy to operate, and can be widely used in fixed-point continuous source item monitoring during outage period of nuclear facilities.

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A Radiation Field Reconstruction Method based on the Combination of Empirical Bayesian Kriging Algorithm and Least-Squares Fitting Algorithm

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During the operation, maintenance, decommissioning of nuclear facilities, workers often need to work directly in the radiation environment. Considering the personal dose limit principle in the radiation protection, specific planning is usually carried out prior to the implementation of the work, which requires the radiation protection personnel to obtain the radiation field data of the entire work area. However, due to the number of detectors is limited, the radiation data can only be obtained at a few locations in the radiation area. Hence, it is necessary to select appropriate algorithm to reconstruct the complete radiation field based on these limited radiation data.
After studying the accuracy and principle of commonly used reconstruction algorithms, the combination of Empirical Bayesian Kriging algorithm and Least-squares Fitting algorithm is introduced to reconstruct nuclear radiation field based on the sparse measurement data. And after many attempts, the semivariogram type of the Empirical Bayesian Kriging algorithm adopts the whittle detrended, while the model of the Least-squares Fitting algorithm is exponential function. In this method, the two algorithms are responsible for calculating different regions, the radiation field of the region surrounded by the measuring points is interpolated using Empirical Bayesian Kriging algorithm. Then the extrapolation is performed to obtain the radiation field of the outside region with Least-squares Fitting algorithm based on the results obtained in the previous step. To demonstrate the feasibility of this method, the simulation experiment with scattered and sparse measuring data is performed based on a large gradient virtual radiation field, and the average relative error of the reconstructed results is 20.7%. Considering more realistic application, another experiment with sparse data along a certain path is simulated. It shows that the average relative error is 25.1%. The results in this study indicate that the combined method is effective for the reconstruction of large gradient radiation field with sparse measurement data, which is helpful for radiation protection in practical engineering.

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Analysis on Characteristics of Occupational Radiation Source Items during AP1000 Unit Overhaul

Author: Sanqiang Xia

China Institute for Radiation Protection

More than 80% of occupational exposure in PWR nuclear power plants comes from overhaul, γ Deposition source term is the main source of occupational exposure during nuclear power plant overhaul. As the third generation advanced PWR nuclear power plant, it is necessary to measure and analyze its deposition source term during overhaul, so as to understand the main components of radionuclides in occupational radiation contributors and provide data for the optimization and evaluation of occupational radiation dose. During the first overhaul of AP1000 unit, the deposition source terms of main pipelines such as cold leg and hot leg in its main circuit system were analyzed in situ γ The spectrum is measured and compared with the source term data of typical M310 unit. It is found that the pipeline exposure dose rate of main circuit system of AP1000 unit is significantly lower than that of typical M310 unit. The average surface exposure dose rate of AP1000 unit's main loop system pipeline is 100 μ SV / h, the average surface contact dose rate of main circuit pipeline of typical M310 unit is 300 μ Sv/hll The main nuclides are co-58, Co-60 and Fe-59. The average surface activity of nuclide co-58 is 104Bq / cm2, the average surface activity of nuclide co-58 in typical M310 unit is 105Bq/cm2.The main reason why the pipeline exposure dose rate of the main circuit system of the AP1000 unit is lower than that of the typical M310 unit is that the compact structure of the main circuit pipeline in the AP1000 unit reduces the source of corrosion; The AP1000 unit began to inject zinc from the first cycle, reducing the corrosion and activation of Ni and CO in the substrate, so that the activity of nuclide co-58 is at a low level.

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Application of 3D Radiation Visualization Technique in Calculation of Radioactive Waste Storage Drums

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In recent decades, China's nuclear power industry has developed rapidly, but the increase in the number of workers has also posed a serious challenge to radiation protection. The visualization and simulation technology of 3D radiation field can construct the radiation field through the measurement data, and carry out 3D visualization of the radiation field, which is an important means of field monitoring and management. This method can make the staff more intuitive to understand the field radiation situation, provide a basis for shielding and protection, so as to effectively reduce the occupational radiation dose level of the staff, to achieve the purpose of radiation protection optimization. 3D radiation field visualization simulation technology is based on the field measurement data, inverse calculation of radiation source term activity, construction of the radiation field, and finally display the radiation field. The most important step is to use the inversion algorithm to calculate the activity of the source term. According to the calculation formula between radiation source and dose rate, the activity of each radiation source item can be calculated from the measured value of radiation field dose rate, which can be transformed into the problem of solving linear equations, so that it can be solved by mathematical method. The Maximum-Likelihood Expectation-Maximization (ML-EM) iterative method was used in this calculation.

A radioactive waste storage tank is selected as an example, and the radioactive waste is divided into four parts, assuming that each part is a uniformly distributed radioactive source. The nuclide of the radiation source is 137Cs. By measuring the dose rate around the storage drums of radioactive waste, part of the measured values are randomly selected for inversion calculation, and the activity of the four parts of the radiation source is obtained as 4.27E9Bq, 4.34E9 Bq, 4.50E9 Bq, and 5.14E9 Bq. At the same time, 60 measurement points were selected to compare the measured value of dose rate with the calculated value, and the results showed that the error of 59 points was less than 20%. The mean margin of error was 10.4%.

Through the calculation of the above example, it can be known that it is feasible to use ML-EM iterative method for source term inversion calculation, and the radiation sources in the radioactive waste storage tank are basically evenly distributed.

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Legal and Institutional Frameworks Addressing Occupational Radiation and Protection of Workers in Nuclear Power Plants in Nigeria**

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This paper foregrounds that in labour law and labour relations, the main focus of the law and policy drivers is to ensure occupational health and safety. This includes the promotion and maintenance of safe working environment ensuring capacity building and sound employee's health; improvement of working environment; development of work cultures and organizations to support health and safety in work places. Government makes laws that direct companies and employers to provide a safe working environment for their employees. This is intended to identify hazardous materials, conditions and practices at workplaces. Such laws will also assist employers and workers to reduce or eliminate the risks factors of their job. Nigeria over the years have enacted different legislations that provided for occupational safety measures for radiation protection in nuclear power plant industries. This paper examines the different legislation that makes provision for the Occupational Radiation Protection of Workers in Nuclear Power Plants in Nigeria. Though, the Constitution of the Federal Republic of Nigeria, 1999 in Section 17(3)(c), specifically provides that, the State shall direct its policy towards ensuring that the health, safety and welfare of all persons in employment are safeguarded and not endangered or abused. Major legislation enacted to provide for the safety and health of Nigerian workers generally and in Nuclear Power Plants in particular includes: the Factories Act, CAP F1, Laws of the Federation of Nigeria (LFN), 2004, Employees Compensation Act, 2010, Nigerian Minerals and Mining Act, 2007, Nigeria Atomic Energy Commission Act enacted 27 August, 1976, (now CAP. N90 LFN 2004), Nigerian Nuclear Safety and Radiation Act, 1995 (now CAP N142, LFN 2004), National Environmental Standards and Regulations Enforcement Agency (Establishment) Act, of 31 July, 2007, the Petroleum Industry Act, of 16 August, 2021. Other related laws that seek to give guidance to the implementation of occupational radiation protection of workers in Nigeria are: Nigeria Basic Ionising Radiation Regulations, 2003, Nigerian Radiation Safety in Nuclear Medicine Regulations, 2006 and the Nigerian Minerals and Mining Regulation, 2011. The paper takes into consideration the provisions of the major legislation that established Institutional Frameworks or bodies that implement and give directions for the proper functioning of laws that addresses safety and protection of workers against the effects of radiation in Nuclear Power Plants in Nigeria. For example, the Mines Inspectorate Department created by the Nigerian Minerals and Mining Regulation, 2011, the Board of the Nigeria Atomic Energy Commission and the Nigeria Nuclear Regulatory Authority and the Governing Board established by the Nuclear Safety and Radiation Protection Act. While the "Authority" acts as the substantive administrative organ of the body, the "Board" acts as the regulatory agency. These institutions assists in giving policy directions and ensure the efficacies of these laws. This paper concludes that Nigeria has enacted laws that provided for institutions with mandates to address issues of Occupational Radiation Protection of Workers in Nuclear Power Plants in accordance with international best practices.

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Occupational Radiation Protection as Part of the Occupational Safety and Health Management System in the Uranium Mining Industry

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NAC Kazatomprom JSC

NAC Kazatomprom JSC is the national operator of the Republic of Kazakhstan for the import and export of uranium, rare metals, and nuclear fuel for nuclear power plants. Since 2009, Kazakhstan has been the world leader in natural uranium mining. Kazatomprom, together with subsidiaries, affiliates and joint organizations, is developing 26 sites on the territory of the Republic of Kazakhstan, combined into 14 mining assets.
Uranium in Kazakhstan is mined by in-situ leaching method. HSE units deal with occupational safety and health issues – appropriate structures have been created at each enterprise, and HSE Department has been established in the headquarters.
Safety issues are one of the company's values, and radiation protection issues in general cannot be separated from health, safety and environment issues.
HSE units are divided into four areas – Occupational Health and Safety, Radiation Safety, Environmental Protection, and Analytics and Methodology. The latter also deals with quality issues.
Uranium mining is primarily characterized by most production processes with various risks to the health and life of the employee: harmful chemicals, work in a confined space, work at height, electrical hazards, transport, pressure vessels, rotating equipment and others. Radiation, taking into account the naturally low activity of natural uranium, is not able to affect the life of an employee at the same time, but it can affect the health of both personnel and the population and the environment in the long term.
Kazatomprom uses a risk-oriented approach to HSE issues. Control measures, or measures that reduce the amount of risk, are selected depending on the risk itself. At the same time, radiation is one of the production risks inherent in uranium mining activities.
At Kazatomprom enterprises, the safety culture is developing at all levels of the organization: leadership programs, programs for identifying dangerous conditions, dangerous actions and near miss have been introduced, behavioral safety audits are conducted.
As for ensuring professional radiation protection, uranium belongs to substances with naturally low radioactivity, the Radiation Safety services conduct constant monitoring of workplaces, individual dosimetry control of personnel, and measures are being taken to improve the state of radiation safety.
One of the measures is the development of an individual electronic dosimeter with a built-in GPS and data transmitter, which allows to practically assess the radiation situation in the workplaces of personnel online, identify abnormal places with pollution and respond to them in a timely manner.
This project for the development of the dosimeter was carried out in 2020-2021 and currently the dosimeter is being tested at Kazatomprom enterprises.
It should also be noted that the development strategy of Kazatomprom includes a measure to comply with the best international practices. In this area, it should be noted that Kazatomprom, especially in the field of radiation protection, cooperates with the IAEA and uses the IAEA guidelines. Kazatomprom also participated in the development of the SR-100 safety report "Occupational radiation protection in the uranium mining and processing industry", in 2019, the first training course in this area was held at the Kazatomprom site.

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Radiation Protection Programme for a Nuclear Fuel Fabrication Plant with Low Enriched Uranium*

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An adequate radiation protection programme must be established for a nuclear fuel fabrication plant with low enriched uranium in order to ensure the protection of people and the environment from the harmful effects of ionizing radiation. Such a programme should include the establishment of radiation protection groups, dose limitation systems, an adequate classification of working areas, the use and maintenance of radiation protection equipment and facilities, radiation and contamination monitoring, and radiation protection procedures. The purpose of this paper is to provide description of nuclear fuel fabrication plant and practical information and guidance to nuclear fuel facility specialists on the establishment of an effective operational radiation protection programme for a nuclear fuel fabrication plant. Training of workers in protection and safety should be a well established part of the overall programme on radiation protection. Doses to workers at nuclear fuel fabrication plant are comparatively low, especially in relation to the dose limit for occupational radiation workers. For workers in the nuclear fuel fabrication plant, the individual dose limits are based on external radiation and intakes. In addition to these limits the ALARA principle (as low as reasonably achievable) must be taken into account in design as well as operation.

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Challenges of Occupational Exposure to Radiation During Initial Radiological Characterization Activity of the Destroyed IRT-5000 Pool Reactor at Al-Tuwaitha Nuclear Center, Baghdad-IRAQ*

Author: Saad Guardh

The main objective of this paper is to identify both the importance of and the major factors relevant to, radiation protection procedures during radiological characterization of reactor pool IRT-5000 in order to support the decommissioning planning effort. There are many difficulties and challenges that faced technical Iraqi workers in carrying out this task for several reasons:
The nuclear reactor was not closed with a normal shutdown but was bombed during the second Gulf War in 1991, there is no historical information about the operation period and the accidents during that period, as well as the Elemental compositions of reactor materials, is unknown because all records were lost during the events in Iraq in 2003, in addition, the initial measurement indicates that there is a high radiation dose rate inside the reactor pool and this is dangerous for workers during the sampling process. The International Atomic Energy Agency greatly contributed to supporting Iraq for the decommissioning of its destroyed nuclear facilities, including the IRT-5000 reactor Several technical meetings were held at the headquarters of the International Atomic Energy Agency, and the recommendations and technical notes of these meetings were followed, in addition to supporting Iraq with the training of worker in different countries have the experience in this field and supplying necessary technical equipment to achieve the task.
There are many measures of radiation protection that have been followed and will be mentioned in this paper for the purpose of completing the initial radiological characterization activity and maintaining the received dose rate for workers within the limits of occupational exposure, despite the dose inside the reactor pool was high (2 Sievert), where the dose rate inside the pool was measured and determined its location and quantities of radioactivity were estimated.

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A Dynamic Point-Kernel Dose Assessment Method for the Dismantling Activities during Nuclear Facility Decommissioning

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There is an increasing international focus on the need to optimize decommissioning strategies of nuclear facilities, especially considering the radiological impacts on workers, the general public, and the environment. Assessing and optimizing occupational radiation exposure during the decommissioning of nuclear facilities is important to ensure the safety and health of workers. A major effort has been spent on the development of Virtual Reality (VR) tools for radiological characterization, dose estimation, and work management.
With the dismantling processes of source terms, new challenges emerged since the radiation field was dynamically changed. Combing the Computer-Aided Design (CAD) technique and the Point- Kernel method, this study aimed at dynamically assessing the radiological doses of workers during the dismantling of radiological components of nuclear facilities. The CAD-based cutting technology was introduced to meet the geometrical splitting of source terms. To accurately simulate the movement of cutting pieces, adaptive grid mapping technology was adopted to track the source terms. The results compared with Monte Carlo calculations in this study indicated that the dynamic changing of the radiation field can be accurately simulated in the phase of nuclear decommissioning. This study will help carry out the occupational safety and health management of decommissioning workers.

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Nuclear Industry Experiences in Occupational Exposure*, **

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The international nuclear industry has for many years had an impressive record of controlling and reducing occupational exposure, as measured by average individual exposure and collective dose. Current average worker doses are around 1 mSv per year for the whole nuclear fuel cycle, which is within the variability of natural background radiation. We hope for regulatory acknowledgement of this success through less pressure for formal optimisation assessments on our occupational exposures where the doses are already very low.

The industry is committed to maintaining the highest performance standards for occupational exposure. Our improvement processes focus on learning from peers and on improving and developing our overall safety culture. We expect our improvement plans to be based on demonstration of clear defined value benefits, and we must not move towards ‘minimisation’ of exposure.

It is important to ensure that we take an ‘all hazards’ approach to occupational safety. Radiation is just one of several hazards that face our workforces, and keeping risks in perspective is what industry does well. Over-prioritising the radiation risk would send mixed messages and reinforce the perception that low radiation levels are particularly dangerous.

Our experience shows that successful optimisation of occupational exposure depends on many factors, but developing a strong radiation protection culture as part of an overall safety culture is foundational to success. An organization with a strong safety culture will have a management that supports the development of technical excellence and a robust monitoring program along with a drive for continual improvement. At the individual worker level a sound culture recognises that knowledgeable and skilled workers can optimise how they complete their tasks.

In addition to the cultural approaches, optimisation comes from having technical competence and a high-level understanding of all processes.

In order to maintain this impressive record, there are several key future challenges for occupational exposure within the industry.

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The Effect of COVID-19 Pandemic Prevalence on Radiation Protection in Nuclear and Radiological Emergencies Investigation with Occupational Radiation Protection Approach*, **

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The lessons learned from the Covid-19 Epidemic show that the risk of an epidemic is associated with a rapid spread and unpredictable impact in the future. Large-scale emission events that trigger radiationenter code here emergency response structures and programs can occur at the same time. In fact, the simultaneous occurrence of effective radiological scenarios during an epidemic is quite possible. [8] Or in other word, the radiation incident may occur during an epidemic [9]. At the intersection of emergency management and the principles radiation protection, it is important to pay attention to these intersections in order to protect against occupational exposure. Therefore, in this article, while taking advantage of the lessons and experiences of IAEA member countries and paying attention to the documentation and standards of radiation safety and radiation emergency management, evaluating the simultaneous effects of radiation exposure and the epidemic situation is considered to give a realistic picture of the two situations is mapped out to ensure health and environmental protection, and suggestions are made for possible future conditions.

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Occupational Radiation Protection at Nuclear Power Plant in Pakistan**

Author: Qamar Huma

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Occupational radiation protection is an area of vital importance during the lifecycle of Nuclear Power Plants (NPPs). Radiation workers are likely to receive exposure mainly during the routine maintenance activities as well as the refueling outages (RFOs). This exposure can be controlled by taking some tangible measures. These measures include regulatory control, licensee's mechanism to control radiation exposure and dose assessment. Pakistan Nuclear Regulatory Authority (PNRA), as the national regulator has established a robust regulatory framework for radiation protection and safety. Under this framework, PNRA Regulations on Radiation Protection-PAK/904 (Rev.1)[1] specifically describe the requirements for occupational radiation protection which are consistent with the IAEA safety standard (GSR-Part-3) and are followed by the licensee to control occupational exposure. PNRA reviews and approves different submissions of license including Final safety Analysis Report (FSAR) and Radiation Protection Program (RPP) in order to verify compliance of these requirements. PNRA also conduct regulatory inspections to verify the implementation of requirements of PAK/904 (Rev.1). Observations and findings of these inspections are communicated to licensee for corrective actions. Furthermore, licensee submits periodic reports on occupational exposure to PNRA for review and analysis of dose trends. Dose trends reveals that occupational exposures at NPPs are well within regulatory limits (20 mSv/y) and almost 80 % of workers receive doses of less than 1 mSv/y. This paper describes the steps taken by PNRA for regulatory control of occupational exposure. Furthermore, it describes measures taken by licensee to control occupational exposure at NPPs. The paper also highlights the analysis of dose trends which demonstrate the adequacy of occupational radiation protection at NPPs in Pakistan.

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Health Physics Experiences during Maintenance Works Performed in High Background Shielded Cells of Fast Breeder Test Reactor (FBTR)

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FBTR is a research reactor operating at Kalpakkam, India, with an installed capacity of 40 MWt. The reactor serves as a test bed for irradiation of fuels and materials and provides experience in handling of sodium and reactor operation. It has attained the design power level of 40 MWt in March 2022. The reactor containment building is divided into four zones and further subdivided into cells. The reactor assembly is housed inside a cylindrical cavity surrounded by biological shield. Primary heat transport system piping and equipment are located in B1 and B2 concrete cells. Primary sodium purification circuit and primary sodium storage tank is housed in B6 and B4 cells respectively. The pipelines in the primary circuit are provided with devices viz., wire and plug type sodium leak detectors and temperature sensors.
In 2021, two major works were performed for the first time in high background B cells of FBTR. In B6 cell, nine sodium leak detectors and a temperature sensor were rectified. Post rectification, all the devices were energized and observed to be in a healthy state. In B4 cell, the primary hot argon line connecting the storage tank and overflow tank was observed to be blocked due to sodium aerosol deposits and normalisation of the line was performed. In B4 and B6 cells, the background gamma radiation level was 0.12-1.4 mGy/h and 0.4 - 0.7 mGy/h respectively. The maximum gamma radiation level of 5.5 mGy/h was observed on the lines of B6 cell.
Radiological work permits were cleared during the work to control exposures. Industrial work permits were cleared to ensure oxygen levels, mask air, illumination and scaffolding to reach different areas as intended. PPEs were provided during the work and personnel monitoring devices were issued. For the reduction of external exposure, temporary shielding was provided at few locations and lead aprons were provided to the individuals. Approved step-by-step procedure, micro schedules, pre-job ALARA meetings and discussions were held during the course of work to ensure safe completion of each task as intended with minimum personnel exposure. The repair works include scaffolding to access different regions, checking healthiness of cable by visual inspection followed by opening the cable termination at sensor end and measurement of voltage. Rectification of sensor was carried out by replacing cables with proper thermal insulation at junction box. Removal of thermal insulation and relaying of the same was performed whenever the sensors could not be repaired at junction box level. In B4 cell, radiography was performed on the nozzle portion of the hot argon line near the storage tank. The line was cut to remove sodium deposits and welded back. No air activity or contamination was observed on the lines and floor of the cells. The collective dose expenditure for the leak detectors rectification work and choke removal operation was 42 P-mSv against the budgeted dose of 64 P-mSv. The works were completed as planned and provided enough confidence to the plant for carrying out maintenance works in high background cells, if required.

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3D-CZT Gamma-Ray Spectrometers and Imaging Spectrometers for Source Term Characterization at Nuclear Power Plants*

Authors: Willy Kaye; Yvan Boucher

H3D, Inc.

The use of gamma-ray imaging spectrometers at nuclear power plants and other facilities for the purpose of understanding the source term environment has grown sharply in the past 10 years. The primary instrument used at nuclear power plants in the United States is the H-Series unit made by H3D, Inc. The instrument uses 3D-CZT detectors, which are able to provide 1% energy resolution along with isotope-specific gamma-ray imaging in a portable, room-temperature system. The system is used at 75% of nuclear power plants in the United States as well as power plants in Europe and Asia. This paper will discuss the lessons learned over the past decade for these instruments for applications such as optimization and verification of shielding, surveys of incoming and outgoing shipments, characterization of high radiation areas and locked high radiation areas, and site-wide contamination surveys. Additionally, gamma-ray spectrometers based on 3D-CZT can also be used for real-time isotopic trending of source term contained in pipes to improve decision making that will lead to lower source term and dose reduction to workers. Results and lessons learned for these systems deployed at nuclear power plants will be discussed.

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Ensuring Radiation Safety at Nuclear Fuel Cycle Closing Enterprises Based on Safety Culture Principles*

Author: Veronika Shelenkova

Co-author: Petr Fominykh

Mining and chemical combine

The entry into the new millennium was marked by a new stage in the development of nuclear energy. The revival of global nuclear energy is directly related to the solution of such problems as:
- increase in energy consumption by the population of the planet;
- problems of ecology and climate change.

It is obvious that the above problems require more environmentally friendly energy sources, the most significant of which is nuclear power.
The closure of the nuclear fuel cycle is recognized as a strategic direction for the development of nuclear energy in Russia. The main purpose of closing the nuclear fuel cycle is to maximize the use of the energy potential of nuclear fuel through the reuse of nuclear materials and to minimize the amount of radioactive waste subject to final isolation. One of the leading positions in the development of a closed nuclear fuel cycle in Russia is occupied by a Mining and chemical Combine (MCC). The following technological facilities that form the basis of a closed nuclear fuel cycle are concentrated at the MCC: spent fuel storage, MOX fuel production, and a radioactive waste management complex. The presence of such radiation-hazardous facilities obliges the company to pursue a policy that shows that ensuring safety has the highest priority over other activities of the enterprise.
The implementation of the following measures at the enterprise makes it possible to ensure radiation safety when handling ionizing radiation sources:
- compliance with the requirements of legislation and regulatory and technical documentation on radiation safety;
- annual planning and monitoring of the implementation of measures to ensure and improve radiation safety in the divisions of the enterprise;
- carrying out work to substantiate the radiation safety of new products, materials and substances, technological processes and industries that are sources of ionizing radiation;
- implementation of systematic industrial control over the radiation situation;
- control and accounting of individual radiation doses of employees of the enterprise.

One of the fundamental directions in terms of ensuring radiation safety is the control of doses of external and internal irradiation of the personnel of the enterprise involved in work using ionizing radiation sources.
The organization of individual dosimetric control includes:
1. Individual dosimetric control of external radiation with the use of individual dosimeters;
2. Control of the individual dose of internal radiation using a human radiation spectrometer or biophysical methods of monitoring biosubstrates to determine the individual intake of radionuclides into the body of each employee;
3. Individual dosimetric control based on the results of dosimetric control of workplaces.

Figure 1 shows the dynamics of the average annual doses of personnel of the main production facilities of the Mining and Chemical Combine in the period from 2000 to 2019.

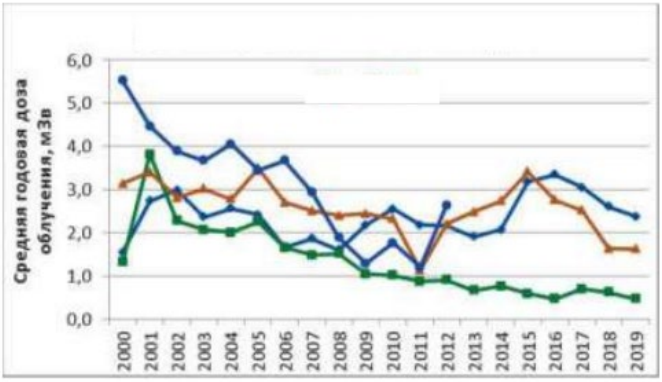

Figure 1 - Dynamics of average annual doses of personnel

In recent years, the values of the average annual doses of the personnel of the main production facilities of the enterprise are in the range of 0.6-3.7 mSv, and for the Mining and Chemical Combine as a whole 0.7-1.1 mSv.

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National Plan for Nuclear and Radiological Emergency Exposure in Nigeria**

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Nuclear technology and application in Nigeria is fast developing; Nigeria and many other developing countries use nuclear application in everyday activities, in health sector, agricultural sector, oil and gas Industries, Construction industries, Manufacturing Industries, Education and training. The Federal Government of Nigeria has proposed to construct its first nuclear power plant by mid-20201. Despite safety, precautions in design and operations accidents involving radiation sources do occur. Many accidents with radiation sources occur due to the lack of Regulatory Authority, or lack of emergency response preparedness is essential in order to mitigate the consequences of an accident, these accidents could lead to significant radiation exposure to the workers, and the public. The National Plan for Nuclear and Radiological Emergency Exposures is a subset of the National Nuclear and Radiological Emergency Response plan which sets out details of Nigeria's planning and preparedness for a national response to a nuclear or radiological emergency likely to cause widespread exposure across Nigeria. The objective of the national plan is to establish a timely, organized and coordinated emergency response by the Nigerian Authorities to promptly and adequately determine and take actions to protect members of the public, emergency workers and environment in line with the highest international standards with respect to safety and environmental protection.

The National Plan was based on the hazard analyses conducted in Nigeria, there exists a potential, albeit small, for emergency exposure situations to occur as the result of accidents or incidents. This plan sets out steps for a national response to an emergency exposure situation, and the subsequent transition to a managed existing exposure situation.

The central goal of this plan is to substantially reduce public exposure to any radioactive contamination which reaches Nigeria as a result of a major nuclear or radiological incident nationally and across boundary. It does this by setting out steps for the rapid implementation of protective measures in the hours and days immediately following the incident. These steps will substantially reduce public exposure to any radioactive contamination which reaches the country. This will in turn minimize the potential long-term health risks to the population.

This paper focuses on Nigeria's efforts in developing this plan, achievements, challenges and way forward to perfect the plan for Occupational radiation protection in emergency exposure situations and subsequent transition.

SESSION 7:

OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO NATURALLY OCCURRING RADIOACTIVE MATERIAL, RADON, AND COSMIC RAYS

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Radon in Nicaraguan Gold Mine

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Nicaragua is a tropical country so the climate is warm, which forces residential houses to be ventilated. This makes Radon gas emphasize in the workplace, especially in closed places and that are underground. One of the places that meet these conditions are gold mine tunnels In Nicaragua, gold is one of the country's natural resources and it is exported generating foreign exchange. There are several mines and types such as open pit but by the same condition of being open pit they are ventilated places. The evaluation that we will carry out will be directed to the underground mines. In the gold mines there are a good number of workers dedicated to this mining activity, from engineers in mines to workers who work shifts in tunnels, also this work to measure Radon gas is carried out in a mine that is authorized by the Ministry of Energy and Mines and the Ministry of Labor with the international standards of worker protection for this activity and where workers use their protective accessories such as helmets, masks, etc. The measurements that will be obtained will be compared with the international limit of 1 KBq / cubic m, depending on the results, actions will be recommended to avoid the inhalation of Radon gas. The procedure to follow is to go to the tunnels of the mine that is approximately 150 kilometers from our capital, which is where the regulatory offices are to place the equipment to measure Radon and leave it for a long time to do the accounts and give us the values in Bq / cubic m and in different periods of time, for example, compare if it is the same value in the morning in the afternoon and in the evening, this in order to evaluate if the flow of Radon gas is kept constant at different times or changes (decreases or increases).

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Control of Natural Radon Exposure to Workers in Schools and Educational Establishments in the Czech Republic**

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Co-author: Ivana Fojtikova

State office for Nuclear Safety (SONS) has been dealing with the issue of radon in schools for a long time. Many measurements have been made under the Radon Programme, and schools have been regularly encouraged to measure and, where necessary, implement protective measures - which may not be costly in nature but can still be very effective. These measurements were voluntary with a concern for a healthy working environment for staff and pupils.
The new legislation has set new obligations for the workplace operator and also for the owner of a school building and educational establishment, effective from February 2018 if at least one of the following conditions is met:
When the school building is constructed, a building permit or a permit similar in content was issued before 28 February 1991 (before the first radon regulation came into effect), and the school building is constructed in one of the areas of the listed municipalities where there is a high probability that high radon concentrations will be detected.
The school building has undergone structural changes that could affect the radon concentration inside the building (typically, this may include, for example, insulation of the building, introduction of controlled ventilation or air conditioning), and subsequently, no measurement of the radon concentration has been made to confirm that the specified reference level has not been exceeded,
the school building has been measured in the past (for whatever reason) to exceed the reference level of 300 Bq/m3 for the radon activity level (OAR), regardless of whether it is present in the named municipality, and no anti-radon measure has been taken to confirm its effectiveness
The operator of the workplace that meets one of the conditions must comply with the obligations set out in the Atomic Energy Act:

1. notify information about the site to the SONS (the pre-defined registration form)
2. arrange for radon measurements and, if the situation requires, determination of the effective dose to employees
3. inform workers of possible increases in radon exposure

If the volumetric activity of radon in the indoor air of a building exceeds the reference level, the owner of the building must take measures to reduce the exposure to a level as low as reasonably achievable, taking into account all economic and social considerations.
The poster will also include information on the process of managing the regulation and control of the workplace and the current results of measurements and anti-radon measures taken to reduce radon exposure.

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Identify and Quantify the Exposure of the General Public to Radon Gas and the Gamma Dose Rate in "Café Bahia" Ornamental Rocks

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Radon is a radioactive gas that emanates from rocks and soils and tends to be concentrated in closed spaces such as underground mines, underground parking and dwellings. Infiltration of soil gases is recognized as the most important source of residential radon.
Radon is one of the main contributors to the dose of ionizing radiation received by the general population, hence the need to identify and quantify the levels of radioactivity and the various contributions in the various construction materials.
This work was developed to evaluate the news published in 2008 in the USA relating Brazilian ornamental rocks with high radon concentrations and also high gamma exposure rates.
Therefore, the theme became a reason for mobilization of institutions such as the IRD, as Brazil at that time and until today is a great exporter of ornamental rocks, in value and physical volume for several countries.
This work was developed with the main objective of identifying and quantifying the exposure of the public to radon gas and the gamma dose rate in "Café Bahia" type ornamental rocks due to its wide use in homes in the national and international markets.
The technique used to develop this work is easy to use and manipulate.
Eighteen samples of "Café Bahia" type ornamental rocks from three different mine fronts were analyzed. For this analysis, the GENITRON AlphaGUARD - PQ2000 PRO equipment was used with measurement cycles adjusted to 60 minutes, for the simulation of a closed environment we used a Container for Emanation and Calibration of 50 liters from SHAPHYMO. The samples were packaged together with AlphaGUARD inside Container for Emanation and Calibration and it was closed/sealed for 25 days. This time was determined for the 222Rn to reach radioactive equilibrium with the daughters, the AlphaGUARD was connected inside the container through external connectors to supply power to the batteries, connection with the notebook in order to view the results of the measurement that was being carried out and a "FAN - Mains Supply" to circulate the air inside the Container. With the sealed Container, we guarantee that there was no interference from the external environment. The results for all samples were as expected, clearly identifying the behavior of Radon Gas in closed environments.

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Radioactivity Levels and the Assessment of the Associated Health Hazards at Um Bogma Area, Sinai, Egypt**

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As a part of the national survey to evaluate some strategic elements such as U, Mn, Fe, Ca and Zn, we have undertaken a quantitative study to fulfill this target. The concentration of some these elements have high values up to 50%, 18.4%, 10.9% and 4.8% for Fe, Mn, Ca and Zn respectively [1]. Um Bogma area has an open industrial field and is considered to be one of the most rich region in natural resources in Egypt. Therefore, safety rules for workers should be precisely estimated and strictly applied. The concentrations and distributions of natural radionuclides for sedimentary twenty two rock samples from Um Bogma which subdivided into four localities [Abu Zarab (AZ), Sad Elbanat (SB), Talet Selim (TS) and Allouga (AG)] have been measured using gamma spectroscopy technique. The average concentration values of 238U, 232Th, and 40K in the surveyed samples are (696.06±5.9) Bq kg−1 for 238U, (45.4784±1.9) Bq kg−1 for 232Th and (362.13±8.5) Bqkg-1 for 40K.the ratios 238U (226Ra)/ 40K and 238U(226Ra)/232Th have been utilized to determine the 238U level of content in the investigated area. Also, these measurements are very important to detect the harmful effects associated with the existing high radioactivity levels in Um Bogma area, Sinai. The radiation hazard parameters, such as absorbed dose rate, the annual effective absorbed dose rate, external hazard index, internal hazard index, and the representative level index were calculated from the measured concentrations of natural radioactivity.

Keywords: X-Ray, Natural radioactivity, Radionuclides, Hazards parameters, Sinai.

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Radiological Characterization of a Calcarenite Quarry used as Raw Material for Construction Materials**

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The objective of this work was to carry out a radiological characterization of a calcarenite deposit used in the production of sand as a construction material. The deposit is divided into two sectors (east and west) and is generally made up of calcareous sandstone sequences. The mining works in the quarry consist of the removal, transfer and storage of the material. For the radiological characterization, a monitoring of the gamma dose rate was carried out along the site of the deposit, with a portable equipment brand STEP OD 02. Samples of the process were also taken for laboratory analysis: uncrushed rock, crushed rock, washed sand (end product), water used in the process and sludge produced from sand washing. All samples were analyzed at the Environmental Radiological Surveillance Laboratory of the Center for Radiation Protection and Hygiene, using a high-resolution gamma spectrometry system to determine the environmental radionuclides of interest. Measurements of radon gas in air and water were also carried out, using Alpha Guard DF2000 continuous measurement equipment. The monitored dose rate values ranged between 0.28 and 0.97 μSv/h. The concentrations of Ra-226, Pb-210 and Th-234 and of K-40 found in the analyzed samples are below the internationally recommended values from which remedial measures must be taken or some type of regulatory control must be established the presence of natural occurring radioactive materials. On the other hand, the values of Rn-222 determined in air are well below the levels recommended for members of the public in the Basic Radiological Safety Standards of the International Atomic Energy Agency.

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Occupational Radiation Protection in the Workplaces Involving Exposure to Naturally Occurring Radioactive Material, Radon and Cosmic Rays in Nigeria**

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Human exposures to ionizing radiation in daily life come from both natural sources - such as naturally occurring radioactive materials (NORM) in soil, water, vegetation, and cosmic rays, as well as anthropogenic sources - such as artificial radionuclides, X-ray, and other medical devices. The Nigerian Nuclear Regulatory Authority (NNRA) is the competent National Authority that is responsible for protection of health of all users, handlers and the public from the harmful effects of ionizing radiation in Nigeria. Accordingly, the NNRA has instituted a robust dose monitoring programme for occupational exposures of all users and handlers of ionizing radiation sources to ensure that established dose limits are not exceeded. The personnel dose monitoring programme requires a madatory systematic assessment of doses to every radiation worker by an NNRA approved dosimetery service provider (DSP), as a necessary step to guarantee occupational radiation protection.

Following the recent policy of the Nigerian Government to diversify her economy to explore the untapped potentials in the mining sector and reinvigoration of the aviation sector, a new scope of challenge of occupational exposure due to NORM in the mining sector and exposure of airline crews and frequent fliers to cosmic rays was identified. Besides, the use of earthen materials to build public buildings and homes, along with building on rocky regions posed another challenge of exposures due to radon in the workplaces and homes. In response to the challenge, the NNRA reviewed its principal Regulations – the Nigeria Basic Ionizing Radiation Regulations, in line with the requirements in International Atomic Energy Agency (IAEA) General Safety Requirements GSR Part 3 to cover the aspects occupational radiation protection in existing exposure situations whereby workers may be exposed to existing sources of radiation such as NORM, radon and cosmic rays. Thus, adequate requirements have been laid out to take care of the protection of workers and workplaces in an existing exposure situation, covering exposures due to contamination of areas by residual radioactive material from legacy sources, NORM, and for monitoring airline crew for possible exposures due to cosmic radiations of the celestial bodies. Moreso, a National Dose registry (NDR) has been established for filing of all records of occupational doses incurred by classified workers throughout their period of work with ionizing radiation to keep track of individual doses so that established dose limits would not be exceeded.

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Occupational Radiation Protection in Coal Mines: Operational and Regulatory Challenges

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Malawi has had coal mines since the 1980s. There are both open and underground coal mines in the Northern Part of Malawi. Most mines are operated by small and medium entrepreneurs who have limited capital to invest in comprehensive operational and safety systems. This poses a challenge to the safety of mine workers especially in underground mines.
The Atomic Energy Act No. 16 of 2011 requires that all facilities and activities involved with radiation sources including radon should put in place adequate measures for workers protection. The Act was passed much later after many coal mines had been in operation for decades and their is need to bring all existing facilities and activities including these coal mines into regulatory control.
The paper explores the various operational and regulatory challenges that exist in the coal industry in Malawi and how these challenges may continue to affect occupational radiation protection. The paper is also meant to open a discussion on how regulatory frameworks can be set to address radiation protection and safety of workers in existing facilities.
A survey of three underground coal mines identified the following operational challenges:

1. limited capital to invest in safety measures e.g. ventilation systems,
2. lack of commitment by management to adopt occupational safety systems;
3. lack of capacity by competent authorities to regulate coal mines e.g. lack of equipment;
4. lack of knowledge among operators and policy makers on the radiation hazards associated with coal mines

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Radiogenic and Dosimetric Characterization of Columbite-Tantalite Mineral Extraction and Processing to Assess Occupational Radiation Exposure in Artisanal Mining in Rwanda*

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Background: Unregulated artisanal mining of columbite–tantalite (coltan) which is widespread in Eastern Africa is growing rapidly due to increased demand for tantalum, a rare refractory metal that is highly resistant to corrosion and a good conductor of heat and electricity. Such mining works that involve naturally occurring radioactive materials (NORM) are however sources of radiation exposures; and, from the environmental point of view the immobilized discharges (mine tailings and mine waste waters) of the [now] technologically enhanced (TE)-NORM) are radioactive wastes. A screening survey of artisanal mining in three regions (Muhanga, Ruli and Ngoma) of Rwanda was undertaken motivated by the need to provide data for development of evidence-based regulatory frameworks for artisanal mining and a method for quality assurance of the mineral.
Methodology: Dose rates in the field were measured using the Sensor Meter (Model G/B) survey meter. Radiogenic and dosimetric characterization of the coltan extraction and processing was done by HpGe-based gamma-ray spectrometry combined with recommended (UNSCEAR) computational, as well as multivariate modeling based on principal components analysis (PCA) utilizing ore gamma-ray spectra as geochemical fingerprints. The various artisanal exposure scenarios and pathways were studied and the results used to estimate the occupational exposure.
Results: The mean activity concentrations of 238U and 232Th in the extracted tantalum were 513 Bqkg-1 and 57 Bqkg-1 respectively; while that of 40K was 267 Bqkg-1. The measured absorbed dose rates ranged 518.34 - 796.92 nGyh-1, 522.4 - 820.7 nGyh-1 and 563.8 - 845.7 nGyh-1 in Muhanga, Ruli and Ngoma respectively: these values are [g11 times higher than the world average (value of 60 nGyh-1) thereby delineating Rwanda's coltan mining belts as high background areas (HBRA). The activity concentration of 238U was 15 times higher than world average. Compared with the dose rates obtained from model computations using radionuclide activities the values were twice as high: the effective doses ranged 0.0173 - 0.272 mSvy-1 in Muhanga, 0.013 - 0.525 mSvy-1 in Ruli and 0.022 - 0.255 mSvy-1 in Ngoma - indicating the significance of radioactive dust and radon in the occupational radiation exposure: dust inhalation accounted for 98 % of the exposure. Processing of the coltan ore was observed to enhance the concentration of 232Th and 238U by a factor of 3 and 2 respectively, while it reduces that of 40K by a factor of 15. The processed coltan samples were uniquely source-apportioned to their respective mining regions using PCA modeling utilizing radionuclide activities and gamma spectral signatures as model inputs. Multivariate modeling by PCA also successfully discriminated extracted from processed coltan.
Conclusión: Radiogenic fluxes due to NORM in the artisanal extraction and processing of coltan in Rwanda were quantified and the occupational dosemetric attributes due to the practice derived. Dosimetrically significant multivariate relations were gleaned from the radiometric data. Although analyses of the effluents showed the mining practices do not radiogenically impact the environment, interpreted together with the dosimetric data, the study raises occupational exposure as well as quality assurance concerns of artisanal columbite-tantalites from Rwanda.

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Management of Norm Contaminated Hydrocarbon Wastes in Gabon**

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In Gabon, the experience of the regulatory authority regarding radiological safety of Naturally Occurring Radioactive Material (NORM) is relatively new. In the oil and gas industry the NORM encountered include scales and sludge formed in the inner surface of production equipment and pipelines. Contaminated soil with NORM as a result of uncontrolled disposal of production water may also be of concern. The main radionuclides involved include Ra-226, Ra-228 and Pb-210. The present paper describes the radiological safety measures put in place for the management of NORM contaminated hydrocarbon wastes from a local operator, from their storage in authorized waste storage installations to their transport for their disposal in a dedicated centre in Europe. In particular, radiological assessment of the storage installations, workplace and individual monitoring are presented.

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Estimation of NORM in Local and Imported Granite used as Building Materials in Tunisia

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Measurements of natural radioactivity in local and imported samples of commercial granites used in Tunisia were carried out by using gamma-ray spectroscopy with hyper-pure germanium detector. The activity concentrations measured of granite samples were determined for 226Ra (from 0.54 to 90.12 Bq.kg−1), 232Th (from 0.47 to 128.36 Bq.kg−1) and 40K (from 14.36 to 1792.08 Bq.kg−1).
The corresponding average activity concentrations for 226Ra, 232Th and 40K were 36.70, 62.16 and 1068.40 Bq.kg−1, respectively. The radiological hazard parameters (radium equivalent, gamma index, external hazard index, internal hazard index, absorbed dose and annual effective dose) were calculated to assess the radiation hazards associated with granite samples. The annual effective dose values ranged from 0.01 in the sample (S1) to 1.8 mSvy−1 in the sample (S9). The international upper limit annual effective dose of 1 mSvy−1 is exceeded in some granites samples.
According to the obtained results, we can recommend that some of the granite samples are safe and can be used for building as interior decoration materials of the dwelling without any radiological complication. The obtained results are lower than the recommended limits; only eight granites samples have a higher value. The results were compared with the published data of other countries. The measurements will help in the development of standards and guidelines for the use and management of these materials.

Keywords: NORM, Gamma ray spectrometry, Radioactivity, Building material Granite, Effective dose, Radium equivalent activity

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Occupational Radiation Protection in the Oil and Gas Exploration Involving Exposure to Naturally Occurring Radioactive Material (NORM) Waste Product**

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The oil and gas exploration industry was well known to indirectly generate Naturally Occurring Radioactive Material (NORM) waste products known as oil sludge and scale. Oil sludge and scale formed during the borehole logging process in the process to obtain crude oil from the reservoir rock. In this process, various impurities were sucked out which eventually precipitation and deposition were formed in the oil and gas production tubulars, valves, pumps, and transport piping systems. The waste products are commonly associated with natural radioactivity of 226Ra, 228Ra, 210Po from 238U and 232Th series and also 40K. In addition, this process might involve the presence of radon (222Rn) which formed the thin radioactive lead films on the inner surface of gas processing systems.

Malaysia which is vastly known in oil and gas exploration is also not excluded from the generation of oil sludge and scale waste products. In Malaysia, any activities related to NORM waste products are regulated under the Atomic Energy Licensing Act 1984 (Act 304). In terms of licensing requirements, the value of the Clearance Level stipulated under the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011 is used to determine the control of NORM waste products whether or not, the waste is subjected to the control under Act 304. The value of the Clearance Level or activity concentration values which less than 1 Becquerel per gram (Bq/g) for 238U or 232Th and less than 10 Bq/g for 40K is not subjected to the licensing under Act 304. If the activity concentration of the stated radionuclides exceeds or equals the values of 1 Bq/g and 10 Bq/g respectively, then the activity is subjected to the licensing under Act 304.

The offshore oil platform facilities located at the seashore of Malaysia dealing with the oil sludge and scale waste products shall take into account the radiation protection aspect during the operation, maintenance, and decommissioning and also subsequent disposal of the waste products containing NORM. The operators closely dealing with the heavily scaled piping systems may also be subject to radiation protection measures. In doing so, the facilities must be monitored to distinguish between NORM waste and miscellaneous waste. The operators must conduct the Operation Radiation Safety Assessment (ORSA) which may include monitoring during normal operation (Routine Radiological Monitoring, RRM) and maintenance works (Specific Radiological Monitoring, SRM). The ORSA parameter may include the measurements of external dose rate, surface contamination level, airborne dust activity level, and radionuclide activity concentration. Thereafter, the decontamination can be performed at the location of the oil and the scale suspected to appear.

Most of the monitoring activities are conducted at the processing plant of onshore and offshore oil platform facilities at the Peninsular of Malaysia, Sarawak, and Sabah. From the monitoring activities, the result indicates that all parameters monitored during RRM in normal operations are below the limits regulated under the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011.

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Seasonal Variation Impacts of Airborne Radon Levels and its Progeny in Public Hospitals: Case Study in Kurdistan Region

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This study involves the assessment of seasonal exposure dose and health risks of indoor radon in public hospitals of Iraqi Kurdistan using CR-39 nuclear track detectors (NTDs) for all seasons of the year. The results showed that indoor radon depends on geological formation, type of building material, and ventilation rate. The highest and lowest values of rate indoor radon were recorded in winter (105.25 ± 17.16 Bq/m3) and summer (39.84 ± 8.14 Bq/m3) season, respectively. The high level of indoor radon was due to poor ventilation rate, while the low levels were as a result of high ventilation rate. Furthermore, estimated risk factors of radon induced lung cancer in public hospitals were shown to vary from 2.7 ± 0.08 to 11.16 ± 1.94 per million persons. The results also show that the indoor radon concentration for the ground level was much higher than the first and second level. The highest and lowest values of internal radiation dose were recorded in winter and summer seasons, respectively. 62.5% of internal radiation dose in winter season ranged between 0.6 - 0.7 µSv/h, which is less than that recorded within summer season (0.1 - 0.14 µSv/h). The highest radon exhalation rate and radium content was recorded in sand sample and lowest in ceramic tile, which depend on high porosity and rate of radium content in the sand samples.

Keywords: indoor radon; seasonal variations; CR-39NTDs; alpha particles; hospitals; annual dose

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Overview on Occupational Radiation Exposure of German Aircrew and Effects of the COVID-19 Pandemic

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The main tasks of the German National Radiation Dose Register (SSR), which is a facility of the Federal Office of Radiation Protection (BfS), is the collection and surveillance of occupational radiation doses from workers which are occupationally exposed to ionising radiation. Furthermore, the SSR regularly performs statistical analyses of the collected data in order to explore the state of the art and trends of the occupational radiation exposure. A solid and broad knowledge in that respect is the basis to further optimise the operational radiation protection. In this context, the SSR performed a thorough analysis of the exposure situation of aircraft personnel since the beginning of the COVID-19 pandemic.

Within all working sectors in Germany, aircraft personnel usually belong to the group with the largest effective doses per year. In 2019, aircrew received a collective dose of 75.0 person-Sievert (person-Sv) and an average effective dose (per measurably exposed person) of 1.82 Millisievert (mSv). A more detailed look at the average effective dose per month shows that the dose values throughout the year are typically subject to seasonal variations. During the summer months, the average effective dose of aircraft personnel is usually higher than during the winter months due to an increased number of holiday and charter flights. This usual dose pattern of aircrew personnel was disrupted with the onset of the COVID-19 pandemic. Statistical analyses of the year 2020 show a steep decline in monthly average effective doses in the early spring and summer months as effect of a significant drop in the numbers of operating aircrew personnel. These unusual low dose values were in particular noticeable for cabin personnel, which is the consequence of the drastic decrease of passenger aircraft activity. Only towards the end of the summer, the dose values of all aircrew personnel slightly increased as a result of a slowly recovering travel industry. Cargo plane activity, on the other hand, experienced an increase beginning with late 2019, and stayed at a high level throughout the year 2020. In summary, the collective dose (23.6 person-Sv) and average effective dose (0.62 mSv) of aircraft personnel was at a record low in 2020.

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Assessment of Naturally Occurring Radioactive Materials (NORM) at Oil and Gas Industry in Pakistan**

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Oil and gas drilling and processing operations have potential to unearth the naturally occurring radionuclides and subsequently accumulate them in the processing equipment. Pakistan Nuclear Regulatory Authority (PNRA) carried out a detailed study at Eleven (11) oil and gas fields with the objective to evaluate the concentration of Naturally Occurring Radioactive Material (NORM). Initial screening of each field was performed through survey meter and dose rates at surface and 1m from all major equipment notably wellheads, separators, production manifolds, well tubing, storage tanks etc. were recorded. Majority of the measurements were in the range of natural background level (0.07 µSv/hr – 0.10 µSv/hr). However, at one facility, dose rate value of 15 µSv/hr was recorded. The estimated annual effective dose to the occupational workers based upon their occupancy at the identified radiation areas was 2.0 mSv [1].

In order to complement the initial measurements, samples of scale, sludge, produced water and contaminated soil were collected from the areas in which dose rate higher than natural background was recorded. Gamma spectrometric analysis of samples, using HPGe detector, was performed and isotopes of Radium (226Ra and 228Ra) and Potassium (40K) were identified. In most of the samples (scale, sludge and produced water), activity concentration of Radium isotopes was below the exemption level as addressed in national regulations [2]. However, maximum activity concentration values of 226Ra (11606 ± 244 Bq/Kg) and 228Ra (8857 ± 187 Bq/kg) were observed in one sludge sample. Similarly, in one scale sample of the same facility, the activity concentration of 226Ra (4127 ± 94 Bq/Kg) and 228Ra (3237 ± 77 Bq/Kg) was measured. Consequent to this, the occupational workers were recommended to reduce their occupancy at radiation areas to avoid unnecessary radiation exposure. Moreover, use of protective equipment during cleaning/maintenance of contaminated equipment were also recommended.

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Assessment of Radiation Dose to Workers by Potassium Compound in NORM Industries in Korea**

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Potassium compounds are used in various industries, such as raw materials in the production of chemical products or as catalysts. A radioactive isotope of potassium, K-40, has a natural abundance of 0.012% in potassium, and a high-purity potassium compound may have radioactive concentration of K-40 exceeding 10 Bq/g. Therefore, it is necessary to assess the exposure level of workers handling high-purity potassium compounds in large quantities. In this study, we assessed the annual radiation dose to workers in workplaces handling potassium compounds in Korea.

In Korea, annual survey is conducted for safety management of NORM facilities. In NORM field survey, a total of 29 facilities handling potassium compounds were assessed for radiation dose to workers. The 10 types of potassium compounds such as KCl, K2CO3, KOH, and KNO3 were assessed, with radioactivity concentration of 6.3 - 21.7 Bq/g, and annual handling amount of 65 - 4,000,000 MBq. Radiation dose to workers resulting from external exposure was assessed using the directly measured ambient dose equivalent rates and hypothetical exposure scenarios. Radiation dose to workers due to inhalation of particulates was assessed based on ICRP-66 Human Respiratory Tract Model and actual measurement data of airborne particulates.

Annual radiation dose to workers was assessed as an average of 0.11 mSv/yr and a maximum of 0.54 mSv/yr in the field of potassium nitrate production. Out of the effective dose of all workers, Radiation dose resulting from external exposure accounted for more than 99%, and Radiation dose due to inhalation of particulates was not significant at several nSv/yr. And in the process where a large amount of potassium compounds are handled, such as fertilizer manufacturing, heavy equipment such as shovel loaders or tank lorries are mainly used or operated as a closed system. It was found that the radiation dose to workers did not increase significantly because the workers were separated from the potassium compound by a certain distance or the handling time was short. Therefore the effective dose to workers due to potassium compounds is expected to be almost less than 1 mSv/yr in Korea. The range of radiation dose to workers is similar to the K-40 exposure level due to potassium homeostasis in the human body, and is lower than the level for exemption of bulk material containing radionuclides of natural origin suggested in the IAEA General Safety Guide.

In this study, we assessed the radiation dose to workers handling potassium compounds in Korea. Radiation safety management for workers handling potassium compounds needs to focus on external exposure. In addition, it needs to consider a graded apporoach from other NORM industries in consideration of the level of exposure. Based on the results, it will contribute to the optimization of radiation protection in NORM industry in Korea.

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Control of Exposure of NORM to Humans at the Tarkwa Gold Mines of Ghana

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Ghana Atomic Energy Commission

Occupational radiation protection was assessed at the Tarkwa Gold mines in the Western Region of Ghana by measuring the radioactivity levels arising from Naturally Occurring Radioactive Materials (NORM) at the operational area of the mine in order to determine the level of exposure to workers. This was achieved by determining the activity concentration of natural radionuclides namely 238U, 232Th and 40K in soil collected from the mine concession using gamma spectrometry. The average activity concentrations of 238U, 232Th and 40K in the soil samples at the depths of 0-20 cm were found to be 7.25 ±1.03 Bqkg-1, 19.47±3.41 Bqkg-1 and 176.98±8.86 Bqkg-1 respectively, which were far below the exemption values of 1000 Bqkg-1 for 238U and 232Th and 10,000 Bqkg1 for 40K in materials that will warrant regulatory control.

In general, the results do not show significant levels of natural radionuclides in the mine. However, since the workers in the mine may be exposed over a long period of time which may result in bioaccumulation, it is recommended that they apply certain protective measures such wearing appropriate PPEs to protect themselves from chronic exposures which may be detrimental to their health.

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Spatial Distribution and Occupational Exposure to NORM in the Artisanal Gold Mines in the Migori Transmara Gold Mining Areas of Southwestern Kenya*

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Gold mining economically empowers not only the miners but also the entire country. However, it involves massive discharge of wastes like tailings, gangues etc. containing radionuclides that maybe harmful to the miners and the populace. It was therefore necessary to determine spatial distribution and exposure to NORM in the artisanal gold mines in the Migori Transamara gold mining complex of Southwestern Kenya in order advice the concerned parties. To achieve our objectives soil samples were randomly collected from various gold mining areas and analyzed using HPGe gamma ray spectrometric technique. Ordinary Kriging analysis was then used to show their spatial distribution.

The average activity concentration of 238U, 232Th and 40K were found to be 33.09 ± 10.12 Bq/kg, 58.37 ± 18.62 Bq/kg and 417.05 ± 163.95 Bq/kg respectively while the absorbed and annual effective doses were 70.48 ± 24.14 nGy/h and 0.09 ± 0.03 mSv/yr respectively. Even though the level of NORM is within the world average according to UNSCEAR, however, there is accumulation of radionuclides around Lake Victoria as seen in the maps. Miners (especially women and children) are encouraged to wearing protective masks and clothing to shield them dust and hence exposure to radioactivity. Results from this study will help local and national government formulate policies on artisanal gold mining besides acting as a baseline for future studies.

Keywords: NORM, artisanal gold mining, Ordinary Kriging, soil

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Regulatory Status and Current Issues for Optimization of Occupational Radiation Protection for Commercial Aircrew in Republic of Korea*, **

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With much economic development around the world, the commercial air transport business is expanding for international trade and travel. Accordingly, the flight time at high altitudes of commercial aircrew is increasing, and the exposure dose of cosmic radiation tends to increase. In recent UNSCEAR and national survey reports, the average exposure dose of cosmic radiation of flight crews is about 2 mSv, which is higher than that of occupational radiation of other radiation workers. Hence, optimization of cosmic radiation protection for commercial aircrews is emerging as important issue globally.

In this background, 'regulatory status and current issues for the optimization of occupational radiation protection of Korean commercial aircrew' are reviewed in this study. Since cosmic radiation- related research has been mainly conducted from the perspective of space/astronomical physics and cosmic meteorology, this study is mainly focused on the perspective and role of the government and regulatory authorities in charge of radiological safety regulation for flight crew members.

IAEA safety standards related to the protection of cosmic radiation due to the performance of duties of aircrews are the GSR Part 3 requirements (2014) and the GSG-7 guides (2018). The IAEA GSR Part 3 classify and manage cosmic radiation exposure of aircrews as existing exposure situations, and present related requirements. In this study, the requirements associated to "optimization" of cosmic radiation protection for aircrews are summarized into the five main factors.

The Act for the protection of cosmic radiation protection for Korean aircrews is the『Act on Protective Action Guidelines against Radiation in the Natural Environment』. In this law, Article 18 presents the safety management requirements for cosmic radiation. The main regulatory requirements related to "optimization" of cosmic radiation protection for aircrews are summarized based on the factors extracted from the IAEA safety standards in this study.

In accordance with Article 23 of the Act, regulatory authorities conduct annual investigation and analysis of the actual state of safety management of air transport operators, and publish annual report. In this study, the latest three-year (2018-2020) reports were analysed and summarized based on the "optimization" factors of cosmic radiation protection.

In Republic of Korea, the outbreak of leukaemia and claims for industrial accidents by a former aircrew of a Korean airline in 2018 were widely reported in the media. It became a big social issue and the problems and responses were discussed at the National Assembly and government. These can be broadly divided into technical issues, regulatory agency issues, and safety management issues. Recent responses for each problem raised are summarized.

In this study, the current status and issues of regulations in Korea related to the optimization of the cosmic radiation protection for aircrews were overviewed. It is considered that Korean regulatory standards and activities are established and operated to comply with the IAEA safety standards. However, it is thought that it is necessary to upgrade the regulatory technology and refine the related guidelines in detail for the evaluation and measurement of cosmic radiation to response to domestic issues.

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Comparison of Regulatory and Occupational Exposure Provisions for Naturally Occurring Radioactive Materials (NORM) in Zimbabwe to the International Safety Standards*, **

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The Radiation Protection (Naturally Occurring Radioactive Materials) Regulations, 2013, is the sole regulation responsible radiation safety within facilities that have the potential to elevate radiation levels. In line with international standards the deliberate exclusion of a particular category of exposure from the scope of an instrument of regulatory control on the grounds that it is not considered amenable to control through the regulatory instrument in question is an excluded exposure. Further, the determination by a regulatory body that a source or practice need not be subject to some or all aspects of regulatory control on the basis that the exposure (including potential exposure) due to the source or practice is too small to warrant the application of those aspects, or that, exemption is the optimum option for protection irrespective of the actual level of the doses or risks.

The regulations do not provide specific provision for graded approach to regulation as there is no possibility of exemption above 1 Bq/g. There is no possibility of disposal or unrestricted release of NORM if dose exceeds 0.25 mSv/a while the international criterion is 1 mSv/a thus possible limitations on NORM waste management options. There are also possible implications in the mining of ores as the definition of NORM excludes material in which the radionuclide concentration has not been enhanced by human activity.

In the Zimbabwean legislation, doses from indoor radon and its progeny shall not be included in Effective Dose calculations. The use, transfer or disposal of NORM shall be done in such a way as to prevent accumulation of radon in residential structures and other public buildings in concentrations exceeding 0.2 Bq/l and 1.0 Bq/l respectively. No person shall dispose or release NORM for unrestricted use in such a manner that the reasonably maximum exposed individual will receive an annual Effective Dose more than 0 .25 mSv/yr, excluding natural background.

In conclusion, Zimbabwe regulations with regards to NORM and occupational exposure to some extent meets international standards but must be reviewed to address the highlighted areas in this paper. The regulation should go beyond just establishing that the 1 Bq/g criterion is exceeded. It should consider, in addition, particular types of operation, process and material in more detail, including a prior radiological evaluation of exposure or dose and consideration of the costs of regulation in relation to the benefits achievable.

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Recommendations on Radiation Protection for Radon Exposure in workplaces in Egypt

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Exposure due to radon might occur in all types of workplaces and facilities, ranging from conventional offices, naturally occurring radioactive material processing industries, underground facilities, and nuclear fuel cycle facilities. This is to present the view of consideration of the International Atomic Energy Authority (IAEA) and The International Labour Office (ILO) recommendations for implementing the requirements of the Safety Standards Series No. GSR-Part3 for Protection Against exposure to Radon. In recent years, the International Commission on Radiological Protection (ICRP) provide specific recommendations on safety Series GSR-PART3 related to protection of the public and occupational safety which have taken into account in preparing a new safety guide for "protection of workers against exposure due to radon in workplaces, in both planned and existing exposure situations, including the case of combined exposure to radon and other sources.

Referring to Our research studies, several workplaces in Egypt are identified such as: Phosphate Mine Tunnels, Coal Mines, Mining of Ores, Tourist Caves, Industrial processes involving NORM, Old style and enclosed building underground having bad ventilation. the reference level for indoor and outdoor for radon concentration at workplaces as existing exposure situations varies from Tenth to hundreds of Bq/m3, while for Workplaces as planned exposure situations; Radon concentration was about Thousands of Bq/m3 which vary with time of day, geographic location & season and height above ground.

In Egypt, The Nuclear and Radiological Regulatory Authority (ENRRA) is responsible for regulatory control for Radiation protection of radiation sources as well as Radon Exposure. Upon that it has to issue licenses for workplaces verifying requirements.

As TSO conclusions, it is concerned for the use of R&D results to be a base for ENRRA inspection and regulatory managements.

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Assessment Occupational Exposure to Natural Radionuclides due to Mining Activities in Kenticha Tantalum Mining*

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Human beings are always exposed to background radiation that comes both from natural and man- made sources[1]. Natural radioactivity is widespread in the earth environment and it exists in various geological formations such as earth's crust, rocks, soils, plants, water and air. Mining has been identified as one of the potential sources of exposure to naturally occurring radioactive materials (NORM)[2][3]. However, mining activities are not being monitored and regulated for NORM in Ethiopia. Most of the NORM industries such as mining and mineral processing are located in developing countries such as Ethiopia[4][5]. The Kenticha mine is a large tantalum mine located in the southern part of Ethiopia. It represents one of the largest tantalum reserves in the country, having estimated reserves of 116 million tons of ore grading 0.02% tantalum[6],[7]. The Tantalum mine is associated with uranium and currently undertakes only surface mining and the process produces large volumes of tailings and waste that may contain NORM.

A radiological hazards to members of the public and workers from exposure to natural radioactivity as a result of mining activities from Kenticha Tantalum Mines have been studied through several exposure pathways using direct gamma spectrometry to determine 238U, 232Th, 40K, in tantalum ore, soil, waste, waste tailing and. The external radiation dose component is obtained directly from the results of the personal monitoring program for designated mining employees operated at the ore dying facility.

To assess the radiological hazard of soils, solid waste, the radiological hazard indices such as absorbed dose rate, annual effective dose equivalent (outdoor), external and internal hazard indices (Hex and Hin), gamma activity index (Iɣ) and estimated excess life time cancer risk (ELCR) are calculated. Gamma spectrometry technique was used to analyse for Uranium, Thorium and K-40 in soil and waste samples from the mining environment. A total of 22 soil samples from the mining site and 10 solid waste samples from tailing dam were analyzed. Moreover 14 mining employee working in ore dying facility used OSL personal dosimeter[8], [9].

The corresponding average external dose rate at 1m above the ground in air for tantalum ore, soil and solid waste samples were 81.14 nGy/h, 65.71 nGy/h, 96.24 nGy/h, respectively which were above the worldwide average value of 59 nGy/h [1], [10], [11].

The annual effective dose limit of 20 mSv and 1 mSv for occupationally exposed workers and the public, respectively; and all-hazard indices, as well as the radium equivalent activity, were within internationally accepted limits. Based on a radiological point of view, it is concluded that all workers within the mine are not exposed to any significant radiological hazard. However, there is a need for constant and systematic monitoring of the environment.

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SESSION 8:

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

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Radiation Protection for Patient and Staff in Interventional Procedures**

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Background

Ionizing radiation is used extensively in cardiac diagnostic and interventional procedures. The radiation is associated with a small but definite stochastic risk of inducing a malignant disease. Low-dose radiation exposure has been shown to induce an increase in the number of circulating lymphocytes and chromosome aberrations, which represent surrogate biomarkers of cancer risk. The long-term cancer risk increases with increasing cumulative dose, there is no known threshold value. Deterministic risk of skin damage both to the patient and the operator, risk of eye injury to the operator, risk by radiation exposure to the operator as many procedures are carried out in a year over 700 interventional

The radiation dose received by cardiologists during interventional procedures and other cardiology procedures can vary by more than an order of magnitude for the same type of procedure and for similar patient doses.

This paper will analyze occupational radiation protection for physicians and other staff in the interventional suite.

Methodology

To Assess the Performance of the Equipment in Terms of Kae and Air kerma rate**

Dose area product (DAP) meters are recommended techniques of dose measurement since exposure parameters vary throughout these tests and the X-ray beam moves across different regions of interest.

The DAP is especially useful for monitoring and comparing radiation dosage from screening procedures, and it provides a better indicator of overall patient exposure than surface dose measurements to specific organs. DAP mean values will be utilized in the investigations.

Simple methods for reducing or minimizing occupational radiation dose included minimizing fluoroscopy time and number of acquired images, using available patient dose reduction technologies, using good imaging-chain geometry, collimating; avoiding high-scatter areas, using protective shielding, using imaging equipment whose performance was controlled through a quality assurance program, and wearing personal dosimeters so you know your dose.

Radiation protection education and training for all interventional cardiology workers, as well as the availability of proper protective instruments and equipment, were essential for effective use of these procedures.

Regular review and investigation of personnel monitoring results, accompanied as appropriate by changes in how procedures are performed and equipment used, ensured continual improvement in the practice of radiation protection in the interventional suite

Conclusion

Reducing radiation exposure during interventional procedure is of paramount importance for both patients and staff safety

Advances in equipment and application of radiation safety protocols have significantly reduced patient doses and operator exposes

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Calculation of Radiation Shielding for Megavoltage Gamma Ray Facility Using Monte Carlo Code EGSnrc**

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This research applies the Monte Carlo simulation method EGSnrc Electron Gamma Shower (EGSnrc) Code with two code is dedicated: BEAMnrc code is used to simulate the beam emitted from the accelerator head and DOSXYZnrc code is used to calculate the dose emitted from the accelerator. From there, evaluate beam attenuation of radiation emitted from the accelerator through the layers of shielding material at staff area and public area.
Result, We have successfully applied EGSnrc simulation program with two dedicated code is BEAMnrc and DOSXYZnrc with the initial results of the study showed that the dose limit in the staff area is 0.11 mSv/week (5.5 mSv/year) and at public area is 0.022 mSv/week (1.1 mSv/year). This result is lower than 8.3% in staff area and in the public area is 10% higher than the regulations of the IAEA, the ICRP. However, these results need to be verified further through further research.

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Occupational Cumulative Effective Doses of Radiation Workers in Hamad Medical Corporation in Qatar

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Hamad Medical Corporation

The number of radiological examinations has increased steadily in recent years. As a result, the risk of possible, radiation-induced consequential damage also increases through continuous, lifelong and increasing exposure to ionizing radiation. Therefore, radiation dose monitoring in medicine became an essential element of medical practice. In this study, the occupational cumulative doses for radiation workers in Hamad medical corporation in Qatar have been assessed for a period of five years. The number of monitored workers selected for this study was 700 (out of a total of 1400 monitored workers) who have been working continuously - with no interruption – with ionizing radiation over the past five years from 2017 to 20201. The aim of this work is to examine the occupational groups and the activities where the higher radiation exposure occurred and in what order of magnitude. The most exposed group was the nuclear medicine technologist staff with an average cumulative dose of 8.4 mSv. The highest individual cumulative dose was 9.8 mSv recorded for the PET-CT Technologist category.

Introduction: In order to limit the radiation exposure to workers and the public, the use of ionizing radiation is regulated by laws, ordinances, recommendations and guidelines. To protect radiation workers and the public from the negative effects of ionizing radiation, dose limits that must not be exceeded are set in order to reduce the risk of exposure to a reasonably achievable level.

Methodology: In this work the Harshaw TLD-100 from Thermo Fisher Scientific was used, which consists of two lithium fluoride crystals LiF doped with magnesium and titanium for estimating the personnel dose equivalents Hp (10) and Hp(0.07), where Hp (d) is the dose equivalent This Harshaw Reader is designed for large facilities and can read a carousel containing up to 1400 four-element cards in one load at 140 cards per hour. To protect radiation workers and the public from the negative effects of ionizing radiation, dose limits that must not be exceeded are set in order to reduce the risk of exposure to a reasonably achievable level.

Results: The average cumulative effective dose of radiation workers at Hamad Medical Corporation (HMC) was assessed over a period of five years. The most exposed group was the nuclear medicine technologist staff with an average cumulative dose of 8.4 mSv. The highest individual cumulative dose was 9.8 mSv recorded for the PETCT Technologist category. All doses were well below the dose limit for radiation workers and did not exceed 15% of the limit. Moreover, all doses were also less than 50% of the investigation level for workers in nuclear medicine.

Conclusion: The average cumulative effective dose for radiation workers over the last five years is summarized as a function of the occupational groups. The relative high doses are registered for nuclear medicine in addition to cardiological intervention categories. The cumulative dose in all other categories is less than 5 mSv, which is only 5% of the dose limit recommended by the ICRP and 15% of the investigation level according to HMC policy.

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Risk Assessment of Eye Lens Dosimetry for Nuclear Medicine Worker**

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The International Atomic Energy Agency: IAEA has reviewed on the dose limit for the lens of the eye followed the recommendation of the International Commission on Radiological Protection: ICRP in its statement in April 2011. The dose limit to the eye was reduced from 150 mSv in a year to 20 mSv in a year, averaged over defined periods of 5 years, with no annual dose in a single year exceeding 50 mSv. IAEA still announced a measurement value of personal dose equivalent at 3 mm depth with a dosimeter worn as close as possible to the eye and calibrated on a head shape phantom in IAEA Technical Document No. 1731(2013): Implications for Occupational Radiation Protection of the New Dose Limit for the Lens of the Eye. The new dose limit and the measurement closed to the eye had made an impact to workers who received dose more than 20 mSv per year and worn dosimeter at whole body which not represented to real dose. The Office of Atoms for Peace announced in the Royal Gazette (2018) with the reduction of the dose limits and recommended to Personal Radiation Monitoring Service laboratory for development of the lens of eye dose calibrated at eye adjacent including with to investigate the risk assessment of the effects of radiation on eye lens upon the new dose limit for medical worker.

The purpose of this research is to develop the lens of eye dose for nuclear medicine (NM) workers due to related with gamma and beta from radioisotope and a longtime exposure. The risk assessment of radiation lens injury was performed from the relationship of averaged eye lens dose to affect the prevalence of radiation-associated posterior lens opacities or cataract. In this research, calibration technique for a small OSL dosimeter was developed to be eye lens dosimeters which inserted at 3 mm depth of head shape phantom. The calibrated dosimeters were worn from NM workers at eye adjacent for finding averaged accumulative dose in a year. 31 NM workers who received the highest eye doses were chosen to eyes examination by experienced ophthalmologists using slit-lamp. Posterior subcapsular cataract (PSC) was graded according to a modified Merriam-Focht scoring system and a grading score of 1 and above in either eye was considered as early cataract by radiation effect. The conclusions of this research shown the NM workers who received high dose might be found the opportunity of cataract when getting older from the results of PSC grades above 1.0 score. From 31 NM workers were found the prevalence of radiation-associated posterior lens opacities in the right and left eye lens was 10 (13.16 %) and was 11(10.26 %) respectively.

Keywords: Eye Lens Dose, Nuclear Medicine, OSL dosimeter

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Managing Occupational Exposures during I-131 MIBG Therapy**

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The use of I-131 MIBG for the therapeutic treatment of relapse neuroblastoma in pediatric patients has been used for over 15 years. This treatment involves the administration of I-131 MIBG at doses up to 0.67 GBq/Kg. The therapy requires careful management of not only the patient but the various hospital staff and caregivers involved in patient treatment and support. The primary supporting care team includes Nuclear Medicine, Nursing, Physicians, Caregivers, and Radiation Safety. The various radiation safety policies and procedures as well as operational best practices that have been established over many years of treating these patients will be discussed.

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Occupational Radiation Protection in Medicine in Veterinary Facilities – A Challenge*

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The Brazilian National Nuclear Authority (CNEN) is the government institution responsible for licencing and regulation of all kinds of facilities that uses sources or equipment that produce ionizing radiation, except the ones for medical diagnosis and odontology uses. New technologies, and new uses of ionizing radiation can be a challenge to the Nuclear Authority, as an example of the medicine veterinary facilities.

The pet industry in Brazil was responsible for seven billion dollars billing in 2019, an increase of 3% compared to 2018 and the absolute second place in the world market, behind only the United States. To date, CNEN regulates 4 veterinary facilities, 2 radiotherapy and 2 nuclear medicines, but these numbers are growing as the pet market becomes more important in the country. These types of facilities are unique and have specific licensing aspects to address.

In December 2019, CNEN held the "I Workshop on Radiological Protection and Safety in Veterinary Medicine". Several aspects of veterinary practice involving ionizing radiation were addressed during the discussions, and a consensus was the need for CNEN to develop a Regulatory Standard that would involve veterinary practice.

In 2020, the project for the preparation of the study committee for this Veterinary Standard was started, and after internal discussions it was decided that this Standard should cover regulatory aspects both in the radiotherapy, as well as in veterinary nuclear medicine, with the objective of elaborating a single standard to license the facilities that already existed in Brazil, and those that would exist in the future. The risk associated with radiotherapy and nuclear medicine veterinary facilities is relevant and a consistent regulatory effort is required in terms of the elaboration of guides and standards. There are specificities in the licensing and control of these facilities not provided in the basic standards, which justify the elaboration of a standard for this practice. The elaboration of the CNEN Standard NN 6.12: "SAFETY AND RADIOLOGICAL PROTECTION REQUIREMENTS FOR VETERINARY RADIOTHERAPY AND NUCLEAR MEDICINE SERVICES" was proposed after several discussions between the CNEN members and the technical staff of the veterinary facilities. In many situations, the handling of animals in veterinary medicine involves the presence of additional persons, such as animal handlers, in veterinary facilities during procedures for diagnosis and therapy, and this necessitates additional protective measures (IAEA TECDOC). One important aspect issued in the elaborated Veterinary standard was the Occupational radiation protection. Differently from facilities that treat humans, were radiation protection of patients are an important aspect, in this regulatory standard the workers and public were the main concern. Table II shows important aspects in the standard concerning to workers.

The publication of this Veterinary Standard showed to be of great importance in Brazil, as the number of new veterinary facilities is growing fast, and there are relevant specificities about those facilities that must be considered during the licensing process.

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Evaluation of Thyroid Exposure of Nuclear Medicine Staff Working with Radioiodine**

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Problem:
Iodine-131 (^{131}I) is the most commonly used iodine radioisotope, and activities used are sometimes very high.
In solution iodine is volatile at room temperature; nuclear medicine personnels are thus exposed both to external irradiation risk of which is monitored by wearing a dosimeter and to internal contamination risk of induced by inhalation.

Objective:
Evaluate the internal contamination by iodine 131 of nuclear medicine personnels.

Material and method:
The I-131 content in the thyroid of staff members working with this radionuclide in the form of solution and capsion has been measured in one Department of Nuclear Medicine performing therapy and diagnosis of thyroid disease in Tunisia.
Measurements were performed with an NaI (Tl) portable detection unit for in situ measurements of radioiodine.
We carried out 45 measurements; 15 from a control group and 30 carried out in two stages one month apart by the personnels

Results:
^{31}I was detected in thyroid for all the medical staff.
Counting rates varid from 88,14cps à 1105,77c/s cps.
The maximum values corresponded to persons most exposed to radiation exposure. Namely they were technicians who prepared and administered iodine to patients.
However, these values remain within the regulatory limits.
Values for control group were of the order of background noise around 90cps

Conclusion:
Several methods and devices have been developed for *in vivo* measurements of ^{131}I in the thyroid by using portable gamma detectors.
This method remains easy to apply thanks to simple, inexpensive equipment and generally available in the MN services.

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Additional Dosimetry while using Techniques of Hybrid SPECT-CT Acquisition during a Bone Scan**

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Background: Nuclear medicine has experienced real success over the past and has brought new perspectives, mainly in the treatment of cancers.

In bone disease, Single photon computed tomography associated to computed tomography (SPECT-CT) combined with conventional scintigraphy makes possible, in a single examination, a whole body exam and CT scan centered on a suspicious bone foci, thereby improving the diagnostic accuracy of planar scintigraphy. However, the additional radiation dose from X-ray CT, is now the subject of numerous public and technical discussions.

Aim: We proposed to evaluate fors patients and workers, doses of radiation delivered during a SPECT-CT bone scan.

Methods: On our nuclear medicine department, equipped with 02 SPECT-CT, additional SPECT-CT was performed for 200 patients with indeterminate foci on bone scintigraphy. For these patients, we estimated effective doses received and analyzed the parameters involved in the variation of doses. The estimated total effective dose following a bone scan, was calculated by multiplying the average activity administered (between 555 and 740MBq) for each patient by the "effective dose per unit activity administered" conversion factors listed in the International Commission on Radiological Protection (ICRP) publication 53 and 80. The effective dose for a CT scan was appreciated from the product of the dose length (DLP) and a conversion factor specific body region, k (mSv mGy-1 cm-1), which take into account the change in biological sensitivities of different organs.

Concerning the workers under radiation (technicians and physiciens), we compared for the same persons values of doses (mSv) recorded by the TLD dosimeters before the installation of the SPECT-CT machines with those recorded after the arrival of the 02 machines in the department.

Results: In fused imaging (SPECT-CT), we noted a significant increase in dose delivered to the patient. Effective dose was estimated on mSv between 3,16 – 4,22. It was depended on the administered activity and patient age; while for CT scan, it depends on: tube current, tube potential, the speed of rotation of the cutting thickness, patient weight.

Regarding radiation workers (technicians and physiciens) to reduce the radiation dose, appropriate protective clothing (lead apron, thyroid collars and lead goggles) should be worn for personnel inside the scan room] and staff should stay away from the scanner as much as possible, as the dose decreases as the square of the distance from the x-ray source.

Conclusion: Keeping radiation dose as low as reasonably achievable (ALARA) is the guiding principle for a medically indicated CT examination. Many techniques and strategies are available for radiation dose reduction. During a SPECT-CT examination following an inconclusive bone scan, the additional dose delivered by a CT scan is justified because of the direct benefit to the patient.

Keywords: bone scintigraphy - CT - Dosimetry

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Implementation of Radiation Protection Committee in a University Hospital

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Aim: to describe the steps of constitution and the work plan of the new radiation protection committee in our University Hospital
Introduction: Military hospital of Tunis is a University Hospital using radiation in many fields: radiology, nuclear medicine and interventional procedures. As it started an accreditation process since 2018. We had decided to establish a specialised committee for the radiation protection to compensate the lack of regulation and to set up a control of ionising radiation exposure.
Steps of constitution:

We had integrated a representative member from every medical department using ionising radiation, the occupational medicine and the technical support service. We had prepared an action plan and took the approval from the medical committee of the hospital.
Action plan of the committee:

- Identification and categorization of all exposed workers:
o identification of all ionising radiation sources
o identification of all the operating workers
o setting up an exposition monitoring and a medical follow up
- Training of exposed healthcare workers in radiation protection issues
- Patient radiation protection: verifying the conformity to diagnostic reference levels and ALARA principle
- Patient Information: area signalisation, dosimetry data in the medical report

Results: We identified five departments using ionising radiation (Radiology, Nuclear Medicine, Cardiology, Gastroenterology and Surgery operation bloc).

One hundred eleven workers are professionally exposed to radiation. All of them are monitored by the occupational medicine department, they all have TLD dosimetry records under the control of the "National Radiation Protection Centre".
We found a lack of radiation protection means in many departments (not enough lead coats, no lead glasses, no active dosimeters). No specific training for technicians in surgery and gastroenterology. The Committee decided to acquire all necessary tools for radiation protection off all the workers and prepared a technical specification sheet to buy lead coats, lead glasses and a platform for active dosimetry. All these acquisitions have been done, in short time, with the help of the hospital administration.
The radiation protection committee has designed a training program with the help of the DPC "Continued Personnel Development" committee and started to give a cyclic course for each category of exposed workers.
Conclusion: Radiation protection issues in our university hospital are now better took in account.

The staff are more aware of this dangerous activity and the administration is aware of the need to procure all necessary tools to maintain the exposure under the regulatory limits.

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Effectiveness of Staff Radioprotective Equipment during Fluoroscopically-guided Procedures: Results and Recommendations from the MEDI-RAD Project**

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Purpose: Various types of radioprotective (RP) equipment exist to protect the staff during fluoroscopically- guided procedures; however, their performance can widely vary and is challenging to assess in clinical practice. To support evidence-based selection of RP equipment, the effectiveness of lead(-free) caps, lead-free aprons, lead(-free) drapes, masks and the Zero-Gravity suspended system was investigated.

Materials and Method: The effectiveness to reduce staff X-ray exposure was investigated by means of Monte Carlo (MC) simulations completed by clinical measurements on staff and phantoms.

Numerous irradiation configurations, including beam projections (at least five) and staff distance from the source (at least two), were modelled. Different equipment compositions and designs were considered where applicable.

The clinical measurements included from a few tens of procedures up to over 600, while phantom measurements included three common and/or concerning configurations.

Recommendations were derived from the study results, including feedback from relevant stakeholders.

Results: According to MC results, a lead(-free) cap reduced the brain dose by 35% on average. The mask could be more effective (65% average reduction for the best model) and also protect the eye (25%). However, the irradiation conditions had a strong influence as both equipment types could become nearly ineffective in specific configurations, particularly when closer to the X-ray field. Besides, some brain regions were left unprotected. Phantom measurements corroborated the results, although with lower effectiveness figures.

The lead(-free) drape over the patient could decrease the dose to the skin of the hands (from MC results: 62% and 30% to the left and right hands on average, respectively) if positioned directly above it. No noticeable effect was observed for other organs. Some clinical measurements, however, also showed considerable dose reduction (˜50%) to the eye lens which were not predicted by MC simulations or phantom measurements.

The effectiveness of lead and lead-free aprons to protect the organs in the chest region was comparable, according to the MC and clinical measurements.

The Zero-Gravity system offered the highest protection to the brain and eye lens according to MC, phantom and clinical results (at least 95%, 66% and 78% on average, respectively), and a protection level comparable to the lead apron for the organs normally covered.

Discussions and conclusions: All the equipment types showed potential for dose reduction. However, the effectiveness of the caps, the masks and the drapes strongly depends on the design, exposure conditions and staff position. In adverse exposure conditions, they can become ineffective.

Independent testing of RP equipment, with reference to typical and realistic conditions of use, would be of great help for the staff to select such equipment. Considering the expertise, time and material necessary for such testing, involving professional associations and RP equipment manufacturers, would be beneficial.

Recommendations were summarised into a concise document aimed at medical physicists and staff. It contains pros and cons of the tested equipment types as well as other commonly used ones.

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Occupational Radiation Protection Challenges in the Radiological Health Services of the Caribbean Countries

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Over the years, an increasing use of complex medical applications utilizing ionizing radiation has been observed in many countries, including the Caribbean, leading to an increase in the number of occupationally exposed workers. Many countries in the Caribbean face challenges with regards to their ability to introduce and establish effective radiation protection programs in medicine which poses several risks to the protection of exposed workers (Adhikari et al, 2021). In 2019, a survey was conducted by the Pan American Health Organization (PAHO) to gather information on the current status of the regulatory infrastructure for radiation safety in the Caribbean. The results from the survey demonstrated that many Caribbean countries do not have national legislation on radiation safety implemented. In addition to the lack of or outdated regulatory infrastructure in radiation protection, Caribbean countries also lack a structure for radiation safety for medical applications and a system for education and training in radiation protection. As a result, there is a great shortage of experts in radiation protection with required knowledge, skills and competences. The observed shortage leads to poor implementation of radiation safety practices and thus may pose danger to the safety of patients, workers and the environment against harmful effects of ionizing radiation. In 2021, PAHO started with a program to aid Caribbean countries in the establishment of a radiation protection program for medical applications. A questionnaire was developed to assess the current status of radiation safety for medical applications in a subset of medical clinics in seven Caribbean countries. Based on the results, a gap-analysis was created and a customized radiation protection manual was developed tailored to the applications in the medical sector. After successfully drafting the radiation protection manual, participating countries will be guided by PAHO to implement safety standards, establish a basic system for education and training in radiation protection and ultimately improve safety culture among exposed workers. In this contribution we will review challenges and report on the outcomes of this project in the establishment of an institutional program for radiation safety in Caribbean countries with no national infrastructure for radiation safety.

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Regulatory Viewpoint of the Occupational Radiation Protection in Medicine: Weaknesses and Challenges in Latin America

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Dirección de Seguridad Nuclear

The use of ionizing radiations and exposure to them involves risks. The improvement and modernization of health services has increased the use of radionuclides and radiation-emitting equipment for diagnostic, therapeutic and interventional purposes, benefiting millions of people worldwide and increase the number of medical procedures and professionals involved, reason why, an adequate occupational radiological protection program is essential, to guarantee the safe and acceptable use of ionizing radiation. On the other hands, the dynamics of the technical and technological progress, which occurs at amazing speed, constitutes a significant challenge, not only for the personnel directly involved in the practice, but also for the personnel of the Regulatory Authority, which need to verify the correct implementations of the safety standards and others good practices, internationally recognized. This paper offers a regulatory view of different aspects of occupational radiological protection in medicine and several areas for improvement, covering both, infrastructure and technical requirements. Additionally, in this work, significant aspects to be taken into account for establishing an adequate occupational radiological control are addressed. Some examples of non-compliance with national regulations and international recommendations in the Latin American region that are currently important challenges to overcome, for various health services with a view to the continuous improvement of this particular, are provided too, among these:

- insufficient human resources appropriately qualified at the facilities.
- RP equipment obsolete and, on occasions, insufficient.
- nonexistence of effective cooperation relationships and coordination among regulatory authorities and with the other institutions involved in the operational radiological protection at the national level.
- inefficient mechanisms for upgrading of the regulations in a context of sustained and vertiginous technical and technological advances and lack of implementations.
- limited scope of dosimetric services and non-compliance with the international standards.
- nonexistence of quality management systems in the dosimetric services.
- radiation protection Programs inappropriate or not formally implemented at the institutions. insufficient size or nonexistence of infrastructures on metrology.
- inexistence of an education and training strategy for staff of the RA.
- non- follow up of ORPAS missions requested by the countries.
- the staff of regulatory bodies don't have the training necessary to ensure that optimization of protection and safety is appropriately applied and enforced.
- non-follow up actions when dose constrains are exceeded.

Many of the deviations mentioned above have been identified through the ORPAS missions, which it has been promoted actively the compliance with the requirements and regulation all over the world. As a conclusion of the work, the most important aspects to be considered in the improvement of occupational radiological protection are highlighted.

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Assessment Of Occupational Exposure from Patient treated with 131i for Thyroid Cancer*, **

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Oral administration of large doses of radioiodine 131 has been a commonly accepted procedure for treatment of benign and malignant conditions of the thyroid since 1940s [1]. Several research papers and guidelines were focused on the external dose rate from patient treated by radioiodine 131 in discussing the release criteria from hospital [2] or assessing the related public or occupational exposures [3,4]. The goal of the present work is to provide a simple equation to assess the medical staff's occupational exposure nearby a radioiodine 131 administrated patient.

A randomized sample of 86 patients administrated with 131I for thyroid radioiodine therapy at AL-BAYROUNI University Hospital was monitored. The patients' administered activities ranged from 3060 to 5650 MBq. A calibrated universal survey meter type RADOS-200 was used to measure the external radiation dose rate from the administrated patients. The Measurements were effectuated post radioiodine dose administration at a distance of 1 meter from the effective point of measurement and standing point of the patient at the thorax level. The patients sample was divided into two groups according to two administrated activity ranges. The patients' age, height, and weight were also recorded. Tables 1 and 2 represent the description of the patient groups and the related anthropometric measurements.

The mean values of the measured patient external radiation dose rates and theirs normalised dose rate values in terms of administered activity for patient groups are presented in Table 3. The calculated mean values was within the range of 50.3-145 and 75.53-209 µSv.h-1 respectively. The mean patient external dose rate in Group B was relatively higher by ~18% than in Group A since the administrated activity in Group B was higher than in Group A, however, the differences in of the external dose rate between female and male was insignificance.

The exposure from an administrated patient to nearby persons is related primarily to the distance from him, to the exposure duration, and to the administered radioiodine activity. The maximum external dose rate measured from the monitored patient sample was 209 µSv.h-1 and the mean normalized value of the external dose rate was 0.031±006 µSv.h-1.Mbq-1 with a coefficient of variation of 18.7%. Therefore, by applying the inverse square law, the average worker's effective dose nearby a patient administrated with an activity A (Mbq) of 131I at a distance d (m) and for a time duration of T (Hour) can be estimated by the following equation:

E(µSv)=0.031*T*1/d^2 *A

For of a realistic exposure scenario simulating the presence nearby an administrated patient with 3700 Mbq of radioiodine 131I for 5 minutes at a distance of 50 cm and for 10 minutes at a distance of 1 meter, the estimated worker's effective dose will be 57.35 µSv. As the average annual monitored effective dose for exposed workers in a nuclear medicine is ranged from 3 to 5 mSv [5], the proposed equation could be a useful tool to estimate instantly the medical staff's occupational or emergency exposure and consequently to maintain the conformity with radiation protection principles.

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Evaluation of Nasal Swab Method to assess Occupational Internal Contamination with I-131, I-123, and Tc-99m*,**

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Introduction
The volatility of some radionuclides during the preparation of radiopharmaceuticals may cause internal contamination and increases the inhalation hazards for workers. Our internal dosimetry laboratory tested the nasal swab method to screen any potential internal radioactive contamination. Materials and methods
The nasal swab method was evaluated for workers at Al-Bairouni nuclear medicine center in Damascus, Syria. Nasal swabs were collected from workers preparing radioactive materials. As the effectiveness of such samples is limited to a very short period after exposure, the sample collection was carried out during the first hour following the expected exposure.
In addition, the collected data from nasal swabs was associated with in vivo (thyroid) and / or in vitro (urine) measurements.
Nasal swabs and bioassay measurements were collected from 15 workers for 92 expected intake cases. The samples were collected by inserting a clean cotton swab (moistened with water) about 2 cm into each nostril in a circular motion.
The committed effective doses were estimated for all measurements and were compared with each other. The measurements of nasal swab and urine samples were carried out by using stationary N- type HPGe detector, whereas thyroid counting was done by using portable unit of HPGe detector.
Results and discussion
The measured value, M, was considered to be significant if it exceeds the decision threshold (DT) of the said measurement method. The value of DT equals half the value of detection limit (DL) according to ISO 11929:2010 (Table 1). The ranges of obtained results were summarized in the Table 2 for three radionuclides (131I, 123I, and 99mTc).
The dataset contained 33 cases where significant activities for both nasal swabs and other bioassay methods have been observed. Also, there were 20 cases where nasal samples had significant activity while the results from other bioassay methods were lower than the relevant detection limit. On the other hand, 13 cases were found to have no detectable activity in nasal samples whereas other bioassay methods measured activities greater than the detection limit. In other words, the absence of activity in nasal swabs does not constitute sufficient evidence that an inhalation exposure has not occurred. Actually, this may be due to various possible reasons like: some workers were breathing by mouth, nose was self-cleaned if samples were not collected early, the worker washed his nose unconsciously before collecting the sample, and also particle size can significantly affect nasal deposition and clearance.
Conclusion
There was great variability in the relationship between internal dose estimated from nasal swab measurements and those from other bioassay results. Nasal swab measurements were found to be a very poor method for the assessment of internal radioactive contamination because of the large uncertainty involved in the proposed nasal model. Gamma spectrometry measurements of nasal swab samples can provide rapid information on radionuclide composition, and it can be used in nuclide identification especially when worker may be exposed to more than one radionuclide in the workplace. Finally, the annual committed effective dose of most monitored workers was lower than 1 mSv.

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Managing Occupational and Patient Doses for an Integrated Optimisation in Interventional Radiology**

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Introduction

The International Commission on Radiological Protection recommends to manage occupational doses together with patient doses for an integrated approach in optimisation for interventional radiology. In most of the cases, occupational doses are not measured for individual procedures but for monthly periods and the level of radiation protection may be different for some specific clinical procedures.

Optimisation of occupational protection also requires to identify the potential problems with the proper and regular use of personal dosimetry. Optimisation may be easier with electronic personal dosimeters, including the use of ambient dosimeters at the C-arm of the interventional X-ray systems. Sometimes audit of occupational doses and a comparison with the values of the ambient (reference) dosimeter allows to identify the lack of occupational protection (e.g. the proper use of the ceiling suspended screen).

Materials and methods

A homemade Dose Management System (DMS) called DOLQA (Dose On Line and Quality Assurance) used in the last two years in our university hospital, allowed to manage patient and occupational doses together for interventional procedures. Results are presented for three cardiac laboratories, two general interventional radiology rooms and one neuroradiology room. The initial approach to identify the optimisation priorities, has been, firstly, to audit the highest patient dose values and to look for the occupational dose values for these procedures and secondly, audit the highest occupational dose values (measured over the protective apron) and to identify the clinical procedures to detect potential lack of protection during some of the procedures. The selected parameters to investigate potential corrective actions have been: occupational doses per procedure higher than 0.5 mSv, or more than 3 mSv per procedure in the ambient dosimeter located at the C-arm.

Results

A total of 4900 interventional procedures with occupational and patient doses have been processed. The percentage of occupational doses higher than 0.5 mSv in only one single procedure, was between 0.1 and 0.5% of the procedures for the six interventional rooms. The percentage with >3 mSv per procedure at the reference dosimeter was between 0.2% and 3.2%. For the ratio between occupational doses (measured over the lead apron) and the dose value at the C-arm (without shielding), the alert to investigate was set for values higher than 10%.

Conclusions

The DMS with the integration of patient and occupational dose values allow the simultaneous management of both quantities and to set alerts identifying abnormal values of different dosimetric indicators to suggest corrective actions. Low, or medium dose values measured by the passive personal dosimeters are not always a guarantee of adequate occupational protection and the DMS with occupational doses, allow to manage several alerts for individual procedures helping to improve the personal protection.

As limitations for the obtained results it should be mentioned some inaccuracies in the scatter dose values measured by the ambient C-arm dosimeter when the dose rates are very high (e.g. for digital subtraction angiography acquisitions close to the scatter source).

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Assessment of Equivalent Doses for the Eye Lens for the Workers in Two St. Petersburg Nuclear Medicine Departments*, **

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Introduction

In 2011 the International Commission on Radiation Protection established the threshold value of the absorbed dose in the eye lens for the development of cataract equal to 0.5 Gy for acute and chronic exposure. A dose limit for exposure of the lens of the eye was established equal to 20 mSv per year, averaged over five consecutive years (100 mSv over 5 years), and 50 mSv for any single year [1].

Workers of nuclear medicine departments can receive high doses in the eye lens [2]. Previous studies show that the measured Hp(3) of the eye lens of the staff involved in the production of radiopharmaceuticals for positron emission tomography (PET) were higher up to a factor of 3 compared to the Hp(10) measured on the chest[2].

The aim of the study was to assess the absorbed doses in the eye lens of the staff of medical facilities working with radiopharmaceuticals and to estimate the relationship between the dose in the eye lens and the activities of the radionuclides in order to determine categories of the staff for regular individual monitoring of the eye lens doses in nuclear medicine departments.

Materials And Methods

Individual dose equivalent of the eye lens Hp(3) of the staff was measured in two medical facilities in St. Petersburg during one month. The staff was divided by two groups depending on the used radionuclides (Table 1).

The Hp(3) in the eye lens were measured with individual thermoluminescent dosimeters (MKD-A with detectors made of LiF: Mg, Ti (DTG-4). The uncertainty of the measurements Hp(3) was ± 30% (P=0.95). Conversion coefficient from Hp(3) to equivalent dose of the eye lens was 1.

Results and Discussions

The highest equivalent doses in the eye lens (1.3 mSv) were determined for technologists from the first group involved into the synthesis of radiopharmaceuticals for PET (Figure 1). Relatively high equivalent doses were determined for radiochemists involved in the synthesis and quality control of radiopharmaceuticals for PET (0.76 mSv). The doses of nurses in PET engaged in dispensing of radiopharmaceuticals in syringes, measurement of the activities and injection to the patient (0.55 mSv) were higher compared to doses of nurses working with 99mTc, 123I and 89Sr (0.34 mSv). The analysis showed a high correlation between eye lens doses of nurses and radiochemists working in PET and activity of radionuclides; there was no correlation for other groups.

Conclusion

High doses were determined for the nurses, radiochemists and technologists working with positron-emitting radionuclides (18F, 68Ga and 11C), which can exceed 20 mSv in a year. It is recommended for this category of workers to perform individual monitoring of the eye lenses after a preliminary assessment of the level of exposure of workers and an assessment of the risks of high doses of the eye lens.

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Contribution of Occupational Dosimetry and Workers towards Occupational Safety Culture*,**

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Nuclear medicine in practice utilize the radiation from the radionuclide to diagnose and treat the human disease. It potentially poses an occupational health risk to the workers, as the personnel monitoring is the most important aspect need to undergo when working in a radiation environment [1]. External exposure of personnel monitoring had been long introduced in Malaysia as enacted in ACT 304 personnel monitoring section paragraph 22(1) and (4). Thus, personnel dose monitoring in medical is legally bound and considered as a must important component in the occupational safety especially to among nuclear medical imaging workers. Generally, the dosimetry of these workers are monitored using various type of personnel dosimeter such as optically stimulated luminescence dosimeters (OSLD), radiophotoluminescence (RPL), thermoluminescence dosimeter (TLD) or conventional film badge.

According to the International Atomic Energy Agency, there is need for the control and monitoring of radionuclide materials and medical [2]. There are many professionals whose mandate includes nuclear security as just one of multiple areas of responsibility, in addition to the obvious contributors such as technical experts in nuclear sciences, plan writers, and analysts focused on the safety of their profession. Furthermore, the self-assessment allows an organization to develop and maintain a occupational safety among nuclear personnel by evaluating their knowledge and awareness involves radioactive sources [3], [4]. Hence, the present study aimed to evaluate the performance of difference dosimeters in estimating whole body exposure and for the second phase we assess the subjects knowledge on nuclear safety.

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Strengthening Radiation Protection of Occupational Workers in Radiotherapy Practice in India: Regulatory Perspective

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Atomic Energy Regulaory Board

Atomic Energy Regulatory Board (AERB) has stipulated various safety requirements in Safety Code No. AERB/RF-MED/SC-1 (Rev. 1),2011 on "Radiation Therapy Sources, Equipment and Installation" under legal provisions and compliance is ensured through process of licensing, regulatory inspection, enforcement, periodic safety review, safety performance evaluation of design of radiation equipment and sources for protecting occupational workers. Further, AERB has taken several steps such as implementation of LMOS in Radiotherapy installations, establishing mechanism for Installation of radiotherapy machine as per approved room layout(vault), verification of shielding adequacy of radiotherapy vault before permitting radiation measurement for commissioning the radiotherapy machine, revision/ development/ of acceptance criteria/QA test protocol of radiotherapy equipment by incorporating safety systems and failsafe mechanism referring relevant international documents, introduction of electronic safety performance indicator, compliance verification through regulatory inspection for strengthening radiation protection measures for occupational workers in radiotherapy facilities.

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Appraising Occupational Radiation Protection in Medicine and the Nigerian Radiation Safety in Nuclear Medicine Regulation 2006**

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With the advancement of cutting-edge technology, radiation-based applications continue to gain more ground in modern medicine. Occupational radiation exposure in the medical field occurs via two broad routes: diagnostic radiation and therapeutic radiation. National regulatory agencies and medical facilities are aware of the potential risks of ionizing radiation and the need to ensure that exposure is avoided or minimized. Ionizing radiation safety is essential for the health and wellbeing of health workers, hence the need for law and regulations regarding the recognition of the occurrence and the need for the control of occupational health hazards associated with ionizing radiation. Satisfactory radiological protection is based on three core principles: (i) the principle of justification for exposure (ii) the principle of optimization of protection, and (iii) the principle of application of dose limits.3 Nigeria like other countries provide safety regulations for health workers exposed to nuclear radiation in the health sector in line with the guiding principles of the International Commission on Radiological Protection (ICRP). 4 The law is made to protect patients, workers and the general public from the risks associated with exposure to ionizing radiation in the course of nuclear medicine practice in Nigeria, and to assist licensees in meeting radiation safety and protection requirements in nuclear medicine practice for the attainment of adequate radiation protection and safety of patients. These regulations are applicable to all established uses of ionizing radiation sources employed in the practice of nuclear medicine, to the facilities where the sources are located and to the individuals involved. 5 These regulations cover occupational, public, medical, potential and emergency exposure situations.

This paper will examine the extent to which the regulation governing radiation safety in nuclear medicine protects the health professionals whose work involves radiation exposure. The enabling law for the Nigerian Safety and Nuclear Medicine Regulation 2006 is the Nuclear Safety and Radiation Protection Act, No. 19 of 1995.6 Section 47 of the Act provides that: the Authority may, with the approval of the President make regulations, prescribing anything required to be prescribed under the Act, hence the adoption of the Nigerian Safety and Nuclear Medicine Regulation to provide for what the principal Act did not cover as it related to safety and the practice of nuclear medicine in Nigeria.

This paper will further appraise the administrative requirements and authorization of practice for nuclear medicine practitioners, renewal of authorization, personal accreditation, authorization of other activities related to nuclear medicine, inspection by relevant authorities, the issue of non-compliance and suspension or withdrawal of authorization. Other foci of this paper include radiation safety and protection requirements for nuclear medicine practitioners in Nigeria, quality assurance indicators measured against international standards, and implications of the regulation on radiation protection education and training. This paper will conclude by identifying the gaps in the Nigerian Regulation and make necessary recommendations for the promotion of safer use of nuclear radiation in the health sector of Nigeria in line with international best practices.

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Occupational Radiation Protection in Paediatric Interventional Cardiology in Latin America and Caribbean Countries: the OPRIPALC Project

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Introduction: The project "Optimization of Protection in Pediatric Interventional Radiology in Latin America and the Caribbean" (OPRIPALC) started in 2018 as a joint response of the Pan American Health Organization and the World Health Organization, in cooperation with the International Atomic Energy Agency, to collaborate with its member states in ensuring that radiation exposures are optimized in paediatric interventional radiology1. Medical staff (physicians, nurses, radiographers, etc.) in cardiac intervention laboratories may receive relatively high radiation doses if radiological protection tools are misused or good operational measures are not applied. Radiation injuries of the lens of the eyes may occur after several years of work if a proper radiation protection program is not applied (2-4).

Objectives: This work presents the results of a survey conducted in the context of the OPRIPALC project to assess the knowledge and attitudes of medical staff concerning individual dosimetry and radiation safety personal protective equipment, as well as the availability of radiation safety devices for use at the workplace.

Materials and methods: The survey was produced using on-line forms and validated by the OPRIPALC coordinating group. Invitations were sent to the 21 OPRIPALC participating centers (corresponding 10 countries). 35 responses were received (15 physicians, 3 nurses, 14 radiographers, 1 medical physicist, and 2 others).

Results and Discussion: The responses indicate that 91% of the professionals regularly use their personal dosimeter but only 53 % of them know the values of their occupational doses. 69% know how to interpret their dosimetric reports in terms of the units and quantities included. Finally, only 17% of the workers have electronic dosimetry available. Concerning the use of commonly available devices for personal radiation safety, the results show that lead apron and thyroid protectors are used by 87 % of the professionals. 66 % used radiation-attenuating sterile surgical gloves and a sterile lead-equivalent patient-mounted drape. This is mainly due to lack of availability (66 %). Opinions about whether the various devices were considered "essential safety device" varied. The three mainstays of individual protections, the lead or lead-equivalent apron, the thyroid shield and the lead eye glasses, were considered by most (97%, 94% and 89%, respectively) to be an essential safety device. When asked to rate the organs at the greatest risk for radiation-induced health problems, the thyroid gland were considered to be at the "greatest risk" (69%), followed by the eyes (54%) and gonads (51%).

Conclusions: Medical staff should have access to their personal dosimetry and be trained for interpreting the results. This should be integrated into radiation protection education and training activities in workplaces where fluoroscopy-guided interventions are performed.

Keywords: Personal dosimetry, occupational radiation protection, interventional cardiology, paediatrics, radiation safety devices.

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Radiation Protection Awareness of Healthcare Staff – An Essential Issue in Medical Uses of Ionizing Radiation**

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Co-author: Anna Petrova

International Atomic Energy Agency (IAEA)

With the rapid advancement in medical use of ionizing radiation for both diagnostic and therapeutic purposes, the importance of radiation protection for healthcare professionals involved in the performance of radiological procedures, along with patient protection has become more prominent. Accordingly, the International Atomic Energy Agency (IAEA) has established several safety standards and provides training materials and other resources to support improving radiation protection competence of the staff. In this regard, the general safety guide (GSG-7) provides general guidance on occupational radiation protection programmes. For the medical applications, this is complemented by the Specific Safety Guide (SSG-46) as well as safety reports, training materials, posters and other informational resources on the Radiation Protection of Patient (RPOP) website. The aforementioned resources offer informative advice related to radiation protection of staff and patients in diverse fields including radiotherapy, diagnostic radiology, nuclear medicine, interventional procedures and dental radiography. This paper aims to review the available IAEA publications, training materials and other resources to build knowledge and awareness of medical staff on radiation protection as an essential issue in medical uses of radiation.

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Occupational Radiation Protection in Diagnostic and Therapeutic Nuclear Medicine**

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The use of radiation in medical applications continues to increase worldwide and has a direct implication for radiation protection of medical staff performing or assisting in medical examinations using ionizing radiation sources. In nuclear medicine, staff is exposed to the risk of external exposure when using radiopharmaceuticals and when performing conventional radiological examinations, and to the risk of contamination when handling unsealed sources.

In Morocco, the number of nuclear medicine centers has increased to 25, working with new imaging technologies, including 13 PET CT, 10 SPECT CT, 15 Gammas cameras, and 44 Radioactive Iodine (I-131) therapy rooms. This technological advance and the increased use of these new techniques require that specific radiation safety regulations be implemented to protect nuclear medicine personnel, patients, and the environment.

In both diagnostic and therapeutic nuclear medicine, the patient becomes a source of radiation, not only for himself but also for staff, carers, and the public. All categories of staff members involved in nuclear medicine must have good knowledge of radiation protection as it applies to specific situations. In addition, established working procedures, availability, and use of proper protective equipment, as well as an efficient monitoring program, are all critical components in ensuring that medical workers are appropriately and acceptably protected.

Many structured recommendations from various academic societies and international organizations, mainly the IAEA, highlight important issues of radiation protection of workers in nuclear medicine departments taking into consideration the technical developments in the field. This article discusses important principles to ensure the radiation protection of workers in daily nuclear medicine practices, useful references, important issues, and future perspectives.

Keywords: Occupational Radiation Protection; Nuclear Medicine; Pet Ct; Radiation Safety

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Development and Implementation of Standard Manual of Radiation Protection Programmes (RPP) for Health Institutions in Malaysia: Regulatory Perspective

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Ministry Of Health

Background

In Malaysia, the Atomic Energy Licensing Act 1984 (Act 304) is the main act that aims to ensure the usage of ionizing radiation is in a safe manner without compromising the safety of the worker, patient, and members of the public. In the year 2017, the Malaysian Ministry of Health has formulated and published the standard document of the Radiation Protection Program (RPP) dedicated to the health institutions in Malaysia. As stated in regulation number 15 (4) of Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010, The licensee shall establish and maintain a radiation protection programmed and safety procedure, including emergency plans to ensure the protection of the health of workers and members of the public and to minimize the danger to life, property and the environment.

The paper aimed to describe the commitment of the government of Malaysia, particularly the Ministry of Health (MOH) and its institution such as hospitals to initiate and developed the standardized manual aimed to be used for every health institution authorized by the regulatory body.

Methods

The Malaysian MOH has developed the document based on the needs of the latest requirements under the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010. These are the subsidiary regulations under Act 304. The scope was in accordance with current requirements set by the Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3. The document was designed through the special working group formed under the Medical Radiation Surveillance Division (MRSD) of the Ministry of Health.

Results

Health institutions through their licensee which was authorized by the Licensing Section of the Medical Radiation Surveillance Division shall fulfill the requirements under the sub-regulation 15(4) of the subsidiary regulation under the Atomic Energy Licensing Act 1984. These standard guidelines apply to all of the following services; radiology (diagnostic & interventional, nuclear medicine, radiotherapy, dental, veterinary, blood irradiator, and medical research in Malaysia. The basic elements of the document were the radiation protection committee, radiation protection officer, radiation protection manuals, and radiation safety and protection's in-house audit.

The manual become one of the standard criteria for the license application for health institutions in Malaysia. The manual consists of the following elements as per Table 1.

Basic Elements	Standard Elements	Standard Elements
Abbreviation	Organizational Administration and Responsibilities;	Classification & monitoring of working area
Definition	Principal of Radiation Protection	Radiation Incidents
Certification	Monitoring of Occupational Exposure	Security of Radioactive Materials
Objectives	Health Surveillance of workers	Record Handling & Keeping
Policy of Radiation Protection & Safety	Details of radiation sources and its associated facilities	Training of the worker
Review of the Radiation Protection's Manual	Disposal of radioactive materials & irradiation apparatus	Local Rules
Reference	Safety Assessment	Management of Radioactive Waste

Table 1: The standard manual has been developed

Conclusions

The standardized Radiation Protection Programmed (RPP) document developed by the Ministry of Health (MOH) and its institution is a very important tool as a reference to ensure the safety of the staff and the members of the public from the harmful effect of the ionizing radiation. Whilst, to protect members of the public and to minimize the danger to life, property, and the environment, the RPP took into consideration the management of radioactive material used in healthcare facilities.

In order to improve the quality of services provided by public and private medical institutions, the Ministry of Health Malaysia (MOH) is always working to produce clear, transparent, and current guidelines/circulars from time to time.

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Regulatory Approach for Dilute and Disperse or Concentrate and Store of the Patient's Excreta after Iodine Therapy**

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The disposal of the patient excreta containing radionuclides after Iodine therapy needs special consideration. The criteria and options for the selection of appropriate technology for either discharge of liquid radioactive effluents into the sewer system directly or after decay is a very important regulatory decision due to the exposure raised, costs involved, the potential complexity of technical, environmental considerations and avoiding contradiction in cost-benefit balances.

The "delay- stored" and "dilute- disperse" approaches have been investigated. The production source term (P) was used as a computational model by assuming that the production of the patient excreta is constant and continuous over time. The buildup activity (A(T)) during a period (T) will depend on the total removal rate (K) which is equal to the physical decay rate and any other removal factor if any. In this case, the buildup activity would be increased up to a certain value and reach equilibrium while the activity concentration is most likely to remain the same if not combined with an additional dilution, and would be substantially decreased when the dilute and disperse approach is applied. The decrease in the activity concentration depends on the dilution volume and hence decreasing in the occupational exposure in the facility. Usually, a large amount of diluted volume is available for direct discharge due to mixing it with other liquid effluent or water streams. By the time the effluent reaches the environment, concentrations of the radionuclides would be reduced to acceptable release levels.

The production rate term is a simple model that can be used to estimate the discharged activity to the final effluent destination as a fraction of the administered activity. The estimated discharged activity and its relevant resulted exposure is mainly depending on the dilution volume. Also, it is easy to obtain and determine the adequacy of the sewage system that can achieve exempted criteria, ensure no radiation risk, and warrant no regulatory concern. Furthermore, it can apply and manage of discharge of low-level liquid radioactive waste generated in other medical activities, educational, research, and Industrial Facilities. In the presence of appropriate sewage infrastructure, it would be better to dilute and disperse the waste activity in a continuous sewage system rather than concentrate and store for decay in order to avoid unnecessary occupational exposure to workers at the facility during the storage period. In addition to reducing the potential of occupational exposure due to contamination also. Moreover, achieve the best cost-benefit balance. The dilute and disperse approach is desirable for managing the patient excreta containing radionuclides since no occupational exposure is raised to workers in the sewer system or treatment plant at no additional costs. In addition, consentient with ICRP and, IAEA recommendation and RPII conclusions where both they recommended that do not require to urine to be stored and no need to provide and install delay tank.

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Non-Lead Light-Weight Glasses for Eye Dose Reduction of Angiography Radiation Workers

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Currently, the development of light-weight, nontoxic, lead-free radiation shields containing micro or nanoparticles has attracted the attention of different investigators (1, 2). Lead Glass is typically used as a transparent protective barrier in making control windows for different medical imaging modalities, like mammography, diagnostic radiology, CT scan, fluoroscopy, and angiography (3). Such transparent shields can be used for making eyeglasses for the reduction of eye dose (4). However, the heaviness and toxicity of the lead have always been a major concern (5). In this study, light- weight lead-free eyeglasses were simulated using MCNP6 Monte Carlo code. For validation of the simulation, the attenuation coefficient of the simulated shields was compared with the XCOM data. The attenuation properties of transparent shields containing 25% PbO, 20%, 30%, and 40% Barium Carbonate were compared with simulated. Usually, eyeglasses are 0.5 to 0.75mm lead equivalent. The results of the simulation indicate that the eyeglasses, containing 40% Barium carbonate, with the same attenuation for 80kVp, are 26% lower than the common lead glasses containing 25% PbO. The results are because of the fact that the K-edge of Barium is 37.4 keV, after which the radiation flux is reduced significantly. Therefore light-weight non-toxic silicate glasses can be made, with high attenuation for diagnostic X-ray.

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Assessment of Extremity Exposure during 18F-FDG Injection with Automatic Injection System*, **

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The extremity exposure monitoring of nuclear medicine personnel is essential to control exposure in the workplace, to ensure that legal limits are not exceeded, to predict extremity doses and, if possible, to optimize workflow. Distribution of the doses over hand is nonuniform and the obtained doses by Hp(0.07) passive dosimeter can be significantly lower compared to fingertips. There are only limited scientific publications referencing detailed studies on hand exposure in the process of work with automated infusion and injection systems. The aim of this study was to assess the extremity exposure of nuclear medicine personnel working with automatic infusion system dedicated for 18F-FDG administration.

Materials and methods

For the measurements of hand doses, thermoluminescent dosimeters (TLD-100 (LiF:Mg, Ti)) chips were used. The thickness of these dosimeters was 2 mm, the diameter 4.5 mm. TLD-100 chips were calibrated 18F source in a dose range of 0.25-2 mSv.

Dosimeters were attached to both hands on a palm side at 14 locations (dosimeters No. 1-14, 7 chips on each hand) under disposable gloves (Fig. 1.). Additionally, to evaluate and compare the difference between obtained doses from typical monitoring position (base of a middle finger of the dominant hand) and the most exposed part, dosimeter No. 15 was attached in part of the measurements while working with 18F. Each technologist working with 18F wore dosimeters from 5 to 6 working days depending on total radionuclide activity.

Working process include 18F-FDG administration in injection room with the automatic infusion/injection system IRIDE (Comecer).

The activity range of administration of 18F for one measurement of dosimeters was 10.76-16.65 GBq (average 12.48 ± 2.94). The right hand was the dominant hand of all radiology technologists. The measured doses were normalized per manipulated activity (mSv/GBq).

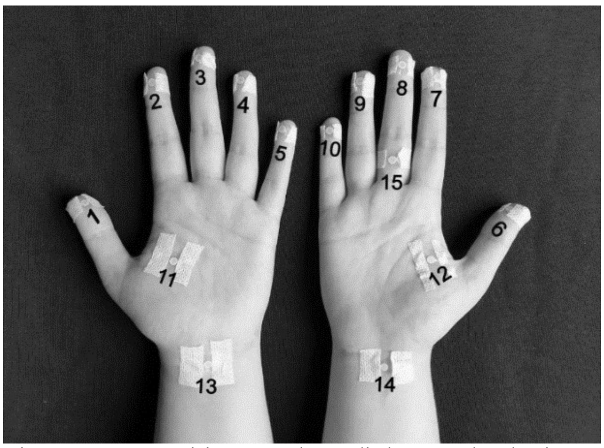

Fig. 1. TLDs positions on the radiology technologist palms.

Results and discusion

Working with 18F, the distribution over different points of hands did not differ significantly, as the average hand dose for the left and the right hands resulted in the dose of 25.64 ± 12.38 and 25.72 ± 6.2 μSv/GBq, respectively. The highest doses were observed by the right hand thumb tip, index finger tip and middle finger tip resulting in doses of 36.1, 33.2, 35.4 μSv/GBq, respectively (Fig. 2.). The least exposed part was the right hand wrist (12.67 μSv/GBq).

In general, the monitoring of extremity exposure performed with one dosimeter wearing on one finger of dominate hand, but to ensure an appropriate radiological protection for workers, the coefficient should be applied considering the injection/infusion system and working practice.

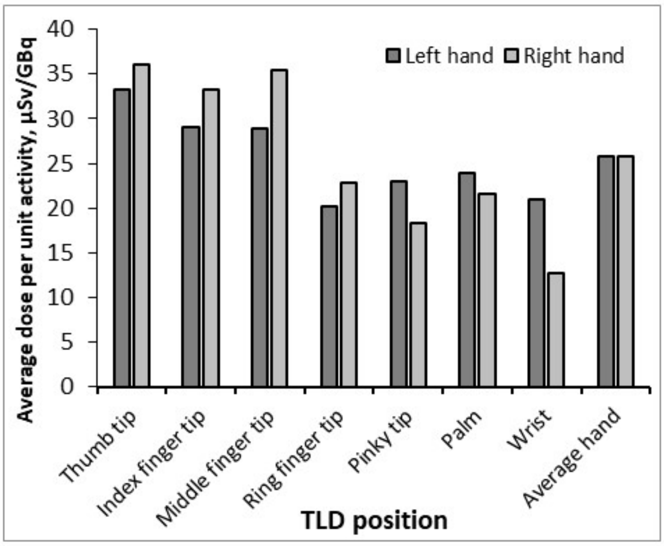

Fig. 2. Hand dose distribution of different TLD positions while working with 18F (N = 5)

Conclusions

The results of our study showed that the most exposed parts while working with open radioactive sources are fingertips of thumb, index finger and middle finger, thus, monitoring of these points would be the most expedient. Also, it was found that the maximum fingertip doses are 1.3-1.7 times higher compared with the doses from typical monitoring position (base of a middle finger of the dominant hand).

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Assessment of Workplace Radiation Exposure Levels in Diagnostic Radiology Facilities in Coast, Lindi and Mtwara Regions, Tanzania

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Background
The aim of this study was to assess radiation exposure levels in diagnostic x-ray units in medical facilities in Coast, Lindi and Mtwra regions in Tanzania, in order to establish whether the exposure levels are within the internationally recommended dose rate limits.

Method
A total of 26 public and private radiological imaging centres were involved in a cross-sectional study carried out from May to July 2021 in Tanzania. These centres had 31 x-ray rooms. A calibrated radiation survey meter was used to measure exposure levels in these x-ray rooms. Scattered x-ray behind the lead glass of the control area, door to control area, wall of the control area and the entry door to x-ray room were measured to assess the levels of exposure of professionals and as well as exposure of the public. Radiation dose rates were compared with the dose limits of 10 and 0.5 µSv per hour (µSv/hr) for workers and the public, respectively. A checklist was also used to obtain information regarding the materials used for radiation shielding, suitability in design and fitting of the materials.

Results
Minimum-maximum doses at the lead glass of control area, entrance to control area, entry to x-ray rooms, and wall of the control area were; 0.098 - 3880, 0.3-263, 0.07-96, 0.05-16 µSv/hr respectively. Average dose rates were 137.59, 25.71, 8.53 and 1.57 µSv/hr at the lead glass, door to control cubicle, door to x-ray room, and wall of control cubicle respectively. Among 31 examination rooms, 32.25% of the dose rates at the lead glass was greater than 10 µSv/hr, 25.8% of the rooms showed the dose behind the door to control cubicle was greater than 10 µSv/hr, 6.45% showed that dose behind the wall of control cubicle was above10 µSv/hr, while 58.06% showed that the dose rates at the entry to x-ray room were above 0.5 µSv/hr. Main factors contributing to the poor radiation shielding were improperly fitted shielding material, poor design of the shields, and use of inappropriate shielding materials such as normal glass instead of lead glass.

Conclusion
These results demonstrated that a significant number of the x-ray rooms have high dose rates above the recommended limits, hence inadequate safety of occupationally exposed workers. A need for the facilities to consult qualified personnel during design and shielding of x-ray rooms, and the need for strengthening of enforcement by regulatory body are apparent, in order to further improve occupational radiation safety.

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Quality Control of Individual Radioprotection Equipment: Methodology and Organization in the University Hospitals of Geneva*, **

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Introduction: In 2018 the new Radioprotection Ordinance in Switzerland came into forced requiring the radiation protection equipment to be checked annually for its proper performance. Indeed, to provide safe operating conditions for staff working with ionizing radiation, the personal protective equipment (PPE) (protective aprons, skirts, jackets, goggles and thyroid shields) should be checked at least once a year. It is up to the radiation protection expert to make an inventory of the existing radiation protection equipment in the institution and to setup a quality control procedure to ensure its performance. A lot of work has been done with the hospital's internal equipment management database system (EMDS) to identify and include the protective equipment in the follow up system. Moreover, a quality control procedure has been established considering the most logical and optimized method inside the Institution. We present here the preliminary results.

Materials and methods: self-adhesive labels were used to identify all 670 radiation protective equipment and the information gathered into the EMDS. Once identified, the aprons, skirts, jackets and protective thyroid shields were tested using different methods: first visually (tear in the outer layer, defects at the fasteners) then tactilely (suspicious mass, internal tear, tear at the fasteners/seams) *(fig. a, b, c and d)* and at the end radiographically. For this last method, several options were considered but the EOS® system was chosen since it provides 2 acquisitions at the same time front/profile *(fig. e, f, g, h, i and j)* in vertical position (wearing position) and without further exposure of the staff. A score, established according to the location of the detected defects *(fig. k)* is provided and the results qualifies the equipment as: 0-2 -> OK; 3-5: to be withdraw in the coming months (until new replacement equipment arrives); larger than 5: waste.

Results: Quality controls are time-consuming, requiring extensive logistics. Three students checked nearly 400 pieces of equipment. The preliminary results of the comparison of the visual and tactile checks performed by different inspectors shows a great disparity in the rate of agreement, from 58% to 91% of agreement depending on the point checked. Furthermore, it turned out that there was only 50% agreement between the visual/tactile and radiological inspection results. The equipment were scored and the results validated by a radioprotection expert. In total, on the 400 equipment checked, 15 items were deemed non-compliant for clinical use and were withdrawn, 10 had an intermediate result and should be changed in the upcoming months. Concerning their lifespan, major defects were observed on equipment over 6 years old used in operating theaters, cardiology and angiology rooms.

Conclusions and outlook: Visual and tactile checks are insufficient to guarantee the integrity of personal radiation protection equipment, imaging is therefore necessary. We observe that their lifespan depends greatly on their use but also on their storage. A more detailed analysis of the data (being collected) will allow us to define an expiry date for PPE according to their class of use, allowing us to target quality controls while offering controls on demand.

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Dose Metrology: TLD/OSL Dose Accuracy and Energy Response Performance

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Performance evaluation and comparison in terms of measured dose accuracy, energy response, and coefficient of variation between two types of passive radiation dosimeters, thermoluminescent (TLD) and optically stimulated luminescence (OSL), used by workers in environments using ionizing radiation, for individual radiological monitoring and control of external exposure at different times (cumulative dose for 1 month), is a very important step to judge the quality and to identify the dosimetric aspects of TLD/OSL passive dosimeters and it is in this perspective that this study has been carried out.

In fact this performance study consists in determining both the accuracy of the dose measurement R(10) and R(0.07) which is considered as the ratio of the measured dose (Hp(10) or Hp(0.07)) to the delivered dose (Hp(10) or Hp(0.07)) for each photon energy, the validity of the results of this test is based on the acceptance limits of the ICPR and the international standard ISO 62387, the relative energy response which is used to calculate the ratio of measured Hp(10) to delivered Hp(10), and Hp(0. 07) measured/Hp(0.07) normalized to 662 keV (Cs-137) energy to find which energy response is closest to the ideal case, and the coefficient of variation that allows to determine determine the statistical fluctuation of the doses found Hp(10)and Hp(0.07).

The results found for the accuracy test are satisfactory for the OSL and TLD dosimeters as they are within the ICRP limit, for the energy response the OSL shows a good performance for Hp(10) and Hp(0. 07) than the TLD, and for the coefficient of variation OSL meets the requirements of the iso 62387 standard for Hp(10) and Hp(0.07) while the TLD meets the requirements of the same standard only for the measurement of Hp(0.07).

Keywords: TLD, OSL, radiation protection, Ener-gy dependence, ICPR trumpet graph, Hp (10), Hp (0.07)

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The Relation between Hp(10), and Hp(3) for Nuclear Medicine Staff*

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The dose to nuclear medicine (NM) staff has been always a crucial topic, and a significant concern owing to manipulation of unsealed radiopharmaceuticals (1). The hands and eye lenses of the radiation workers are exposed significantly during the preparation and administration of radiopharmaceuticals in nuclear medicine departments (2). Three operational quantities, whole-body Hp (10), extremity dose Hp (0.07), and eye lens dose Hp (3), are suggested for use for measurement of skin, eye, and whole-body dose estimation (3). The eye lens is found to be more sensitive to radiation than previously considered, and the dose limit to the eye lens has reduced significantly Previous studies have focused on finding a relation between Hp (10), which is routinely monitored, and Hp (3) (5). This study aimed to measure Hp (10), and Hp (3) for NM staff at Shiraz Hospitals and evaluate the relationship between these quantities. First, a group of 200 TLD-100 chips was selected and the ECC (element correction coefficient) was calculated for each of them. The dose values to the eye lenses and personal dose equivalent values were measured in 1 working month. To measure the Hp (10) and Hp (3), two groups containing three TLD chips were packaged in a tissue-equivalent holder which had prepared to put on the staff forehead for eye lens estimations (Figure 1) (4). The TLDs were read out by a TLD reader model Harshaw 4500, and the TLD readings were converted to the operational dosimetry quantities. Table 1, listed the Hp (10) and Hp (3) values which are collected for 13 workers and the results were validated with film badges reports. Lindholm et al. in their research showed that the Hp (3)/Hp (10) ratio was 0.7. However, based on our measurements, the Hp (3)/ Hp (10) ratio isn't as a constant coefficient (5). Our findings didn't show any significant relation, the ratio was found to be between 0.18, and 16.05. The possible explanation for such differences between Hp(3), and Hp(10), is the different working manner of the staff, i.e. their working speed, or head, hand, and their body positioning during the work. Therefore it is suggested that the Hp(3) quantity be measured separately with some dosimeters, and it can't be measured based on their personal dosimetry results.

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Evaluation of Occupational Radiation Doses in Orthopedic Surgery Procedures for Fractures of the Proximal Femur*, **

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The use of fluoroscopy procedures in intraoperative orthopedic procedures has increased in the last years since it allows a better assessment of the anatomical structures under surgery and visualization of implants, besides reducing the time needed for the surgical procedure and length of hospital stay of the patients and risk of complications [1]. Despite these benefits, scattered x-ray radiation received during the procedures from fluoroscopic equipment represents a risk of radiation-induced effects to the orthopedic surgeons and the medical staff. There is growing concern about the radiation doses received by orthopedists due to surgical procedures since procedures are executed at close distances to the patient and, in general, orthopedic surgeons are not trained in radiation protection and the procedures adopted using fluoroscopy systems may not be optimized, resulting in high doses to the patient and medical staff. There are few studies published regarding the occupational doses during orthopedic interventions. The aim of this paper is to estimate the occupational radiation doses and risk to medical staff during surgical procedures on fractures of the proximal femur, and therefore contribute to the optimization of radiation protection to staff.

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Assessment of Occupational Radiation Exposures at Some Selected Diagnostics Centres in the South West Nigeria**

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The Nigerian Nuclear Regulatory Authority is the competent Authority charged with the responsibility of nuclear safety and radiation protection that ensures adequate monitoring of radiation workers in Nigeria. Personnel monitoring is a major way to ensure compliance with international standards and the national regulatory dose limit for safety of radiation worker in the radiological facility. The occupational exposures of radiation workers in Diagnostics radiology facilities in the Southwest Nigeria was assessed using TLD LiF 100 badges for personnel radiation monitoring while integrated dose was measured at the control console using RDS 31 survey meters in 40 diagnostic radiology centers. This comprises of Federal government, State government and privately owned diagnostic centers. The average annual dose obtained using TLD LiF 100 for Diagnostic Radiology ranges from 0.01 to 2.4mSv with average value of 0.31 mSv and upper third quartile of 0.36 mSv while the annual dose estimated with survey meters ranges from 0.01 to 0.011mSv

It was observed that the values obtained with TLD LiF 100 dosimeter in this work is slightly higher than the estimated values obtained using survey meter. The maximum value obtained with TLD LiF 100 dosimeter is slightly higher than the average personnel dosimetry report published by NNRA for 2012 to 2016. The occupational exposure values obtained are far below the relevant national dose limit and international standards. A practice specific occupational exposure reference value of 1mSv is hereby proposed as dose constraint for radiological facility in the Southwest Nigeria.

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Workload of Medical Linear Accelerator at a High Throughput Cancer Treatment Centre in Sri Lanka

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General Sir John Kotelawala Defence University

Background

Bunker design and shielding are fundamental to the radiation protection of staff and the public in a radiation therapy department. The workload is an important factor in the design of protective barriers [1]. With the advent of Intensity Modulated Radiotherapy (IMRT), the workload of linac increased significantly since it requires more monitor units (MUs) per treatment [2,3]. The aim of this study was to evaluate the workload of linac at Apeksha Hospital, Maharagama, Sri Lanka.

Methods

This study was conducted in the Varian (Varian clinic 2300CD) unit of Apeksha Hospital, Maharagama, Sri Lanka. The data was collected from 1st of August 2020 to 30th of November 2020. All the treatment data were accumulated using the Varian ARIA oncology information system. The total workload during the study period (four months) was calculated and then averaged to one week to obtain for the average workload. The physics workload measurement was ignored in this study. There was no any research related workload during this period of measurement.

Results

Month	3D-CRT		IMRT	
	Number of patients	Total dose delivered at isocentre (cGy)	Number of patients	Total dose delivered at isocentre (cGy)
August 2020	742	544251.724	548	584667.019
September 2020	842	577595.859	661	694643.231
October 2020	624	164220.279	706	145698.781
November 2021	541	135562.912	471	98496.459

Table 1: Number of patients treated under each treatment procedure (6 MV) and the total dose delivered at isocentre. The notations are indicated as follows: 3D-CRT – 3-dimensional confomal radiotherapy, IMRT – Intensity modulated radiotherapy.

Month	3D-CRT	
	Number of patients	Total dose delivered at isocentre (cGy)
August 2020	492	174388.137
September 2020	709	270901.168
October 2020	513	98529.337
November 2021	270	61328.650

Table 2: Number of patients treated using 3D-CRT (15 MV) and the total dose delivered at isocentre.

3D-CRT		IMRT	
Workload for 6 MV (cGy/week)	Workload for 15 MV (cGy/week)	Workload for 6 MV (cGy/week)	Workload for 15 MV (cGy/week)
89 983.056	38 431.764	99 608.964	0

Table 3: Average workload for one week for treatment procedures.

Conclusions

The average workload for one week was 1918.97 Gy/week for 6 MV photons and the average workload for one week was 403.37 Gy/week for 15 MV photons.

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A Questionnaire Survey on Radiation Protection among Medical Staff Working in Cardiac Catheterization Laboratory**

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Background and aims

It is essential for cardiologist, technologists, and nurses working in e cardiac catheterization laboratory to understand radiation protection. However, protective equipment usage is still low, wearing dosimeters also very low and there is little awareness of radiation protection in practice.

Objectives

To assess the awareness and knowledge of medical stuff working in cardiac catheterization laboratory of occupational radiation protection tools and detect areas of defects in their knowledge.

Methods: We conducted a validated questionnaire to 180 participants from September 2021 to December 2021. The participants were medical staff working in cardiac catheterization laboratory including cardiology doctors, nurses, and technicians.

Results

We surveyed a total of 180 subjects from different institutions. There were 103 cardiologists (57.2%), 53 nurses (29.4%)), and 24 technologists (13.3%). Although almost all staff members (97%) always wore a lead apron, only (87%) wore a thyroid collar and lead glasses (79%). The rate of wearing a radiation dosimeter was insufficient (42%). A few subjects knew the radiation exposure dose of the procedure (19%), and slightly about (21%) had attended lectures on radiation protection. Awareness of radiation exposure doses, years of experience, knowledge of ionizing radiation, or attendance at basic lectures on radiation protection all that did not affect radiation protection among stuff significantly. However, medical doctors who were aware of the radiation exposure dose of each procedure were significantly more likely to wear dosimeters than those who were not ($p=0.0006$).

Conclusion

Medical staff in cardiac catheterization laboratory do not have enough radiation protection knowledge or education.

Keywords: education, ionizing radiation, cardiac catheterization laboratory, questionnaire survey, occupational radiation protection, safety.

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Novel Catheterization Laboratory Radiation Protection System Eliminates Need for Personal Lead Aprons

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Background
Interventional Cardiologists are exposed to occupational health hazards related directly to radiation exposure and indirectly to the orthopedic burden of wearing only partially protective lead aprons. Innovations to reduce these risks are warranted.

Methods
A commercially available comprehensive lead shielding system (ProtegoTM, Image Diagnostics Inc, Fitchburg, Ma), consisting of an upper shield suspended from a floor-based pedestal, a lower shield attached to the table and interlocking soft drapes, which together achieve a complete radiation barrier (Figure 1). We recorded scatter radiation doses to the primary operator during consecutive clinical cases utilizing this lead shielding system.

Results
Pre-clinical laboratory testing by the State of Michigan certified the ProtegoTM shield provides protection sufficient to allow an Interventional Cardiologist to operate without personal lead aprons. Clinical data in 98 cases documents a mean radiation dose of 0.71 mrem per case. Extrapolating to annual exposure levels, based on these data an Interventional Cardiologist performing 400 cases per year would be exposed to only 5.7% of the maximum allowable annual radiation per the ALARA guideline (5000 mrem/annum). The umbrella of radiation shielding from this device also provides protection to ancillary staff (nurses and technicians).

Conclusions
Utilization of the ProtegoTM shield has potential to reduce direct and indirect Catheterization Laboratory occupational health hazards.

Keywords: Occupational Health and Safety, Radiation Safety

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SESSION 9:

OPTIMIZATION IN OCCUPATIONAL RADIATION PROTECTION

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Radiation Safety Management Regulation of Thai Research Reactor - 1/ Modification 1 for Reactor Health Physicist Implementation**

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Co-authors: Chotika Dararutana; Sittipong Polthum; Nopparit Changkit; Wasin Vechgama

Thailand Institute of Nuclear Technology (TINT)

Thailand Institute of Nuclear Technology (TINT) is the Thailand government organization that has been carrying out core missions about nuclear applications and radiation techniques. Thai Research Reactor-1/Modification 1 (TRR-1/M1) has been one of the main cores for the utilization of nuclear applications at TINT since 1962 in order to serve the radioisotope production, nuclear technology research and development, and nuclear reactor education and training. The TRR-1/M1 is the TRIGA- Mark III type having 8.5 wt.% and 20 wt.% uranium fuels and four neutron beamlines within an open reactor pool covered by high-density concrete shielding. Light water is used as the coolant, moderator, and reflector. The maximum operation power of TRR-1/M1 is 1.3 MW. Generally, during the TRR-1/M1 operation performed by the Reactor Center, health physicists from the Nuclear Safety Section have the responsibility to help regulate the nuclear safety management for TRR-1/M1 operators and others in the plant. The reactor safety management for the health physicist is constructed in the “Procedure of Radiation Safety Management of The Research Reactor” so-called PM-ST-01, which is contained as a control document in the ISO 9001 system of TINT. The main purpose of the PM- ST-01 is to implement the nuclear and radiation safety evaluations for workers and visitors in the TRR-1/M1 performed by the health physicists. This procedure is also consistent with the regulations such as the “Ministerial Regulations Prescribing Conditions How to Get a License and Operations on Special Nuclear Materials, Source Material, By-Product Material, Atomic Energy B.E. 2550 (A.D. 2007)”, “Ministerial Regulations on Radiation Safety, B.E. 2561 (A.D. 2018)”, and “Announcement of the Nuclear Energy for Peace Committee on Safety Criteria B.E. 2562 (A.D.2019)”. The main responsibilities of the health physicists in the PM-ST-01 include (1) the preparation of nuclear-measuring instruments for ready to use, (2) the safety control for radiation workers and visitors, (3) the inspection of radiation exposure from I-131 radionuclide and others, (4) the investigation of contamination from fission product in reactor coolant during operation, and (5) the safety mechanism service of irradiated sample transfer. All tasks in the PM-ST-01 are explained in the flow-chart working in all operation time. The safety procedures of PM-ST-01 for the health physicists have been used to serve the safety management regulation of the reactor and to-create the safety mechanisms for radiation workers and visitors of TRR-1/M1 effectively.

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Communication Strategy for Supporting Occupational Health and Safety Management Systems of Thailand Institute of Nuclear Technology**

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Thailand Institute of Nuclear Technology (TINT)

Thailand Institute of Nuclear Technology (TINT) is an organization that provides nuclear and radiation technologies through research and development and industrial services of Thailand. TINT focuses on the safety and welfare of nuclear workers and the other people who use its nuclear technologies and services as the first priority. Since 2019, the Safety subcommittees of TINT has purposed policy for the certification of ISO 45001:2018 Occupational Health and Safety Management Systems as the primary objective for demonstrating its commitment to conduct any nuclear activities safely in order to build public confidence. To obtain certification, TINT must comply with the requirements of the standard system. One of the key requirements is the effective communication issue. TINT has announced the occupational health and safety policy and to ensure the most efficient communication of the important information. The Nuclear Safety Section on behalf of the Occupation Health and Safety Management Representative (OHSMR) had created the procedure on communications and employee engagement of TINT. This procedure has been prepared to ensure that stakeholders who participate in the occupational health and safety management system will receive the correct/needed information for the communication including occupational health and safety policies, objectives, key performance indicators, occupational health and safety action plans, incident investigation results, organization chart, announcement of appointment in the occupational health and safety management system, occupational health, safety surveillance, measurement plan, laws and commitments, etc. The above information has been communicating through appropriate channels such as clarifications and announcements, circulars, meetings, e-mails, and the institution's website, etc. Once safety information is communicated to personnel effectively, the personnel will perform missions with the primary concern for the safety of themselves and the public. The results of the first internal audit in 2021 showed that the auditees were able to answer questions about critical occupational health and safety information. This demonstrates that the communication process was effective and appropriate to the context of TINT well.

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Consideration on Reflected Dose Component (Medical Perspective)*

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Photon dosimetry is indispensable in designing an irradiation medical facility shielding. The purposes of radiation shielding are to protect the patients, the department staff, visitors and the public. As an example, for controlled and public areas, the radiation dose level should be in a reference value range of 0.75 μSv/h and 0.5 μSv/h [1]. While doing the calculations for the required wall thicknesses to protect people outside of the treatment area, it might be necessary to evaluate for the contribution of reflected photons energy fluence and its contribution to the dose. It is important to evaluate the particles that might be reflected by a certain region in designing an irradiation facility shielding, particularly in the medical application where the patient or personnel are within the room during the procedure.

From a dose standpoint, there is a need to optimize radiation protection of patients (clinical dosimetry) and medical personnel (occupational dosimetry). Clinical dosimetry is the cornerstone of any dose optimization attempt. Radiation delivery to cancer patients for radiotherapy could be including leakage and scatter radiation which provides unnecessary additional radiations or dose to other parts of the patient's body [2]. However, it is generally difficult to predict accurately. The difficulty of implementing to take measures to reduce reflection could be reduced with the aid of the Monte Carlo method. It is known that the calculation of incident radiation toward a surface and reemitted toward a certain point of interest is commonly encountered a problem in radiation shielding. Tajudin et al. [3] had calculated backscattered photon spectra from different radioactive sources with concrete material as a scatterer to have reflected photon energy up to ~200 keV photons.

As in the figure, the photons that enter the shielding material and go out from the region, either backscattered (denoted as reflected) or passed through the concrete region (denoted as transmitted), had been followed in the code. The backscattered photons information such as its photon spectrum and dose that contributed to the tally in the receptor volume or area were scored. As an example, a simple approach is to add some lead to the inner walls to reduce the reflection dose component.

In another example, Tajudin et al. had demonstrated how to reduce reflected photon spectra from the clay material for Am-241 gamma source by using an iron (Fe-26) element.

Whenever necessary, if the added reflected dose is high enough to justify trying to reduce it, then it becomes a matter of cost and convenience in deciding what approach might be best to reduce reflection.

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The Development of a Mobile Application to enhance Fetal Dose Monitoring among Pregnant Radiographers*

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University of Pretoria

Ionizing radiation has the potential to cause harmful effects to cells. The risk of these effects increases in a fetus, whose tissues are still developing. The effects of radiation, which is dependant on the amount of exposure received, can present as deterministic effects, which can be immediately seen or stochastic effects which present later in life or in the offspring of the fetus exposed. Based on this theory, occupational health and safety is heighted for the pregnant radiographer who is required to wear a special dosimeter to record and monitor the fetal dose exposure. This process is self-regulated and done by the pregnant radiographer herself. In the clinical department it was observed that pregnant radiographers don't use their dosimeters correctly and do not have a consistent method of recording and monitoring their fetuses doses. The aim of the study is to develop a fetal dose monitoring mobile application to enhance the manner in which pregnant radiographers record and monitor fetal doses. The research will follow a Design Science Research (DSR) paradigm and Behaviour change, User-centered and Social marketing (BUS) framework, which will guide the objectives The study will follow a mixed methods research design, incorporating four major phases, each aligned with the DSR paradigm, namely 1) Problem awareness, 2) Suggestion, 3) Development, 4) Evaluation and 5) conclusion. In problem awareness, literature and the proposal will serve as a strategy to highlight the problem as it exists. In the suggestion phase, a quantitative approach will be followed with the use of a national survey which will inform the features that need to be included in the mobile application. In the development phase of the mobile application, two cycles of development will take place following the BUS framework. In the evaluation phase, the usability of the developed prototype will be evaluated through eye tracking in a laboratory setting. The usefulness of the mobile application will be evaluated qualitatively through telephonic in-depth interviews with participants who used the mobile application in their natural setting. The study envisions to contribute to the body of literature by describing the rigorous process of development and evaluation. In addition to this, it aims to provide a solution to the challenge identified, and thus is inline with the pragmatic nature of DSR.

The development of the mobile application envisions to use technology innovatively to provide a solution to inconsistent fetal dose monitoring among pregnant radiographers in South Africa. This will therefore contribute towards enhancing radiation protection methods for the pregnant radiographer and thus improve occupational health and safety for both mother and the unborn child, which aligns to the World Health Organisation (WHO) Sustainable Development Goals (SDG) three; good health and wellbeing. The study also aligns with the 17th SDG, namely industry partnership, whereby it will foster a collaboration with the Faculty of Engineering, Business and information technology (EBIT) and the faculty of Health Sciences

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Multi-Objective Optimization Model for Occupational Radiation Exposure

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Introduction

Continuous supervision of employee radiation dosage is crucial to sustain dosimeter standards in workplaces. In a variety of work places, radiation accidents continue to occur and eliminating them totally is still a great challenge. Employers strive to ensure compliance with radiation protection standards; where emergency plans are taken in the event of a radiation accident. However, historical review of the radiation exposure among workers indicate that dozes have decreased with time due to radiation protection practices since the discovery of x-rays. Despite the positive trend realized towards minimum radiation exposure, continual evaluation of occupational doze records is recommended due to the increasing number of medical imaging procedures that are currently being performed.

Methods

In this study, a multi-objective goal programming model is proposed and initially, the objective function is defined. The model seeks to minimize the positive deviations of the objective function; subject to the goal values of doze limits for employees at a radiation facility. The study examines four categories of exposure: whole body, lens of eye, skin and pregnant mothers. The sum of weighted deviations is minimized so that actual doses of radiation exposure do not surpass the recommended dose limits. The solution is determined using the simplex method for linear programming; whose solution is obtained by solving the standard minimization problem. A numerical example is presented for illustration; indicating the optimal dose limits for radiation exposure considering the four categories of exposure at the radiation facility.

Results

Results from the numerical example presented indicate a satisficing solution for radiation exposure among workers. However, overachievement or underachievement of the targeted radiation doses depends upon the priority levels and targets set in line with the categories of body exposure to radiation at the facility considered in this study.

Conclusion

The multi-objective goal programming model for regulating occupational radiation doses can be effective; where relevant categories of exposure can be prioritized if desired. Efficient regulation of radiation doses among workers creates a positive path towards sustainable occupational radiation protection for workplace management and dose monitoring.

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An Exposure Dose Evaluation System based on Virtual Reality Technology

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China Institute for Radiation Protection

The radiological protection of the workers in the nuclear industry is an important part of the safety culture. Optimizing the radiation exposure through the "As Low As Reasonably Achievable (ALARA)" principle is a very important procedure for assessing workers' safety and health.

A 3D ALARA planning tool is developed by China Institute for Radiation Protection (CIRP) to provide advanced, radiation exposure analysis technology to different users, who can benefit from an interactive 3D visual representation of radiation risks to support ALARA optimization.

By integrating radiological information with 3D models of radiological environments, this tool provides the possibility to plan the work in a 3D environment by taking into account the geometric shielding, material, and radioactive source specifications. This tool is supposed to facilitate risk- informed planning and work execution and to support the optimization of radiological protection for activities in nuclear environments and enhance safety in the nuclear industry.

The geometrical information, the material information, and the radiological information are imported from files or entered interactively through direct manipulation of 3D UI components. This information is integrated to define the radiological layouts and job scenarios.

This system supplies three simulators. The first simulator introduces the Point-Kernel technique with the infinite media buildup method to estimate the dose, isotopic contribution to dose, and shielding effects. The second is a simulator that contains several interpolation algorithms including Inverse Distance Weighted (IDW) algorithm and Kriging interpolation techniques. Hence the second simulator does not compute dose maps itself but uses data from imported dose maps to estimate the dose at any location within the dose mapped space. The third simulator provides a source inference technique to estimate the source strengths based on a dose mapping and the knowledge of the source positions and the isotopic composition of the sources.

The radiation visualization technique is also developed in this system. Given a set of sources and a shielding configuration, or a set of pre-calculated dose maps, the system enables the user to toggle a 3D visualization of the radiological conditions to support decision-making. The visualizations are color-coded by mapping radiation levels to colors and it provides user-configurable setting functions for changing the properties of visualization.

Based on the visualized 3D radiation field, it allows assessing the individual and collective dose uptake for a defined work scenario and enables the comparison of multiple scenarios for the optimization of efficient ALARA planning. Multiple data formats such as 2D charts, graphs, and plots of radiological conditions are provided to support the decision-making and evaluation of alternative scenarios.

This system also provides several digital management functions for assisting the person responsible for radiation protection on a nuclear facility. Users can add, access, and manipulate data in the database, and produce reports. These data include the geometrical information, measured radiological information, equipment information, radiation work permit (RWP) information, work scenarios, et al. This system is currently being used at the commercial nuclear reactor. It will contribute to improving safety in nuclear facilities by increasing stakeholders' comprehension of radiation risks.

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Optimisation of Radiation Protection in Practice: An ANSTO Perspective**

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Australian Nuclear Science and Technology Organisation (ANSTO)

ANSTO has three campuses across two states of Australia and is the centre of Australia's capabilities and expertise in nuclear science and technology. The variety of radiation sources at ANSTO encompasses the breadth of the health physics field. Our sources of ionizing radiation include but are not limited to: the OPAL multi-purpose research reactor; the Australian Centre for Neutron Scattering; the Australian Synchrotron; Particle Accelerators; Unsealed radioisotopes used in medical radioisotope production settings; as well as biomedical and chemical research applications; and naturally occurring radioactive materials.

There is a potential for the principle of optimisation to be misunderstood, and taken as implying a need to minimise exposures regardless of cost. The level of protection should be the best under prevailing circumstances and should provide for adequate margin of benefit over harm. Think optimisation not minimisation.

Optimisation of protection is a process that is at the heart of a successful radiological protection program and is a frame of mind. Effective Implementation of Optimisation measures occurs when all stakeholders are involved, who know and agree with the principles of radiological protection, and adhere to an active safety culture.

The responsibility of implementing optimisation lies with all parties involved including management, workers and radiation protection. It should be a collective effort to strive for doses that are ALARA.

This paper discusses optimisation of radiation protection in practice, and gives a couple of real world examples at ANSTO from the last few years.

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Dominican Republic's Experience about Occupational Radiation Protection Appraisal Service (ORPAS)

Author: Jorge Gomez

Ministry of Energy and Mines

In the Dominican Republic, the activity related to the use of Nuclear Technology basically begins with medical applications, particularly with cancer treatment and radiodiagnosis. In this way, the first steps are begun in search of regulating all practices which will need regulations, such as production, acquisition, importation, use and possession, for industrial, medical, veterinary, agricultural, research, teaching, transparency, etc. transportation, storage of sources and management of radioactive waste, as well as any other practice that could involve ionizing radiation.

Our development in the country's nuclear activities over time will be presented, as well as the country's experience in the Occupational Radiation Protection Appraisals (ORPAS) mission, which served to independently evaluate the implementation of occupational radiological protection requirements. in the most relevant facilities in the country.

ORPAS focused on all types of facilities and activities, as well as for technical and scientific support services or entities dedicated to protection and safety in relation to the evaluation of occupational exposure due to external sources of radiation and the incorporation of radionuclides.

The main objectives of the mission were to provide the country with the possibility of an objective evaluation of its provisions for occupational radiological protection, as well as to identify the country's own strengths, worthy of being considered by others. To promote the use of self-assessment as well, identify areas with possibilities for improvement in order to comply with international safety recommendations.

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EURADOS WG2: 25 Years of Networking to foster Harmonisation in Individual Monitoring for External Radiations**

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The European Radiation Dosimetry Group (EURADOS) is an association of about 80 European institutions collaborating for scientific understanding of the dosimetry of ionising radiation. Created 25 years ago, the specific working group, WG2, has been dedicated to fostering harmonization in individual monitoring. This network is composed of about 40 members from 18 countries that participate actively to the WG2 actions, with about 180 observers.

Over the years, WG2 has set activities to improve quality and reliability in individual monitoring, including the organization of inter-comparison exercises of personal dosemeters, ensuring continuing and future personnel skills through training, sharing best practice through publishing recommendations through developing research actions, networking, and through dissemination.

One WG2 action consists in organizing regularly self-sustained inter-comparison exercises of personal dosemeters [1] [2]. Started in 2008, this action has become essential for many Individual Monitoring Services (IMSs) as being an integral part of their accreditation process, stimulating IMSs to improve the quality of their results and assisting them with harmonisation of their quality control standards.

WG2 regularly organizes a training course, intended for all stakeholders in individual monitoring, to implement the European Commission Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation [3].

The WG2 network is also an opportunity to have open discussions within the community with intention of some common problematic could be shared and raised. Many work actions are derived, for example:

- Some broad recommendations were/are being elaborated: to assist and encourage IMSs to apply for accreditation according to the ISO/IEC 17025 standard [4], to solve data and IT problems that IMSs may face or to help defining what training IMS staff should have.
- A specific research action is addressing the issue of the variable quality of the CR-39 material to improve and harmonize neutron dosimetry performed with solid-state nuclear track detectors.

WG2 also benefits from collaboration between EURADOS and the International Organization of Standardisation (ISO). A practical example of a common action between these two networks is illustrated by a survey, currently in progress, aiming at giving an up-to-date overview of routine practices of IMSs.

Finally, a significant part of the WG2 actions is dedicated to dissemination through webinars, presentations at various scientific meetings or conferences, or via the publication of its activity in the open literature or through EURADOS Reports.

As a conclusion, the work of WG2 continues to make a significant contribution to improving quality and harmonisation in individual monitoring for external radiations in Europe and beyond.

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Optimization of Radiation Protection for the Control of Occpational Exposures**

Author: Simeon Esseyin

The main emphasis in radiation protection is the "optimization of protection".

The methods for reducing doses covered a broad spectrum, which ranges from simple organizational adjustments to a modification of the design of the facility concerned. This presentation adopts the ALARA techniques means of avoiding exposure to radiation using the three basic protective measures in radiation safety as; time, distance and shielding. Effective work management is necessary for the optimization and reduction of exposures; such as work planning and scheduling; general workers education; awareness; involvement of workers; communication; facility and equipment design; reducing the number of works necessary; reducing dose rates and specialized training.

Other component of the presentation is a general review of the means that are available in most workplaces to reduce exposure. These global means is the application of effective and efficient procedures for the management of work and provision for the education and training of workers.

SESSION 10:

TECHNICAL SERVICE PROVIDERS IN OCCUPATIONAL RADIATION PROTECTION

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Calibration of Occupational Industrial Radiation Protection Equipments

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The need for specification of X-ray beam quality arises from the fact that several parameters are required to realize and measure operational quantities accurately. X-ray measurements are affected by target material, tube potential, monitor chamber, absorber material and thickness, collimation shape, calibration factors and the source-chamber distance. The aim of this research is to analyze the performance of X-ray source (dosimetry) by indirectly specifying the radiation beam quality and quantity through measurements of half value layer (HVL), homogeneity coefficient and air-kerma. The work involve determination of quality of X-ray of photon field, physical characteristic and calibration radiation protection equipment. The air kerma quantity is useful for calibration of reference photon radiation fields and calibration of radiation protection instruments. Ionization chamber is used as primary reference instrument for ionizing radiation measurement. The reference ionization chamber is connected to an electrical electrometer and is capable of accurately measuring charge. The corrections are applied to account for the effects of air pressure, air temperature, ionic recombination and other influence parameters. The measurements were carried out at the Secondary Standard Dosimetry Laboratory (SSDL) at Kenya Bureau of Standards (KEBS). The X-ray beam were generated from bombardment of tungsten anode, at tube voltages between 40-200 kV, for radiation protection level. The investigation were done following inter-comparison measurements that showed variation of results in operational quantities at KEBS facility. Different HVL X-ray beams measurements results were obtained by introducing various filters across the beam and compared to international standard, ISO 4037-1,1996. The operational quantities and physical properties were then established and used to calibrate survey meter. Uncertainty of measurement was then tabulated after identification of several parameters that contribute to measurement errors. The homogeneity coefficient results were found to be consistent with ISO 4037-1 recommendations. However errors and inconsistencies were found in beam qualities, operational quantities and physical characteristics. The calibrated survey meter had a relative error of 10%, and therefore calibration factor was derived for error correction.

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Internal Exposure Monitoring for Polish Nuclear Facility Personnel – Current and Future Status

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Co-authors: Małgorzata Dymecka; Katarzyna Rzemek; Grzegorz Szaciłowski

National Centre for Nuclear Research

The National Centre for Nuclear Research (NCBJ) is one of the largest science institutes in Poland and the operator of MARIA nuclear reactor. The NCBJ encompasses: 17 divisions (11 research and 6 development), which include among others the MARIA reactor and supporting facilities. At NCBJ research in various fields of nuclear chemistry (nuclear medicine, dosimetry in radiation protection), physics (accelerator physics, nuclear physics, radiation medical physics), cosmology, advanced materials and technologies (material science, electronics and detectors for nuclear industry) are conducted. Major part of personnel employed at NCBJ is classified as workers occupationally exposed to ionizing radiation thus have to be properly monitored and covered by the radiation dose estimation procedure.

Radiation Protection Measurements Laboratory (RPML) is a science division created in order to provide constant radiation monitoring of Świerk nuclear facility along with exposure monitoring and dose assessment for NCBJ personnel. Within the structure of RPML operates a research laboratory accredited in the field of internal dosimetry and environmental radiation monitoring by Polish Centre for Accreditation (certificate No. AB 567). The laboratory offers internal exposure monitoring for NCBJ personnel and external customers, using both in vitro and in vivo methods, and also coordinates the external exposure monitoring outsourced to other laboratory. RPLM offers the wide range of internal dosimetry measurement techniques including whole body measurements, thyroid measurements and radiochemical analyses of urine samples.

The whole body counter used by RPLM allows to assess internal contamination with gamma radioisotopes at energy range between 60 and 2 100 keV and activity from 0,5 to 10 000 Bq/kg. The thyroid counter allows to measure iodine radioisotopes activity gathered in thyroid at energy range from 20 to 500 keV and activity between 200 and 100 000 Bq for 131I and from 100 to 100 000 Bq for 125I. The radiochemical laboratory is capable of analyzing urine samples for determination of HTO, 14C, 32P, 35S, 90Sr, 90Y, 210Po, 238Pu, 239+240Pu, 241Am, 244Cm, gross alpha and gross beta activity concentrations.

All mentioned techniques are covered by the quality management system compliant with the national standard ISO/IEC 17025:2018. RPLM regularly participates in international laboratory comparisons. The results of comparison are used as a quality management system development tool.

Within this study the internal exposure monitoring rules for Polish nuclear facility personnel and registered radiation dose levels will be presented.

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Implementing Hp(3) in Uruguay: DXT-100 Compliance for IEC 62387 Coefficient of Variation and Non Linearity*

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Introduction
Almost 20% of the occupationally exposed workers assessed are interventional radiology professionals. Although lens of the eye radiological surveillance is not mandatory, implementing this type of dosimetry in the country is an important asset in prevention of lens of the eye injuries due to radiation. The aim of this study was to evaluate DXT-100 extremity dosemeters suitability for lens of the eye dosimetry by compliance of IEC 62387 for photon radiation requirements of Coefficent of variation (CV) and Non linearity.

Materials and Methods
Element correction coefficients were determined previously at the laboratory using a 0.5 mCi Sr-90 source incorporated in TLD Reader according to user´s manual.
68 DXT-100 Thermo Fisher ® dosemeters where assembled on a 42mg/cm2 cap with an orange holder attached to a band and delivered to the national SSDL to be irradiated with a Cs-137 source at reference conditions for measuring Hp(3). (Fig 1)

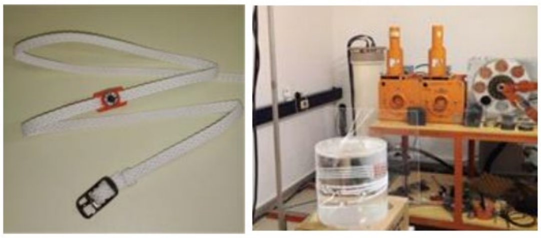

Figure 1. Left: Hp(3) dosemeter assambled Right: dosemeters allocated in water phantom for irradiation

Order of magnitude (mSv)	Dose delivered (mSv)			
	20%	40%	80%	Others
0-0.1	0.02	0.04	0.08	0.1
0.1-1.00	0.2	0.4	0.8	1.00
1.00-10	2	4	8	10
10-100	20	40	80	100

Table 1. Evaluated dose values

Dose values (w=16) were selected considering IEC 62387 section 11.3.2 (Table 1). For each dose value, 4 DXT-100 dosemeters were irradiated. 4 DXT-100 were assigned to background measurement. All readings were performed in a Harshaw 6600 plus model with acquisition set up and Time Temperature Profile as suggested in user´s manual.
Coefficient of variation was calculated as follow (eq 3.3 IEC 62387):

$$v = \frac{s}{\overline{G}} = \frac{1}{\overline{G}}\sqrt{\frac{1}{n-1}\sum_{j=1}^{n}\left(G_j - \overline{G}\right)^2}$$

s= standard deviation, G = average dose for each dose value n. For Non Linearity doses from 0.1 to 100 mSv where evaluated. Percentage of relative response was calculated (eq. 3.35, IEC 62387): where R = reader value, R0= dose delivered

Results and Discussion
Coefficient of Variation
Results are shown in Table 2. Requirements are met when CV is equal or below c1 column for w-2 evaluated doses and the last 2 (no adjacent doses) equal or below c2 column.

Evaluated dose$_i$ (mSv)	Coefficient of variation ecc applied (%)	Coefficient of variation no ecc (%)	IEC 62387 Requirement c1 (%)	IEC 62387 Requirement c2 (%)
0,02	5,84	4.19	20.00	28,77
0,04	4,1	9.18		
0,08	0,96	4.72		
0,1	11,4	8.03		
0,2	4,45	10.50	18,66	26,85
0,4	8,74	8.48	16.00	23,02
0,8	2,05	2.25	10,66	15.34
1	0,14	**3.79**	8.00	11,64
2	0,6	3.19	6,76	9,59
4	3,43	11.83	6,67	
8	0,84	**5.18**		
10	2,71	4.36		
20	4,5	1.34		
40	4,44	2.00		
80	11,59	3.36		
100	10.47	2.24		

(*)not met

Table 2. Calculated Coefficient of Variation for Hp(3)

In general, requirements were met with or without ecc correction. When ecc where applied better CV values where obtained. Three evaluated doses (shown in red) didn´t met the requirements. In these cases, further analysis with a greater number of dosemeters tested would be needed.

Non Linearity
Non linearity shall be between -9% and +11%. Results are shown in table 3.

Evaluated $dose_i$ (mSv)	Coefficient of variation ecc applied (%)	Coefficient of variation no ecc (%)	IEC 62387 Requirement c1 (%)	IEC 62387 Requirement c2 (%)
0,02	5,84	4.19	20.00	28,77
0,04	4,1	9.18		
0,08	0,96	4.72		
0,1	11,4	8.03		
0,2	4,45	10.50	18,66	26,85
0,4	8,74	8.48	16.00	23,02
0,8	2,05	2.25	10,66	15.34
1	0,14	**3.79**	8.00	11,64
2	0,6	3.19	6,76	9,59
4	3,43	11.83	6,67	
8	0,84	**5.18**		
10	2,71	4.36		
20	4,5	1.34		
40	4,44	2.00		
80	11,59	3.36		
100	10.47	2.24		

(*)not met

Table 3. Relative response -non linearity (difference in %)

Better linearity was achieved when ecc´s where applied.

Conclusion

DXT-100 extremity dosemeters are suitable for Hp(3) determination in terms of coefficient of variation and Non linearity requirements of IEC 62387. Best results were obtained when no ecc´s were applied. Further type test- angle of incidence,energy dependence - must be perform. The use of DXT-100 for evaluate Hp(3) will allow to set national reference levels for lens of the eye.

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The Use of Conversion Coefficients (CC) in the Calibration of Radiation Monitoring Instruments

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In the Philippines, radiation monitoring instruments (RMI) used in measuring ambient dose equivalent H(10) and personal dose equivalent Hp(10) are expressed in various units, namely Sievert (Sv)and Roentgen (R). The Philippine Nuclear Research Institute – Radiation Protection Services Section (PNRI- RPSS) adopted conversion coefficients (CC) in the calibration of RMI by converting units from mR to µSv through improved calculations from the reference exposure rates in the PNRI-Secondary Standards Dosimetry Laboratory (PNRI –SSDL). From measurements in PNRI-SSDL, reference exposure rates were derived from converting measured air kerma in Gray (Gy) to R instead of estimating from calculated H (10) in Sv. Improved calculations for reference exposure rates paved to more accurate RMI response since values are not overestimate/underestimate. PNRI-RPSS now includes CC in reporting RMI calibration results to help customers relate measurements to levels of radiation hazards in their facility by comparing measured levels to regulatory limits and ensure occupational exposures are within safety limits.

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Assessment of the Current Neutron Occupational Exposure Monitoring in the Philippines

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With increasing number of facilities utilizing neutron radioisotopes and high-energy radiation fields in the Philippines, there is a growing need to ensure the safety of radiation workers from neutron exposures. Philippine Nuclear Research Institute -Secondary Standard Dosimetry Laboratory (PNRI-SSDL) established a neutron dosimetry facility to develop capabilities in occupational exposure monitoring following national and international standards. Through PNRI –Radiation Protection Services Section (PNRI –RPSS), occupational exposure of radiation workers is being monitored through their Individual Monitoring Service. However, only few facilities are being monitored for neutron exposure due to various limitations. This may lead to under-assessment of radiation workers' exposures and facilities' radiation protection measures involved in neutron sources. Doses of workers monitored by photon and neutron IMS were compared with workers only monitored for photon occupational exposure. The results may help in showing associated risks of neutron exposure and address gaps in ensuring effective RP programs for neutron exposures.

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Developing National Standards for Occupational Radiation Protection in the Philippines - New Capabilities & Challenges Ahead

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Better accuracy and consistency in dosimetric measurements is an important aspect in the quality assurance and safety of nuclear technology applications growing in trend and complexity over the years. While there is an existing local capacity for calibrations in the Philippines, there are still a several gaps need to be addressed. The Philippine Nuclear Research Institute's Secondary Standards of Dosimetry Laboratory (PNRI -SSDL) is tasked to establish and maintain national standards for ionizing radiation measurement. Through a combination of IAEA Technical Cooperation Project, Grants-in-Aid Projects and national funding which started in 2017, the PNRI-SSDL was upgraded to establish national standards for neutron, beta and narrow spectrum series radiation qualities, including procurement of associated secondary standard reference instruments. Standardization measurement results from new facilities and their impact on additional capabilities particularly for protection level calibrations could serve as a cornerstone to allow diagnostic level calibrations and other services in the future.

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The Effects of the Covid-19 Pandemic in Occupational Radiation Protection - A Technical Service Provider's Perspective

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SARS-CoV-19's (COVID-19) had impacted significantly medical radiologic examinations for the diagnosis of the COVID-19 virus in the patient. This has resulted in the increased number of examinations in hospitals that thus potentially increasing the risk of workers receiving radiation doses. The pandemic also led to various nationwide restrictions that greatly affected the operations of many sectors, technical service providers included.
Philippine Nuclear Research Institute through the Radiation Protection Services Section (PNRI-RPSS), as a technical service provider, experienced various challenges in ensuring the continuous provision of radiation protection services for the safety of the workers while operating in accordance with the national restrictions such as limited workforce mobility, supplies, and transportation.
This paper presents how the PNRI-RPSS adopted with the new normal brought about by the pandemic. The lessons learned, different measures and new systems developed will be presented such as the following:

1) Additional laboratory protocols in the receiving and releasing of samples, dosimeters and instruments:
2) Online booking and appointment-based One Stop Shop established to limit number of customers
3) Customer communications
   3.a. Web-based information systems
   3.b. Information dissemination and response to customer inquiries by adding more communication channels (added Facebook page for announcements and Messenger)
   3.c. Customer advisories on use of dosimeters and instrument calibrations
4) Guidelines on the conduct of field works for Radiation Monitoring/Hazards Evaluation, Leak Testing of Sealed Sources, and Calibration of Activity Meter were coordinated with the regulatory body All service provisions were ensured to comply with national regulations and international recommendations to ensure safety of nuclear facilities and protection of radiation workers.

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Current Status of Individual Monitoring Service in Sudan

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Radiation and Nuclear Safety Institute (RNSI) of Sudan Atomic Energy Commission (SAEC) is the only body approved by the national regulatory authority to provide individual monitoring service for occupationally exposed workers (OEWs) allover Sudan.

This Institute has been offering this service since seventies using film badges at the beginning and then switched to thermoluminescence dosimeters (TLDs).

In the year 1996, Harshaw model 6600 TLD reader was installed and used to provide monitoring service to OEWs in medical, industrial and research applications utilizing ionizing radiation.

In 2005, RNSI experienced technical problems with the Harshaw TLD reader which led to complete suspension of the service in 2008.

In 2016, a new TLD systems (RA'04 TLD Analyzer and TLD-Cube) were installed, tested and calibrated in the secondary standard dosimetry laboratory (SSDL) of SAEC.

Since 2017, RNSI started to provide monitoring service to OEWs in radiotherapy and nuclear medicine departments and then after to all OEWs in other medical and industrial applications.

In the present work, the current status of individual monitoring service in Sudan was described in terms of coverage, types of dosimetry provided, instrumentation, operational aspects and dose record system.

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Procedures for the Ensuring the Validity of Results in the External Dosimetry Laboratory of Nicaragua

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In Nicaragua, the External Dosimetry Laboratory (LDE) provides individual monitoring services and is located at the Radiation Physics and Metrology Laboratory (LAF-RAM). Between the end of 2017 and 2018, the quality management system based on the reference standard NTN-ISO/IEC17025:2017 was implemented at LAF-RAM where a procedure was developed for compliance with the technical requirements for ensuring the validity of the results [1]. The purpose of this work is to describe the procedure and the results of the activities intended for this process at LDE. The procedure LDE- PT-04 Procedure Ensuring the Validity of Results was elaborated which includes mechanisms for the review of reading parameters of the dosimetric system such as daily controls and trend analysis of reader sensitivity, reference light counts, dark counts, background and linearity verification. The data are plotted over time since 2017 and 2018 through control charts where the trend of fluctuations of the average values of the measurements between ±2 and ±3 standard deviations (σ) has been observed and checked for quarterly periods. Nevertheless, we have observed data considered as outliers caused by corrective and preventive maintenance of the equipment. The dosimetry system has been calibrated twice in the magnitude Hp(10) and H*(10) with traceability to IAEA Dosimetry Laboratory, Seibersdorf in May 2019 and in the magnitude Hp(10) and Hp(0.07) with the Laboratory of Metrology of Ionizing Radiations of the University of Pernambuco of Brazil in June 2021. The calibration of the system was verified by performing dose linearity of the dosimeters exposed as a function of a number of turns in a 90Y/90Sr tabletop irradiator. In all cases a linear proportionality was found with coefficients of determination R2 above of 0,95. The LDE has also participated in other processes such as Interlaboratories, and intercomparisons including EURADOS 2020 for photons and with the LAF-RAM Dosimetry Calibration Laboratory whose results according to the trumpet curve analysis described in ISO 14146: 2018 meet the requirements [2]. Regarding the final report of the test method, it was observed that the dosimetric information is maintained independently from the technical personnel involved, so it is considered that the reporting process and route is robust and independent. It is therefore concluded that this methodology for detecting deviations allows the continuous improvement of the service, the confidence of the clients and the competitiveness of the laboratory.

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The Moroccan Experience in the Implementation of Approval of Technical Service Providers in Occupational Radiation Protection

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Since the promulgation of the law 142-12 related to nuclear and radiological safety and security and the creation of the Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR) in 2016, the Kingdom of Morocco through AMSSNuR, has been upgrading its regulatory framework to ensure compliance with Law No.142-12 and consistency with the international safety standards, in particular the IAEA General Safety Requirements (GSR part 3).
In this regard, AMSSNuR has established the basic framework for occupational exposure to ionizing radiation in planned, existent and emergency exposure situations, which defines among others the requirements for dose limits (including lens equivalent dose limit reduction), monitoring and recording of occupational exposures, responsibilities of employers, registrants, and licensees, radiation protection program, assessment of occupational exposure and workers' health surveillance.
In order to reinforce the radiation protection system and provide technical support to the licensee especially in strengthening occupational radiation protection within his facility, Law No.142-12, assigned to AMSSNuR the responsibility of providing approval of the following technical services:

- Individual dosimetry monitoring.
- Calibration of instruments used for the detection of ionizing radiations.
- Training and evaluation of the radiation protection officer.
- Control of the efficiency of technical and organizational aspects related to safety and security.
- Technical control of the radiation protection of ionizing radiation sources, of the protection and alarm systems and of the measurements instruments.

In this framework, the regulatory text implementing the Law No.142-12 related to the approval of service providers fixes the conditions and modalities for the grant of approval for each technical service. In fact, one of the most important requirements for approval of calibration and dosimetry services is accreditation according to ISO 17025 and for approval of technical controls mentioned above, having a management system in compliance with ISO 17020.
The aim of this paper is to introduce AMSSNuR's approach for enhancing occupational radiation protection system at the national level, through the transposition of the GSR part 3 requirements related to technical service providers in the regulation pursuant to the Law No.142-12.

Keywords: Morocco, AMSSNuR, Radiation Protection, Regulatory Authority, Regulatory Control, Occupational Radiation protection, Technical Service Providers.

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Developing a Procedure on Performance Testing for Personnel Monitoring Services (PMS) in the Philippines*

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Introduction
Accreditation to ISO/IEC 17025 for personnel monitoring services (PMS) is recommended to meet the safety standards of the International Atomic Energy Agency (IAEA) [1]. Performance testing is one of the requirements of ISO/IEC 17025.
The Philippine Nuclear Research Institute-Radiation Protection Services Section (PNRI-RPSS) is one of the three (3) PMS providers in the Philippines. In 2020, two (2) dosimetry systems of PNRI-RPSS, the Optically Stimulated Luminescence Dosimeters (OSLD) and Thermoluminescence Dosimeter (TLD); was awarded ISO/IEC 17025:2017 accreditation. The PNRI-RPSS regularly participates in the intercomparison activities organized by the IAEA Network of Secondary Standard Dosimetry Laboratory (SSDL).
Performance testing for local PMS providers is challenging because: (1) most of the intercomparison activities cater OSLD and seldom for TLD, (2) sending dosimeters to laboratories abroad that provide testing is expensive, (3) there is no local service provider that offers performance testing for radiation dosimetry, and (4) PNRI manages both SSDL and PMS that is subject to impartiality.
In the absence of performance testing, the RPSS developed a procedure on blind testing of dosimeter for OSL Personnel Monitoring Service (OPMS) and TLD Personnel Monitoring Service (TPMS) method validation. The PNRI-SSDL performed a blind sampling of OSLD and TLD to validate the performance of both dosimetry systems.

Materials and Methods
The activity was performed as described in the diagram. The purpose of the test is to validate the method and accuracy of reported dose by the OSLD/TLD personnel monitoring services. The SSDL Team implements the procedure and analysis for blind testing of the dosimeter to address the impartiality.

Result and Discussion
In 2020 blind testing, results are within the acceptable limit of ±10% of unity and within the trumpet curve. The Hp (10) response +2% and -7% of OSLD are demonstrated in Figures 1 and 2. The Hp (10) response is nearly perfect and -7% of TLD illustrated in Figures 3 and 4.
For 2021 performance testing, the result of OSLD gave acceptable results. However, the irradiation of TLD needs repetition for verification. The results are outside the range.

Conclusion
The performance testing of Hp (10) is promising since the result of both dosimetry systems are within the acceptable limit of ±10% of unity. The method caters to both OSLD and TLD. The PNRI- SSDL demonstrated its capacity to organize intercomparison exercises and addressed impartiality. The RPSS could offer performance testing services for local PMS providers although there are still improvements like uncertainty calculation or other radiation quality.

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Occupational Radiation Protection in Public Health Institute of RS

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Public Health Institute of Republic of Srpska

Public Health Institute of Republic of (PHIRS) is specialized health institution with wide scope of activities in the public health area. Radiation Protection Center (RPC) as operational unit of PHIRS is one of three technical service providers for occupational radiation protection in Bosnia and Herzegovina. Founded in 2001, its first measurements related to occupational exposure were limited to workplace monitoring only. Ten years later, in 2011, Laboratory for Personal Dosimetry has been established and following the authorization of the State Regulatory Agency for Radiation and Nuclear Safety, in 2012 laboratory commenced its work with semiautomatic RADOS RE-2000 TLD reader. Since 2017, in accordance with Bosnian legislative, RPC is authorized to conduct education and training to workers occupationally exposed to ionizing radiation. Nowadays, qualified experts in RPC do not only perform measurements to ensure dose levels are kept below the limits but also are proactively involved in creating shielding facility calculations, radiation safety assessments, radiation protection programs and categorization of exposed workers to A and B category. To conclude, over the years, RPC has been increasing its capacities in personnel, educations, new equipment installations, networking, accreditation process etc and founded strong system for occupational radiation protection and radiation protection in general in Bosnia and Herzegovina.

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Occupational Radiation Protection in Zimbabwe: Challenges and Opportunities

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Radiation Protection Authority of Zimbabwe

Zimbabwe has considerable use of radiation technologies across the medical, research, manufacturing, mining and security areas with a potential exposure to over 5000 workers. The use of these technologies is anticipated to increase in line with the projected economic growth in the quest for the national vision: Vision 2030 of “An empowered Upper Middle-Income Society”.

Regulation for radiation safety and security of sources commenced in 2010 although the enabling legislation, Radiation Protection Act [Chapter 15:15] was enacted in 2004. The law established Radiation Protection Authority of Zimbabwe as the regulatory body. Regulations have been passed which provide for among others, demarcation of areas, employee training and awareness, as well as workplace and personal monitoring. Regulatory body Inspectors conduct regular scheduled inspections to check on compliance with regulatory requirements and licensing conditions.

Since commencement of regulation, only the technical services department of the regulatory body has been able to establish dosimetry capabilities monitoring around 2500 radiation workers. Meanwhile, a small number of companies are providing the much-needed technical services for licensees in order to meet regulatory requirements. As such, a gap exists for the entry of TSOs. The main limitations include:
- limited awareness on the prevailing opportunities, lack of technical capacity (personnel and training), lack of capital to invest in the required equipment and software that meet regulatory requirements.

SESSION 11:

EDUCATION AND TRAINING IN OCCUPATIONAL RADIATION PROTECTION

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Strengthen National Capacity to Minimize Ionizing Radiation Exposure in the Catheterization Laboratories in Iraq

Author: Salwa Al-Salhy

Operators are routinely exposed to high doses during catheterization procedure, this increased exposure to ionizing radiation is partially due to a lack of awareness to the effects of it In 2020 the total number of workers in the field of radiation in Iraq was 6200 for all sectors, including 4493 in the health sector and the percentage of health workers amounted to 73% in relation to the total number. All statistics available indicate the categories of exposed workers who are working in catheterization, represented by the catheter doctor and staff working with him during the past five years (2015-2020), 300 cases of health workers were monitored (60 cases per year) also the nature of work based on interventional radiology and catheterization, the training center at (regulatory body) indicated the causes of exposure of workers in the catheters are due to (the momentum of work and non-rotation among the workers, especially the staff working in the catheterization room, where doctors participate in all catheter operations , Lack of attention to the factor of time as a factor in reducing the dose of exposure , lack of interest in determining the number of radiographs and the radiation filters, protective barriers and protective means (such as bra, collar, gloves and glasses) are not used continuously in some operations) . The recommendations to the workers in the catheter section are: the operation time of the Fluoroscopy device should be reduced during operation as much as possible to reduce the exposure time to ensure the safety of the workers. It was suggested that a field should be added to the recorded data for each operation that includes recording the operating time of the Fluoroscopy device installed in the control panel so that we can estimate the cumulative doses received by the staff in the catheterization division, also increase the number of workers in the catheters to distribute the dose and thus reduce the dose received. The awareness and safety culture programs include advance planning and good management in dealing with radiation sources and to learn about and how to lower it.

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Occupational Radiation Protection Awareness among the Lebanese Health Professionals**

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This study aims to investigate the occupational radiation protection (ORP) awareness among occupationally exposed health professionals (OEHP) in Lebanon.

A cross-sectional study has been conducted in December 2020 by the Department of Authorization, Inspection and Regulation - Lebanese Atomic Energy Commission (DAIR-LAEC) in 55 (out of 170) Lebanese health facilities, by filling out an anonymous questionnaire. The survey was prepared following the requirements of IAEA Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, No. GSR Part 3, and IAEA Occupational Radiation Protection, No. GSG-7. The survey consisted of four parts and a total of 40 questions including demographics of OEHP participating in the study, requirement of ORP training, level of knowledge about ORP and OEHP contribution to protection and safety for themselves and for others at work.

232 OEHP participated in the survey with 9 doctors, 32 nurses, 179 radiographers/technologists, 7 medical physicists and 24 radiation protection officers. 49% were female and the majority (34%) had ≤ 30 years old. The majority of the respondents are postgraduate (72%), working in private hospitals (43%), in diagnostic radiology departments (72 %), with 11-20 years of experience (32 %). Almost all the participants know that ORP training is mandatory (96%). However, only 75% of them received a formal training on ORP and 12% (out of the 75%) responded that the information provided during the training were not efficient to raise their awareness on ORP.

Meanwhile, the majority of the respondents (86%) knows that cancer is among the main risks associated with ionizing radiation. However, only 71%, 46% and 38% knows that skin burns, nausea and vomiting and hair lost, respectively, at very high doses are also potential detriments of ionizing radiation. Unexpectedly, 6% and 4% of the participants think that magnetic resonance imaging and ultrasound, respectively, involve the use of ionizing radiation. Meanwhile, 47%, 59% and 90% of the respondents know that justification, optimization and dose limitation, respectively, are the general principles of radiation protection for OEHP. Still, 53% think that wearing a dosemeter is one of those principles. Furthermore, 9% of the respondents does not know the annual effective dose limits for OEHP over the age of 18 years. Moreover, 73%, 85% and 72% of the respondents acknowledge that time, distance and shielding, respectively, should be used to reduce their occupational exposures. However, 24% think that wearing a dosemeter could also reduce their doses. Furthermore, only 81% of the respondents always wear their whole body dosemeters. However, 46% of the participants does not know the dose they received last year. Finally, only 78% of the respondents perform a regular health surveillance checks at the hospital where they work.

The present study demonstrates an insufficient/low level of knowledge and awareness on ORP among OEHP in Lebanon. Therefore, it is important to develop and implement a national strategy for education and training. In the absence of specialized institutes and/or organizations for education and training in ORP in the country, the DAIR-LAEC is aiming to provide such training.

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New Approaches in Radiation Protection Education**

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In the teaching of Radiation Protection, the following sequence has traditionally been used: Theory; Problems; Practical Laboratory Work and Supervised Practical Work, the relationship between them varying according to the educational level of the addressees and the objective of the training. However, although all members of this scientific and technological community know the theory and its practical application measures, its systematic application in real work scenarios presents a great dispersion on the part of occupationally exposed personnel. (Einisman, 2013)

The general objective of this work is to postulate a new epistemological basis for the teaching of Radiation Protection based on the concept of Phronesis or "practical wisdom, prudence or precaution" (Muñoz et al., 2011) applied to the optimization of processes and procedures with ionizing radiation (González, 2010). Its particular objective is to show its didactic implementation through the presentation of an advanced simulator prototype for use in Higher Education, Vocational Training and Continuing Education in activities that use open sources of radioisotopes, such as Health, Oil, Mining or Industry. (Einisman, 2021)

As has been widely demonstrated in the transportation industry, simulation-based training (SBT) is an exemplary solution to develop professional capabilities. SBT is presented as a superior option to traditional didactic models in terms of speed of learning, amount of information retained, and problem-solving capabilities in work practice (Bilotta et al., 2013; Issenberg et al., 2005; Einisman, 2018).

The use of simulators allows students and workers to construct and critically analyze the relationships between physical, environmental and occupational factors, specific to each activity. The proposed system allows evaluating the effects of each of the decisions taken on the radiation dose received in each operation and the projected annual dose. Thus, the user can conclude personally and experientially - not only theoretically - that maximizing protection in each operation is the only way to minimize risks throughout his working life.

In this way, the synergy between epistemology, didactics and technology acts to promote a greater awareness of care among students and workers, reducing the occupational dose throughout working life.

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A Qualification Course in Radiation Protection for Registration of Radiation Protection Supervisor at Teaching and Research Laboratories**

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Introduction: In Brazil, several researches use radioactive isotopes, where Occupationally Exposed Individuals (OEIs) are subject to external exposure and internal contamination. Thus, teaching and research laboratories (T&R) must be authorized by the National Nuclear Energy Commission (CNEN) and monitored [1]. According to CNEN Standard NN 6.01, the OEIs must submit an application, in addition to the diploma recognized by the Ministry of Education (MEC) and the proof of a course of 40 hours in Radiation Protection (RP) [2]. In this sense, this abstract aims to present a proposal and experience report of a training course, since there are few offered in the country.

Materials and Methods: The course, developed in the State University of West Paraná (UNIOESTE) / Cascavel campus, was offered to teachers and technicians of the Chemistry and Biology courses, and carried out at UNIOESTE's Fine Equipment Laboratory, in 2020. The Laboratory uses a gas chromatograph equipped with a flame ionization detector and an electron capture detector (sealed source of Ni-63).

Results and Discussion: The Course during 40 hours (each Module, on average, lasting 5 hours/class). The material was made available in media and printed form. The syllabus was the following: 1. Radiation (Composition and structure of matter and atomic theory; Origin of radiation; Nuclear radiation; Radiation produced by the interaction with matter); 2. Natural and Artificial Sources of Ionizing Radiation; 3. Interaction of Radiation with Matter (Ionization, excitation, Activation and braking radiation; Directly and indirectly ionizing radiation; Interaction of electromagnetic radiation, directly ionizing radiation and electrons with matter); 4. Biological effects of radiation (Cell structure and metabolism; Interaction of radiation with biological tissue; Tissue radiosensitivity; Biological effects); 5. Radiological quantities (Conceptual evolution of magnitudes; Procedures for defining radiological quantities; Relationship between the quantities; New operational quantities); 6. Radiation detectors (Operating principles; Detectors using photographic emulsions; Thermoluminescent detectors); 7. Notions of RP (Principles; The RP plan; RP service activities; Practical rules for RP); 8. CNEN Standards (Standard NN 6.01; 6.02; 7.01). After the training, individuals were registered for the preparation, use and handling of radioactive sources and as Supervisor of RP by CNEN. With this certification, the professional will have a registration valid for 05 years in low-risk facilities.

Conclusion: It is understood that the course is of great importance for T&R that use radioactive material, and can be applied in all regions of Brazil, since there are few courses offered in the country. That is why it is important to disseminate and apply these courses throughout the country.

Keywords: radiation protection course, radiation protection supervisor, teaching and research laboratory, standard CNEN NN 6.01.

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The Effectiveness of Radiation Protection Intervention (RAPI) Module on Radiation Literacy among Radiation Workers in Southern Region of Malaysia**

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Background: In Malaysia, the number of x-ray examinations had increased by 19.02 per cent from 805,122 (2015) to 958,230 (2017); hence healthcare workers are at potential risk for occupational radiation hazards. A study in 2018 regarding radiation protection among healthcare workers in Negeri Sembilan showed that the scores on knowledge and practice were marginal despite a positive attitude. Thus, proper training in radiation protection is pertinent to ensure safety and health at work and preserve patient safety.

Objectives: This study aims to develop, implement and evaluate the effect of an educational intervention module based on Protection Motivation Theory (PMT) on the level of knowledge, attitude, and practice (KAP) of radiation protection among radiation workers in Negeri Sembilan and Malacca.

Methodology: This is a single-blind, parallel randomized control trial study involving 158 radiation workers from the Department of Health Negeri Sembilan and Malacca. The sample size required was 79 in intervention and 79 in control groups. A questionnaire about knowledge, attitude and practice regarding radiation protection was distributed among the respondents at the baseline. An educational intervention based on Protection Motivation Theory on radiation protection was introduced to the intervention group, and the median score of KAP level was analysed at one month and three months post-intervention. The data analysis was carried out using SPSS version 25.0. Data for respondents were analysed as per-protocol analysis and based on the intention-to-treat principle. Mann- Whitney U tests, Chi-square tests, Friedman test, Fisher's exact test and multivariate analysis of Generalized Linear Mixed Model was used in the statistical analysis.

Results: The response rate were 95.2% at baseline. Attitude was found significant associated with training on radiation protection ($p < 0.05$) at 1 month post intervention; income ($p < 0.05$), workplace ($p < 0.001$) and age ($p < 0.05$) at 3 months post intervention. Practice was found significant associated with level of education ($p < 0.05$) and workplace ($p < 0.05$) at 1 month post intervention; age ($p < 0.05$) and workplace ($p < 0.05$) at 3 months post intervention. The GLMM analysis showed the intervention did improve knowledge ($F (2, 2782) = 11.068$, $p <0.001$), practice ($F (2, 2782) = 7.132$, $p < 0.001$) and threat appraisal ($F (2, 2782) = 15.798$, $p < 0.001$) score in intervention group. In intervention group median score of knowledge and attitude of radiation protection increased significantly from baseline to 1-month and 3-month after intervention (35 (IQR 8), 41 (IQR 4), 40 (IQR 4), $p<0.001$) and (41 (IQR 5), 43 (IQR 6.25), 42 (IQR 7), $p< 0.001$) respectively.

Conclusion: In a nutshell, the Radiation Protection Intervention (RAPI) module effectively increased the level of knowledge attitude and practice of radiation protection among radiation workers in public healthcare facilities. Therefore, the Ministry of Health and other relevant authorities must revamp their current radiation protection training policy by standardizing radiation protection curricula nationwide using the RAPI module to increase the radiation workers' knowledge, attitude and practice on radiation protection in Malaysia and worldwide.

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Radiation Protection Training in a PET Centre: Working the Way Towards Safety Culture*, **

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The Uruguayan Centre for Molecular Imaging (CUDIM) is the only provider of PET diagnostic assistance and therapy with Lutetium-177 in Uruguay. It is also a regional reference centre in research and development of new positron-emitting radiopharmaceuticals with potential use in oncological, neurodegenerative and infectious diseases through the training of undergraduate and postgraduate students in collaboration with leading institutions in the country. All these activities are framed in the development of the safety culture in the institution, with particular emphasis on the training of all its workers in radiological protection (RP). The aim of this work is to present the curricula and evolution of the education in RP through twelve years of operation. The training courses encompass different levels of responsibility including both the personnel who handle radioactive material and the administrative and managerial staff. The courses, time duration, number of trainees and basic curricula are described below.

- Basic induction course (3 hours): aimed at all personnel who have just joined CUDIM to provide service and maintenance tasks. The curriculum includes concepts of radioactivity and operating procedures linked to their specific tasks. Ten workers are averagely trained per year.
- Basic course in radiological protection (12 hours): Aimed at cyclotron maintenance personnel. The curriculum includes: Basic concepts of nucleus and decay, Interaction of radiation with matter, Chemical and biological effects of radiation, Basic safety standards, fundamental, dosimetric and operational magnitudes, dose limits, Transport, reception and storage of radioactive material, Final disposal of waste. This course has mandatory evaluation and two workers are averagely trained per year.
- Refresher course in radiological protection (4 hours): Dictated for all occupationally exposed personnel every 2 years. The curriculum varies depending on the needs detected in the period, for example, review of the centre's RP manual, surface contamination measurement methods, dosimetric and operational magnitudes, calculations for disposal of waste and national regulations, among others. This course has mandatory evaluation and twenty-six workers are averagely trained per year.
- Training for personnel with management tasks in the administration of the CUDIM (4.5 hours): Aimed at the centre's administrative and managerial personnel. The curriculum includes Introductory Concepts to the Safety Culture, Basic Principles of Radiological Safety, Quality Management, Current National Regulations, Radioprotection and Emergency Manual. This course has mandatory evaluation and five workers are averagely trained per year.

All courses are evaluated in agreement with the Radiochemistry Department of the Faculty of Chemistry (University of the Republic) and they are accepted by the National Radioprotection Regulatory Authority to obtain working licences with radioactive material.

Although this training program does not constitute, by itself, a guarantee of safe behaviour typical of a solid Safety Culture, it is a fundamental step for its construction and it is the only initiative currently developed in the country. The work carried out to date is a fundamental pillar for the establishment of a safety culture in the institution and that it creates a valuable precedent in training in radiation protection at the region.

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Strengthening the Capacities for Medical Physics in Tunisia: Gaps and Challenges

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Background: Medical physicists have long played an integral role in medical imaging, radiation therapy, and radiation protection. In Tunisia, the status of the profession is flawed, the most important of which are the system of obtaining certificates and the legislative framework that regulates the sector. Most importantly, this situation can negatively impact treatment quality, patient and worker safety, whether through reluctance or relocation of staff.

Methodology: Statistical studies were conducted on the number and location of medical physicists and a national report on the status of medical physicists was prepared. Gaps have been identified and solutions presented to relevant decision-makers in the form of recommendations to advance the health care system.

Medical physicists exist only in the field of radiation therapy, absent in the fields of medical imaging (diagnostic nuclear medicine and radiology) and radiation protection. Therefore, we only focus on the first area. Then, update the radiotherapy health card (equipment, medical physicists).

Since the number of medical physicists is related to the number of devices emitting ionizing radiation, the number of devices must be given:

The thirteen radiation therapy centers (5 public and 8 private) contain: 15 linear accelerators (10/15 equipped with CBCT and 3/15 with Free Flattening Filter FF), 10 medical Cobalt-60 sources (3 sources not usable), 4 brachytherapy sources (2 low dose rate and 2 high dose rate), 4 scanners dedicated to radiotherapy, and this is another problem: not all radiation therapy services have their own scanners.

About 40 physicists with hospital technician status and no residency program. Not all studied medical physics, some have a physics background.

Results

Certification of medical physicists:

Since 2013, the Higher Institute of Medical Technologies of Tunis is running a master’s degree in medical physics to meet the demand. About 6-7 medical physics degrees graduate each year. Despite the efforts, there are still quantitative and qualitative deficiencies: some modules are missing compared to international medical physics courses such as anatomy, biostatistics, and diagnostic radiology.

Regional and international collaboration: Masters and Ph.D. students seeking guidance often have difficulty finding specific expertise needed for their research in Tunisia. Contribution of IAEA in providing technical support in the field of medical physics. We cite the regional project RAF6058 “Strengthening the capacities for Radiopharmacy and Medical Physics and Radiology for expansion and sustainability of Medical Imaging Services”, the Master’s Program in Medical Physics from the Abdus Salam International Centre for Theoretical Physics in Italy and the ICTP-IAEA Sandwich Training Educational Programme (STEP).

Residency program: There is no accredited society that offers a clinical medical physicist’s certificate. Here, through this paper, we appeal to the European Federation Organizations of Medical Physics (EFOMP) and the Middle East Federation of Medical Physics (MEFOMP) in the capacity building, empowerment, and experience acquisition of medical physicists in Tunisia.

Conclusion: Medical physics in Tunisia must fulfill the need of hospitals and the current legislative framework must be updated.

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Implementation, Experience and Challenges of Radiation Protection E-learning in China

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Nuclear technology utilization is highly specialized which involves a wide range of laws and relevant and professionals. Some nuclear technology utilization enterprises have a low level of radiation safety system documents and inadequate protection measures. To standardize radiation safety and protection training, and effectively reduce the burden of enterprises, the National Training Platform for Radiation Safety and Protection of Nuclear Technology Utilization(hereinafter referred to as the National Training Platform) has been online since January 1, 2020, established by the Ministry of Ecology and Environment (MEE)of China.Since the National Training Platform was put on line, more than 76000 radiation safety practitioners have learned online and passed the exam. Meanwhile, it was also found some challenges such as the low pass rate of the training assessment and the management of the National Training Platform to be improved.

Background

In the control of normal and potential exposures, the provision of information and training related to radiation protection to all workers involved in radiation work, which is an important component of the health management system for radiation workers, is considered as a basic requirement for the implementation of the principle of optimizing radiation protection.The findings of the International Atomic Energy Agency (IAEA) on radiological accidents highlight the importance of adequate and appropriate training for all those who work with ionizing radiation, and it is clear from the many accidents that the lack of training is a major cause of errors with serious consequences.

China formulate relevant laws, regulations and standards in radiation protection,which made relevant provisions on radiation protection safety and training, such as the Law on the Prevention and Control of Occupational Diseases, the Law on the Prevention and Control of Radioactive Pollution, the Regulations on the Safety and Protection of Radioisotopes and Radiation Devices, and the Basic Standards for Ionizing Radiation Protection and the Safety of Radiation Sources and so on.

Objective

This paper emphasizes the importance of radiation protection training, demonstrates that China has attached great importace on radiation protection human resource development, and expresses experience and challenges on improving training and education for workers.

Structure

This paper is divided in six sections. The first section introduces overview of the National Training Platform as the China's sole comprehensive radiation protection e-learning platform. The second section provides introduction of main function. The third section explains the unique features of the National Training Platform. This explanation will include an in-depth discussion of five constituents: curriculums, training resource, user profile, news, registration for exam.The fifth section describes challenges and the way forward, and the sixth section concludes the paper.

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Development and Implementation of Standard Syllabus on Nuclear Medicine in Malaysia: Essential Training for Worker

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Ministry of Health

Background

In Malaysia, the Atomic Energy Licensing Act 1984 (Act 304) is the main act which aims to ensure the usage of the ionizing radiation is in a safe manner without compromising the safety to the worker, patient and members of the public. In the year 2017, the Malaysian Ministry of Health has designed and published the training scheme dedicated to this field. As stated in regulation number (12) of Radiation Protection Regulations (Licensing) 1986, 'the applicant shall employ or otherwise employ persons or persons who have the knowledge, skills and training necessary to ensure the activities to be licensed according to a way of protecting the health of workers and the public and reducing the dangers to life, property and the environment'.

The paper aimed to describe the commitment of the government of Malaysia particularly the Ministry of Health (MOH) and its institution such as hospitals to initiated and designed the training scheme for allied health professional involved directly in the field of nuclear medicine department.

Methods

The Malaysian's MOH has developed the document based on the needs of the latest requirements under the Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010. This is the subsidiary regulations under the Act 304. The topics of the syllabus are designed through the special Task Force formed under the Training Committee of the Ministry of Health.

Results

All professional includes the Nuclear Medicine Specialists, the Nuclear Pharmacists, the Medical Physicist, The Nuclear Medicine Technologist, the Radiochemist and the Nurse should undergo the prescribed training as mentioned in Table 1. The new personnel can only be registered after completing the training.

The application for approval for the registration of new personnel of nuclear medicine services must be submitted to the relevant authorities within six (6) months of completing the training. Those who fail to submit their application within six (6) months of completing the training must undergo re-training. Proof of attendance of personnel and log books certified by the supervisor shall be submitted to the relevant authority. For personnel who work during the period before approval is granted, all activities performed should be supervised by the supervisor.

Professionals	Module of Training	Credits Hours	Note
*Nuclear Medicine Physician	-	-	Shall comply with the National Credentialing Committee and register with Malaysia's National Specialist Register (NSR)
*Nuclear Pharmacist	-	-	Shall comply with the training scheme made by the Division of Pharmacy Services, Ministry of Health Malaysia
Medical Physicist	All module under 'Section A and B'	57 hours theory; 69 hours hands on/ practical.	
Nuclear Medicine Technologist	Module 1, 2, 3, 4, 5 and 7 in Section A and Section B	41 hours theory; 85 hours hands on/ practical.	
Radiochemist	Module 1, 2, 3, 4, 5 and 7 in Section A and Section B	53 hours theory; 73 hours hands on/ practical.	
Nurse	Module 1 and 7 in Section A and Section B	12 hours theory; 114 hours hands on/ practical.	

Note: Asterisks (*) will not discuss in this abstract

Table 1: The academic syllabus has been developed

Section A: Theory
Module 1: Radiation Safety Awareness
Module 2: Legislative Requirements
Module 3: Instrumentation and Associated Facilities
Module 4 Principle of Radiation Protection
Module 5: Radioactive Source Management
Module 6: Medical Radiation Dosimetry
Module 7: Clinical practice
Section B: Attachment/ Hands on
The details of each topics will not be highlighted in this abstract.

Conclusions

The training scheme developed by the Ministry of Health (MOH) and its institution is a very important tool to ensure the safety of the patient, staff and the members of the public from the harmful effect of the ionizing radiation. The supporting document like this will directly improve in term of services provided by the Nuclear Medicine Department in Malaysia.

In order to improve the quality of services provided by public and private medical institutions, the Ministry of Health Malaysia (MOH) is always working to produce clear, transparent and current guidelines/circulars from time to time. This is to ensure that patients' interests take precedence over optimal and optimal diagnostic and therapeutic aspects. MOH will ensure that radiation exposure from unsealed sources to workers and the public is regulated and the source is always monitored in terms of radiation safety.

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Strengthening Radiological Safety at Cnesten through Emergency Preparedness Exercises**

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The Internal Emergency Plan (IEP) of the National Center for Nuclear Energy, Science and Technology (CNESTEN) represents the set of measures taken by the Center's management, in the event of a radiological, nuclear or toxic emergency: to place the CNESTEN facilities at the least degraded state of safety possible and limit the consequences of accidents by implementing emergency procedures; to protect workers, neighboring populations, and the environment from ionizing radiation by limiting and controlling releases and implementing the necessary preventive and protective measures; to provide first aid to victims; Etc.

The IEP describes: CNESTEN and its installations, including the research reactor; the different accident situations envisaged to occur at the center; the reference accidents considered for the CNESTEN facilities; and the organization put in place if the IEP is triggered; Etc.

For the management of an emergency, CNESTEN has a technical crisis center (TCC), whose missions are: To assess the radiological risks and consequences in case of an emergency; to recommend preventive and protective actions; to evaluate the dose rate and the shielding calculation.

For TCC to succeed in its mission, TCC uses human and material means (video conference communication system; Tools for calculation, modeling and simulation; Radiological measurement equipment; Etc.).

In this sense, and to improve radiological safety within the CNESTEN, the center carries out several emergency exercises, including a periodic global exercise to trigger the internal emergency plan, which involves all the CNESTEN's internal response teams. The organization of such exercises allows the training of the emergency response team in crisis management and in achieving the objectives of the internal emergency plan.

The conduct of a periodic global emergency exercise at the CNESTEN requires following a set of preparation steps before the exercise to reach the global objective, which is good crisis management.

Among the steps for preparation of exercises adopted at the CNESTEN, we emphasize the choice of the scenario. In this sense, the exercise scenarios adopted are based, for example, on accidental situations described in the CNESTEN internal emergency plan. These accidental situations are exploited to develop exercise data (Definition of the technical components of nuclear facilities; definition of events, critical moments and sequences of events of the accident; definition of the radiological data; The carrying out simulations to determine the extent of the actions of the responders and the means of intervention; etc.).

Periodic exercises carried out at the CNESTEN help to improve the measures implemented for emergency intervention to protect personnel, the public and the environment against ionizing radiation.

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Developments in Radiation Protection Education, Training and Qualifications in the UAE

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Since the establishment of the Working Group on the "National Strategy on Education, Training and Qualification in Radiation Protection in the UAE", as a follow-up to the 2017 IAEA EduTA to the UAE, various developments took place in the United Arab Emirates to enhance and further develop the infrastructure for the competency of Radiation Protection Professionals.

First and foremost, the UAE established in 2019 the "National Strategy on Education, Training and Qualification in Radiation Protection in the UAE", according to the IAEA guidance, as a reference framework for the coordinated developments of all subsequent actions.

In close collaboration with the "National Qualifications Center" (formerly known as "National Qualifications Authority") of the UAE Ministry of Education, a Committee was also established in 2018 between FANR and various UAE governmental and commercial Stakeholders, to develop detailed and comprehensive national vocational Qualifications for five categories of Radiation Protection Professionals: the Qualified Expert (QE), the Radiation Protection Officer (RPO), the Medical Physicist (MP), the Exposed Worker (EW) and the Emergency Worker (EmW).

Three National Workshops have been organized in 2015, 2017 and 2019, to publicly discuss of the roles, responsibilities, mutual interaction and formal qualifications of QEs, RPOs and MPs: a fourth Workshop, initially planned in 2020 -and rescheduled due to the global pandemic-, will conclude the current development phase of the Qualifications, presenting the overall framework to Professionals and Training Institutes.

To cope with the absence of formal recognition for Qualified Experts in the UAE, and to respond to a specific EduTA Recommendation, the Working Group also established criteria for interim qualification, and set up, in 2019, a first Temporary List of Qualified Experts in the UAE, to be used in Licensing and Occupational Radiation Protection practices in the Country.

The Working Group also fostered the creation of two Academic Master Degrees, able to cater for the growing needs of young graduates with an interest towards the field of Radiation Protection and Medical Physics.

The Federal Authority for Nuclear Regulation, FANR, is considering to propose new Regulation and Guidance for Education, Training and Qualifications in Radiation Protection, in the near future, given the importance of these topics, and their complexity.

Thanks to the initial guidance of the IAEA EduTA Mission and the coordinated efforts that FANR and its Stakeholders have deployed in these years, the quality, level and harmonization of Education, Training and Qualification for Radiation Protection Professional have been greatly improved, and represent a cornerstone of the modern and comprehensive Radiation Safety regime that FANR is fostering in the UAE.

A future follow-up review of the IAEA EduTA Mission is already planned, to acknowledge the significance of the efforts undertaken by the UAE, and to indicate final improvements to the System, also based on the experience gained by other Member States in the cyclic implementation of the National Strategy.

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The Moroccan Approach Regarding Training in Occupational Radiation Protection

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Ionizing radiation sources are widely used in Morocco, mostly in the medical, industrial and security fields. However, these sources, if not controlled and safely used can be hazardous to workers, public and environment.

The Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR), since its creation in October 2016, has been working on upgrading nuclear and radiological regulatory framework in order to fully comply with IAEA safety standards especially regarding training of occupationally exposed workers.

Regulatory texts implementing Law No.142-12 represent a major reform in the organization of radiation protection, particularly in the training of occupationally exposed workers, assigning to the license holder the responsibility of ensuring this training and providing for the possibility to seek expertise of a Radiation Protection Expert (RPE) in order to get advice on the trainings that need to be delivered to the workers, taken into account the nature of the handled radiation sources.

The licence holder is also required to appoint a radiation protection officer (RPO) who will be in charge of providing training to the exposed personnel. Operators of the industrial field, on the other hand, need a specific training to be certified as Qualified Operators (QO) capable of handling radiation sources safely.

The modalities of training and recognition of RPE, RPO and the training of QO are detailed in an order which specifies the objectives of training for each radiation protection actor. Nevertheless, these trainings can only be carried out in training centres approved by AMSSNuR.

Thus, the regulatory texts implementing Law No.142-12 aim the transposition of IAEA standards, particularly GSR part 3 requirements, regarding capacities building for occupational radiation protection as an effective factor of optimization of radiation protection.

Keywords: Occupational radiation protection, Training, Regulations, IAEA standards, RPE, RPO, QO.

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Using Kirkpatrick's Model to Measure the Effect of Radiation Protection Online Workshop for Radiation Workers

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Radiation offers extraordinary benefits for the diagnosis of a wide range of medical issues and the application of ionization and non-ionization radiation is widespread all over the world (1). The radiation protection of the workers is a significant issue in imaging and therapeutic departments which depends on the effective education systems. Radiation protection education plays a crucial role in worker protection and their performance (2). This study focused on the assessment of the role of radiation protection training classes in medical issues for the workers who had participated in radiation protection classes of the radiation research center (RRC) of Shiraz university. There are many methods to survey the effects of these classes on knowledge and Kirkpatrick is one of the best ones (3-4). Our study society contains 74 participants 62 of them were chosen based on the Morgan table in the reaction level. For assessment, the reaction level of this method, the level of participant satisfaction was surveyed using a questionnaire which contained the questions about the concept of the lessons, teaching (skill or Rhetorical of the teacher, his/her experience in this field), and class arrangement and discipline. This level includes 5 degrees and the average was estimated. For assessment of the role of the radiation protection class in the knowledge of the worker the pretest and post-tests were done and the results were analyzed based on the T-square method. The results of the T method were listed in Table 1. In all three factors of the concepts, teaching skill, and programming the class, the meaningful level of the T-test was estimated as sig=0 which means there weren't differences between estimated values and expected values. The estimated average shows the higher values compare to the reference average which is mean the effective role of the radiation classes. For evaluating the effect of the class on the knowledge the pre and post-tests were analyzed and the average grade was increased by 2.42 level (Table 2). Its means that Kirkpatrick had the desired results. There is abundant room to survey the other factors in 3 other levels of Kirkpatrick and implement the results of this kind of research on the education systems.

The expected average= 3					factors
Standard error	Standard deviation	Average from 5	Meaningful level	T	
0.11	0.85	3.75	0	61	Concepts
0.12	0.93	3.78	0	61	teacher
0.13	1.01	3.66	0	61	Programming and arrangement of the class
0.12	0.93	3.73	0	61	Total evaluation

Table 1: the results of the effective role of the classes in reaction level

Meaningful level	T	Degree of freedom	Standard deviation	Average from 5	factor
0	13.55	61	0.92	1.89	Pretest
			0.92	4.31	Posttest

Table 2: the results of the T-test in the assessment of the learning level

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Post-Graduate Education and Training in Occupational Radiation Protection in Ghana**

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The Department of Nuclear Safety and Security is one of the Departments of the School of Nuclear and Allied Science (SNAS) established in 2006 jointly by the Ghana Atomic Energy Commission, (GAEC) and the University of Ghana with the collaboration of the International Atomic Energy Agency (IAEA). The Department offers MPhil and PhD Degree programmes in Health Physics and Radiation Protection and also an IAEA sponsored Postgraduate Education Course in Radiation Protection and Safety of Radiation Sources (PGEC). The mandate of the Department is to develop human capability and capacity in Radiation Protection, Nuclear Safety and Security. The department has educated and trained about 90 MPhil and PhD graduates in the past decade, most of whom now constitute the core human resource base for the Nuclear regulatory authority and the its key TSO, the Radiation Protection Institute of the Ghana Atomic Energy Commission. Additionally, the department has since 2011been recognised as an IAEA Regional Designated Centre for Professional and Higher Education in Radiation Protection which has trained over 200 fellows from various IAEA member countries from Africa through the PGEC programme in Radiation Protection and Safety of Radiation Sources. Beneficiaries from the PGEC programme in Ghana are contributing significantly in various capacities in their respective regulatory bodies and TSO's within the Africa region. The department continues to offer support to regulatory bodies and TSO's within the Africa region through Graduate Education and training in Occupational Radiation Protection which are key components needed to develop and maintain technical expertise. In this Paper, the experience of a comprehensive theoretical, practical and field work in occupational radiation protection Education and training following a well structured and internationally accepted approach is presented.

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Radiation Protection and Safety Training Programmes organized by the Radiation Protection Institute for Occupationally Exposed Workers in Ghana: A Six-year Review from 2016 to 2021

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In Ghana, it is a requirement by the Nuclear Regulatory Authority (NRA) that all Occupationally Exposed Workers (OEWs) be trained in radiation protection and safety. In order to ensure best international practice, Ghana has also adopted the provisions of the International Basic Safety Standards (BSS) of 2014 published by the International Atomic Energy Agency (IAEA). The BSS compels employers, registrants and licensees to provide adequate instruction and training and periodic retraining in radiation protection and safety to ensure safety standards for protecting people and the environment. The NRA has also authorized the Radiation Protection Institute (RPI) of the Ghana Atomic Energy Commission (GAEC) as a Technical Support Services Application for Training Service Provider.

The training modules consisted of theoretical presentations and practical demonstrations; specifically lectures, case studies, video shows and open forum discussions in the training process. The courses were mounted between 3 – 5 days either at the clients' facility or at the RPI premises. The training facilities include Desk Top Projector, Video Films, Overhead Projector, video Camera and other Training Materials (lecture notes, relevant literature, National/International Regulations, Guides or Codes of Practice, etc.). Currently, RPI through a collaborative project with the Skills Development Fund, Ghana, has developed an Ionizing Radiation Safety Training Manual. A Technical Visit to facilities of GAEC, and RPI and other Institutions whose facilities are relevant of the Client training need is organised as part of the training programme.

The Syllabus and Training Materials that are utilized are mainly from the National Policy for Education and Training in Radiation Protection, Transport and Waste Safety training modules for various practices; and the IAEA standardised training modules for various practices based on new requirements of the new BSS of 2014. There are also design of new training modules based on clients' needs assessment/specific competencies required; as well as a continuous review of modules based on new knowledge, emerging technology, revised regulations, etc.

The target audience of the trainees include Qualified Expert (QE), Radiation Protection Officers (RPOs) and Qualified Operators who work with application of ionizing radiation in authorised practices in industrial, medical, research, etc. institutions for practitioners like Radiographers, X-ray Technicians, Biomedical Engineers, Operators of Density Nuclear Gauges, Well Logging Sources, Mining Engineers, Transporters of Nuclear and Radioactive Materials, etc.

Within a Period of five (5) years (2017-2021) the Institute has trained about 860 OEWs on Radiation Protection and Safety from 74 different facilities. In all, the training courses have equipped them with the requisite knowledge and skills and recent trends in radiation protection and safety. The feedback from the post course questionnaire by trainees indicates a demonstration of good safety culture to aid radiation protection and safety, and help minimize/prevent accidents and incidents in the utilization of ionizing radiation applications.

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Establishing an E-Learning Radiation Protection Training Course for Occupationally Exposed Workers: Challenges and Successes**

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International Atomic Energy Agency

Addressing the requirement for the regular training of its employees in safety and security as determined in the Radiation Safety and Nuclear Security Regulations and in established Radiation Protection Programmes, the International Atomic Energy Agency (IAEA) developed an e-learning Radiation Protection Training Course for the Agency's Occupationally Exposed Workers (OEWs). Considering the diverse nature of the Agency's activities with radiation, developing a "*one-size-fits- all*" training course presented challenges and required collaboration with stakeholders throughout the Agency. While the e-learning format optimized the training process and allows for the OEWs to complete the course in a self-paced manner, this presented its own challenges. The limitations of the e-learning course must also be recognized, including that the course must be supplemented with task-specific and hands-on training. The IAEA's Radiation Safety Technical Services Unit developed the course, drawing from its extensive experience training OEWs at the Agency. The course was finalized and successfully issued for Agency-wide use in 2021. The course includes seven core modules, with an additional two modules for staff who travel to Member States' facilities:

Module 1: Radiation basics, exposure and dose
Module 2: Radiation health effects, safety principles and standards
Module 3: IAEA rules, regulations and safety culture
Module 4: Radiation protection for external exposures
Module 5: Radiation protection for internal exposures
Module 6: Contamination control and personal protective equipment
Module 7: Incidents, emergencies and reporting
Module 8: Handling and transport of radioactive sources on duty travel
Module 9: Safety and radiation protection on duty travel

This poster will describe the process for developing the course, and the challenges and successes incurred along the way.

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Proposing the Formal Recognition for Qualified Expert in Indonesia

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Indonesia as one of IAEA member states has stipulated requirements regarding the radiation protection officer in Bapeten Regulation (BR) 2 Year 2022 regarding the amendment of the Bapeten Chairman regulation 2 year 2012 on the compliance test of the x-ray machine for diagnostic and interventional radiology purpose. In the current regulatory framework, a recognition for qualified expert (QE) is only stipulated specifically for the compliance test.

QE may provide authoritative advice to licensees or employers regarding the compliance with applicable radiation protection requirements, specifically in occupational and public exposure. A set of formal recognition system is proposed in this paper. The aim is to document the acknowledgement by the relevant authority that a person has the qualifications and expertise required for the responsibilities that he/she will bear in the conduct of the authorized activity. The possible involved relevant authorities are the ministry of manpower (who currently developing national work competence standards), national standardization agency, and nuclear energy regulatory body in Indonesia (BAPETEN).

The proposed scheme for formal recognition of QE in Indonesia refers to several countries such as Finland, Italy, and UK. Those countries are deemed to have an established recognition system for QE. A review is conducted to obtain most applicable scheme in Indonesia. Essentially, the formal recognition system for QE can be approached from two points of view. i.e. related field such as nuclear medicine, radiotherapy, industrial radiography, or from the stage of practice with graded approach. The identified formal recognition structure covers from the specific legal entity, scope of certification, qualification standards, requirement (knowledge, skill, experience), assessment method and recertification.

Gaps is also analysed as Indonesia already implemented partial recognition system and currently developing the national work competence standards and the guidance in some practice recommends QE to be in vicinity area of the practice. In summary, formal recognition system for QE in Indonesia need to be established, with development in the previously existing partial recognising system of QE.

SESSION 12:

SAFETY CULTURE IN OCCUPATIONAL RADIATION PROTECTION

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Development of Radiation Safety Culture in Ghana: Impacts on the Health of Occupational Radiation Workers and Quality Services**

Author: Abdallah Munir Abdallah Dawood

Radiation Protection Institute

The Radiation Protection Institute (RPI) of the Ghana Atomic Energy Commission (GAEC), among other objectives provides radiation protection and safety training and consultancy on radiation exposure control; safety and security of radiation sources and effective radioactive waste management services. The Institute further conducts on-site radiation safety assessment for sectors of the economy where radiation sources are applied i.e. health, agriculture, industry etc. When radiation sources get damaged and/or fail to function optimally, they are retrieved from their end-users and transported to the Centralized Radioactive Waste Management Centre for proper management. In the health sector, radiation sources are used for X-ray imaging and diagnosing and treatment of cancer. In construction, mining and oil rigging, they are used for level gauging and moisture content determination. In all these applications, the workers and to a less extent members of the general public are exposed to some amount of ionizing radiation that may be detrimental to their health. To achieve the fundamental principle of protecting people and the environment from the harmful effects of ionizing radiation, there is the need to establish radiation safety culture at every centre where radiation sources are applied. The RPI of Ghana through its quality management system (QMS) which comprises radiation protection training modules as well as safety and security mechanisms is helping to achieve this purpose. The QMS provides standard operating procedures for major facilities; safety principles and practical measures for radiation safety. It is also designed to achieve quality technical services, and protection of the health of the radiation worker. The QMS recommends routine (monthly) environmental radiation monitoring and (bi-annual) safety assessment operations as means of achieving radiation safety in and around the immediate environment of the facilities, and protection of the general public from inadvertent exposure.

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The Importance of Safety Culture In Occupational Radiation Protection

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China Institute for Radiation Protection

1. The Meaning of Safety Culture

We first saw term of safety culture in the OECD Nuclear agency Report of 1987 [1]. Later, more and more people accepted it and thought of it as a culture where safety is a top priority.
Safety culture has different interpretations on different occasions. For example, The IAEA (1991) defined safety culture as, "that assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance"[2]. This means that safety culture can be interpreted as a combination of tendencies, beliefs, rules and practices of organizations and individuals.
① Tendencies: indicates the method that an individual or organization likes to take in dealing with something. This is a mindset formed by long-term practice, which will inadvertently determine their behavior and culture.
② Beliefs: is the foundation of safety culture and the source of tendency. If tendency is the final choice, then belief is the power that drives this choice. Organizations usually will turn beliefs into rules and make individuals learn.
③ Rules: refers to both written laws and regulations and enterprise rules and regulations, and unwritten constraints. Various rules determine the way individuals and organizations practice.
④ Practices: is the ultimate tangible and concrete behavior of an organization or individual. Long-term practice will determine a specific tendency. In addition to the inheritance of previous cultures, there are also new culture arising from new practices and new members.

2. The Role of Safety Culture in Occupational Radiation Protection

As nuclear technology becomes more widely used, the number of people potentially exposed to radiation increases and the risk of radiation harm increases. Especially, new nuclear power plant workers, doctors operating radiation therapy machines and researchers. They usually lack operational experience or theoretical knowledge related to radiation protection. A top-down safety culture helps them get into character quickly. The most immediate benefit of a safety culture is an effective reduction in staff doses. According to Fetterly, implementing a safety culture can reduce the mean cumulative skin dose of 27 staff cardiologists and 65 fellows-in-training by 40% over 3 years [3].

3. How to Establish Safety Culture The establishment and perfection of safety culture is inseparable from the joint efforts of organizations and individuals.

① For organizations: establish a safety system based on past experience and require all staff to learn, managers should promote the atmosphere of safety culture from top to bottom, organize safety protection training regularly and actively check the mastery of the staff, promote use of current national or international sources for these guidelines/criteria (ACR, IRQN, NIRS, IAEA, etc.) [4].

② For individuals: actively integrate into the atmosphere of safety culture, strictly abide by various laws and regulations, pay attention to communication with peers and organizations, develop the habit of lifelong learning safety culture.

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How to create a Safety Culture in the Green Jobs Sector? **

Author: Giulia Giaimis

The purpose of this paper is to use the notion of "culture" given by Socrate, in the Green Jobs sector context, reflecting on building up a safety culture making system, useful to stakeholders involved in green activities that include radiation production as a side effect of their processes. Socratic thinking considered culture as the result of knowledge added to reason, and the only instrument to aim at good. Through culture, individuals operate choices that would nurture their personal growth as well as society's flourishing. Taking that into account, the paper also addresses the issue of a lack of knowledge among entrepreneurs and stakeholders about Green Jobs, due to the incorrect assumption "green means natural, thus green is safe".

An example of this misjudgement can be found in geothermal energy production, and its correlation with TENORM/NORM contamination. Therefore, the work aims to seek both regulatory and corporate tools, which are needed to initiate a stratification of good practises in occupational radiation protection in order to create a proper Green Jobs' safety culture.

Employees' health and safety is a relevant topic to the Sustainable Development Goals (SDGs) set by the United Nations, in terms of good health, decent work and economic growth, and social justice. Thus, this paper tries to draw a virtuous path, getting started with testing stakeholders' level of knowledge on occupational radiation safety in Green Jobs. Agencies like ILO and EU-OSHA could provide online tests, categorised by professional profiles that are involved in managing or handling potential radioactive materials at any level of the working process. From there, it will be possible to elaborate an educational strategy, according to States' safety legislation.

Regarding the educational strategy, the utilisation of Portage Method, properly modified, aiming at stakeholders' re-education appears to be an innovative and promising solution. The said method was born as a re-educational programme for those children who suffer from pathologies related to development delays. Its versatility is proven by the fact that the Portage Method system is divided in five different areas of development (respectively cognitive, physical, linguistic, socialising, autonomy), that are easily adjustable to be used with adult people. In addition to that, the incorporation of information technology (declined as Apps and simulation video games) in the educational project makes this approach suitable for companies of any size.

However, creating a culture requires time. Once the behaviour related to each development area is transformed into a habit, instead of being considered as a corporate demand, a proper level of knowledge among stakeholders will be reached. As this change will be happening, radiation occupational safety culture will be existing in the Green Jobs sector.

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Management of Personal Dosimeters: The Lessons Learned from Mistakes

Authors: Olga Lillo; Sergio Aguiar; Federico Lorenzo; Alejandro De Rosa; Adriana Castano; Mariela Dalla Rosa; Lujan Guerrero; Valentina Ferreira; Marcel Frederico; Carlos Vega; Franco La Paz; Gustavo Paolini; Aldo Quarneti

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Background

Dosimeter management in the Radiotherapy Department, Pereira-Rossell Hospital (HPR) Montevideo-Uruguay, has been difficult due to: 1) The Dosimetry Service (Ministry of Industry) has increased the cost of the personal dosimeter replacement. It was warned that the cost could be transferred to radiation workers (RWs). 2) HPR has a delay in the payment to the Dosimetry Service; thus, RWs of Radiotherapy-HPR do not have their month exposure value in Sievert since August-2021. 3) The hired transportation for dosimeters left RWs without them for two and three days every month. It must be highlighted that all technicians, some physicians and physicists work for at least two institutions, so they have a personal dosimeter in each one (1,2,3).

The present problem

The Linear-Accelerator at HPR has a failure since October 18, 2021. Patients were derived to the Clinicas-Hospital (CH) Radiotherapy Department, as well as certain HPR technicians. Dosimeters were not given to these RWs at first, understanding that the HPR Accelerator would be repaired in a few days. At the end of November it was notified that the Magnetron was definitely broken and the new installation would require months. To redistribute the dosimeters it was taken into account that some physicians, physicists and technicians had another dosimeter in the alternative institutions in which the patients would be sent (CH and National Institute of Cancer [INCA]). The situation was evaluated with the National Radiation Regulatory Authority and the Dosimetry Service. On December 17, the dosimeters reached the RWs which had begun to work their entire work time outside HPR: five technicians and one physicist. Since certain technicians, physicians and physicist already had personal dosimeter at CH/INCA, they used them during the work with HPR patients. Six HPR physicians and two physicists went to work at the Radiotherapy Department of the two alternative institutions without dosimeter; it was assumed that their main exposure probability was at HPR where they work most of the time. From this group, four physicians continue performing tasks in HPR-brachytherapy and they attended CH/INCA once a week; however, two physicians transferred their radiation work almost entirely to CH/INCA and their dosimeters remained at HPR.

Conclusions

The main errors detected were: 1) a delay of 8 weeks in providing a dosimeter to certain RWs whose tasks were completely transferred to another institution; 2) no additional dosimeter was given to RWs who went on to work in more than one institution; 3) lack of communication between the Radiation Protection Officers from the involved institutions.

The variety of errors in the redistribution of personal dosimeters showed the need of an action protocol for future and similar situations. Our team must take training courses in safety culture and occupational radiation protection.

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Assessment of Health and Safety Awareness Level of Occupationally Exposed Workers in a Radiology Department: A Case Study of a Ghanaian Hospital

Authors: Kofi Okyere Akyea-Larbi[1]; Stephen Inkoom[2]; Francis Otoo[2]; Daniel Nii Adjei[1]; Kwasi Frimpong[3]; Francis Hasford[1]

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Imaging for medical purposes typically involves a team comprising radiologists, radiographers, sonographers, medical physicists, biomedical engineers, and other support staff working together to enhance the health of every patient they encounter. For best results and the assurance of quality, the imaging teams must adopt a multidisciplinary and integrative approach to work to assure patient safety but also importantly ensure worker safety and welfare. The Ionising Radiation Regulations 2017 (IRR17) of the United Kingdom (UK) compels employers to keep exposure to ionising radiations as low as reasonably practicable and must not exceed specified dose limits. Also, 2013/59/Euratom demands uniform basic safety standards for the protection of the health of individuals subjected to occupationally exposed health workers. In Ghana, the Nuclear Regulatory Authority (NRA) requires that, an appropriate personnel monitoring system should be provided for all occupationally exposed personnel.

The aim of the study was to assess the level of health and safety awareness among occupationally exposed workers in a diagnostic imaging department. A systematic approach involving administration of questionnaires, personal observations and focus group discussions was adopted to elicit information for the study.

Analysis of the gathered information, revealed that most of the respondents were aware of the health and safety issues with regards to the potential radiological risk emanating from exposure to ionizing radiation such as stochastic and genetic effects and also issues of risk communication in the radiology department. Good knowledge of the consequences of ionizing radiation and its effects among radiologist and radiographers was expected due to their level of education, training and experience due to several years of practice, and also introduction to radiation protection during their academic training. A senior radiographer acts as the Radiation Protection Officer (RPO), at the facility and handles all the radiation protection issues that arises.

The study indicated that 75% of the radiation protection safety measures which includes wearing of personal protective equipment (PPE), monitoring of staffs and dose optimization were present in the radiology department and majority (79%) of the respondents were aware of the radiation protection and safety measures. The overall awareness and knowledge of radiation was satisfying with definite possibilities for further improvements through regular trainings, workshops and continuing medical education (CME) programs related to radiation protection and safety.

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Promoting Safety Culture in Ghana; the Role of the Radiation Protection Institute

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Ghana Atomic Energy Commission

Establishing a strong safety and security culture is one of the fundamental management principles for an organization dealing with radioactive material. According to the IAEA, safety culture is the assembly of characteristics, attitudes and behaviours in individuals, organizations, and institutions which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance. The Radiation Protection Institute of the Ghana Atomic Energy Commission is the foremost technical Scientific Support organization in Ghana. The institute renders various technical services include; personal monitoring, structural shielding design, and assessment, leak test, environmental monitoring, nuclear security consultancy, education and training services for licensee in Ghana. This work presents the role of the RPI in promoting safety culture in licensee organisation in Ghana.

ANNEX: Supplimentary Files

The supplementary files contain additional attachments with extended abstracts, tables and figures, as well as posters related to the abstracts.

The online supplementary materials can be downloaded from the file submission system IAEA INDICO by registered users at https://conferences.iaea.org/event/276/page/652-abstracts-and-posters.

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