IAEA HUMAN HEALTH REPORTS No. 13

Staffing in Radiotherapy: An Activity Based Approach

IAEA
International Atomic Energy Agency

IAEA HUMAN HEALTH SERIES PUBLICATIONS

The mandate of the IAEA human health programme originates from Article II of its Statute, which states that the "Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world". The main objective of the human health programme is to enhance the capabilities of IAEA Member States in addressing issues related to the prevention, diagnosis and treatment of health problems through the development and application of nuclear techniques, within a framework of quality assurance.

Publications in the IAEA Human Health Series provide information in the areas of: radiation medicine, including diagnostic radiology, diagnostic and therapeutic nuclear medicine, and radiation therapy; dosimetry and medical radiation physics; and stable isotope techniques and other nuclear applications in nutrition. The publications have a broad readership and are aimed at medical practitioners, researchers and other professionals. International experts assist the IAEA Secretariat in drafting and reviewing these publications. Some of the publications in this series may also be endorsed or co-sponsored by international organizations and professional societies active in the relevant fields.

There are two categories of publications in this series:

IAEA HUMAN HEALTH SERIES

Publications in this category present analyses or provide information of an advisory nature, for example guidelines, codes and standards of practice, and quality assurance manuals. Monographs and high level educational material, such as graduate texts, are also published in this series.

IAEA HUMAN HEALTH REPORTS

Human Health Reports complement information published in the IAEA Human Health Series in areas of radiation medicine, dosimetry and medical radiation physics, and nutrition. These publications include reports of technical meetings, the results of IAEA coordinated research projects, interim reports on IAEA projects, and educational material compiled for IAEA training courses dealing with human health related subjects. In some cases, these reports may provide supporting material relating to publications issued in the IAEA Human Health Series.

All of these publications can be downloaded cost free from the IAEA web site:

http://www.iaea.org/Publications/index.html

Further information is available from:

Marketing and Sales Unit
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria

Readers are invited to provide their impressions on these publications. Information may be provided via the IAEA web site, by mail at the address given above, or by email to:

Official.Mail@iaea.org.

STAFFING IN RADIOTHERAPY: AN ACTIVITY BASED APPROACH

The following States are Members of the International Atomic Energy Agency:

AFGHANISTAN
ALBANIA
ALGERIA
ANGOLA
ARGENTINA
ARMENIA
AUSTRALIA
AUSTRIA
AZERBAIJAN
BAHAMAS
BAHRAIN
BANGLADESH
BELARUS
BELGIUM
BELIZE
BENIN
BOLIVIA, PLURINATIONAL STATE OF
BOSNIA AND HERZEGOVINA
BOTSWANA
BRAZIL
BRUNEI DARUSSALAM
BULGARIA
BURKINA FASO
BURUNDI
CAMBODIA
CAMEROON
CANADA
CENTRAL AFRICAN REPUBLIC
CHAD
CHILE
CHINA
COLOMBIA
CONGO
COSTA RICA
CÔTE D'IVOIRE
CROATIA
CUBA
CYPRUS
CZECH REPUBLIC
DEMOCRATIC REPUBLIC OF THE CONGO
DENMARK
DJIBOUTI
DOMINICA
DOMINICAN REPUBLIC
ECUADOR
EGYPT
EL SALVADOR
ERITREA
ESTONIA
ETHIOPIA
FIJI
FINLAND
FRANCE
GABON
GEORGIA
GERMANY
GHANA
GREECE
GUATEMALA
GUYANA
HAITI
HOLY SEE
HONDURAS
HUNGARY
ICELAND
INDIA
INDONESIA
IRAN, ISLAMIC REPUBLIC OF
IRAQ
IRELAND
ISRAEL
ITALY
JAMAICA
JAPAN
JORDAN
KAZAKHSTAN
KENYA
KOREA, REPUBLIC OF
KUWAIT
KYRGYZSTAN
LAO PEOPLE'S DEMOCRATIC REPUBLIC
LATVIA
LEBANON
LESOTHO
LIBERIA
LIBYA
LIECHTENSTEIN
LITHUANIA
LUXEMBOURG
MADAGASCAR
MALAWI
MALAYSIA
MALI
MALTA
MARSHALL ISLANDS
MAURITANIA
MAURITIUS
MEXICO
MONACO
MONGOLIA
MONTENEGRO
MOROCCO
MOZAMBIQUE
MYANMAR
NAMIBIA
NEPAL
NETHERLANDS
NEW ZEALAND
NICARAGUA
NIGER
NIGERIA
NORWAY
OMAN
PAKISTAN
PALAU
PANAMA
PAPUA NEW GUINEA
PARAGUAY
PERU
PHILIPPINES
POLAND
PORTUGAL
QATAR
REPUBLIC OF MOLDOVA
ROMANIA
RUSSIAN FEDERATION
RWANDA
SAN MARINO
SAUDI ARABIA
SENEGAL
SERBIA
SEYCHELLES
SIERRA LEONE
SINGAPORE
SLOVAKIA
SLOVENIA
SOUTH AFRICA
SPAIN
SRI LANKA
SUDAN
SWAZILAND
SWEDEN
SWITZERLAND
SYRIAN ARAB REPUBLIC
TAJIKISTAN
THAILAND
THE FORMER YUGOSLAV REPUBLIC OF MACEDONIA
TOGO
TRINIDAD AND TOBAGO
TUNISIA
TURKEY
UGANDA
UKRAINE
UNITED ARAB EMIRATES
UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND
UNITED REPUBLIC OF TANZANIA
UNITED STATES OF AMERICA
URUGUAY
UZBEKISTAN
VENEZUELA, BOLIVARIAN REPUBLIC OF
VIET NAM
YEMEN
ZAMBIA
ZIMBABWE

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world''.

IAEA HUMAN HEALTH REPORTS No. 13

STAFFING IN RADIOTHERAPY: AN ACTIVITY BASED APPROACH

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 2015

COPYRIGHT NOTICE

Marketing and Sales Unit, Publishing Section
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
fax: +43 1 2600 29302
tel.: +43 1 2600 22417
email: sales.publications@iaea.org
http://www.iaea.org/books

Printed by the IAEA in Austria
September 2015
STI/PUB/1705

FOREWORD

Radiotherapy is highly technologically dependent and requires competent professional staff to ensure safe and effective patient treatment and management. There is a need to provide guidelines that recommend appropriate staffing levels to support the initiation of new services as well as the expansion or upgrade of existing services. Simple upgrades or the replacement of existing equipment may have a significant impact on staffing needs. Similarly, the introduction of education and training programmes will require staffing adjustments.

All radiotherapy facilities should be staffed by radiation oncologists, medical physicists and technical personnel. In addition, appropriately trained support personnel are usually in attendance, such as nursing and administrative support. Staffing levels are dependent on the number and complexity of equipment, the number of patients, the types of procedures and activities and the number of students or trainees. A quantitative algorithm that proposes staffing levels based on all these factors requires an analysis of typical clinical workflow and a designation of professional roles to each of the activities that could be encountered. Non-clinical factors, such as academic activities, need to be considered in addition. The best evidence to be incorporated into such an algorithm would be based on surveys of detailed timekeeping of all types of staff performing each of the activities in a variety of environments. However, this is not practical in the radiotherapy environment, as rapid changes in technology result in a highly dynamic process in which techniques are introduced and refined all the time. In addition, different regions adopt different skill sets for the core professional groups and there is variability in the clinical presentation of patients at the individual level. As a result, activity based staffing levels are often based on benchmarking and expert consensus, if no evidence exists.

This publication introduces a calculation algorithm that has been developed to predict staffing levels based on inputs that are known or can be easily estimated. Economic and human resource constraints may affect the implementation of optimum staffing levels, and national regulatory requirements may differ, but the staffing algorithm presented here is not influenced by these factors. Variations in staffing requirements are influenced only by the data that need to be input into the algorithm, which reflect the technology sophistication and services implemented in each setting.

The present publication complements other IAEA publications used to support the initiation of basic radiation medicine services as defined in publications such as Setting up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, which was published in 2008.

The IAEA wishes to express its gratitude to D. van der Merwe (South Africa) and J. Van Dyk (Canada) for their major contribution to this document. The IAEA officers responsible for this publication were B. Healy and E. Zubizarreta of the Division of Human Health..

CONTENTS

1. INTRODUCTION 1

1.1. Background 1
1.2. Objective 1
1.3. Scope 1
1.4. Structure. 1

2. RADIOTHERAPY STAFFING ALGORITHM. 2

2.1. Introduction 2
2.2. Description of the algorithm 3
2.2.1. Therapeutic decision making and first consultation 3
2.2.2. External beam radiotherapy (EBRT) technique: Imaging, planning and first set-up 3
2.2.3. EBRT: Additional activities 4
2.2.4. Brachytherapy 5
2.2.5. Equipment (technology or areas). 5
2.2.6. Specific complex techniques 5
2.2.7. Other factors 6

3. WORKED EXAMPLES. 7

4. GUIDANCE 9

APPENDIX: NON-ZERO INPUT PARAMETERS FOR EXAMPLE FACILITIES 11

REFERENCES 15
CONTRIBUTORS TO DRAFTING AND REVIEW 17

1. INTRODUCTION

1.1. BACKGROUND

The International Atomic Energy Agency (IAEA) assists with the initiation, expansion and sustainability of radiotherapy services through technical cooperation projects. An important component of delivering radiotherapy services is staffing levels. There is very little evidence based documentation that precisely quantifies the number and type of professional(s) needed to support a service, a number that would also be directly related to patient workload, technology, techniques, procedures and infrastructure. As a result, the initiation of new radiotherapy services in low and middle income countries has traditionally been planned in accordance with IAEA guidelines, which list a suite of equipment constituting a basic service that is resourced by a core number of professionals who attend to a given patient workload [1–3]. These professionals, including radiation oncologists and medical physicists, are required for the practice of radiotherapy under the International Basic Safety Standards [4].

1.2. OBJECTIVE

The IAEA publications that suggest the minimum equipment and staffing levels needed to initiate or sustain basic radiotherapy services are rigid in that they do not take into account variations in techniques, technology and services. Also, major professional organizations in North America and Europe have published guidelines on minimum staffing levels in radiotherapy that are based solely on patient numbers [5–7]. It was recognized that a new algorithm should be developed to provide hospital managers, facility planners and policy makers, as well as radiotherapy departments with staffing guidelines that are more transparent, flexible and that allow for an expansion of existing services, a broader range of modalities and emerging technologies, and in so doing, maintain safe, effective and high quality patient care.

1.3. SCOPE

In order to ensure that a useful universal algorithm could be developed, it was ultimately decided to forego detail in favour of ensuring that the algorithm was easy to use. This meant that several different kinds of activities have been collapsed into broader categories. In all cases, the grouping of procedures, activities or equipment was only performed after it had been established that they all had the same impact on the final result.

Additional human resources need to be allocated to the number of professional staff for non-clinical activities such as administration, auditing, management and continuing education, and further personnel are needed to support an educational environment, which includes the fulltime equivalent staff complement assigned to didactic teaching, clinical training programmes and clinical development and research. The algorithm requires the user to estimate the human resources allocated for non-clinical activities.

The economic status, human resource constraints and regulatory variations may affect implementation of optimum staffing levels but the staffing guidelines presented here are not influenced by these conditions. It is clearly recognized that there are differences across regions; however, continuous striving towards optimal staffing levels is considered a key element to ensure and maintain standards of safety and quality in radiotherapy services. Inadequate staffing has been identified as one of the significant root causes of errors in radiotherapy [8, 9].

1.4. STRUCTURE

The new algorithm was implemented in a spreadsheet (Microsoft Excel format, but the file can be opened in various other spreadsheet programs) and is a tool for determining staffing levels. The details of the algorithm are described in Section 2 and the spreadsheet is provided on this CD-ROM. This spreadsheet requires the user to define the local working conditions and to estimate the workload, number of pieces of equipment and modalities, the number of procedures and the techniques to be employed. The specific user inputs required were considered to be readily available to users of the tool, or alternatively, possible to estimate from other indicators such as the patient population and disease incidence.

The tool was also tested using statistics from departments covering a wide range of settings and resources. The results are given in Section 3, and final guidance is given in Section 4.

2. RADIOTHERAPY STAFFING ALGORITHM

2.1. INTRODUCTION

Staffing levels in the clinical environment are not only important for planning and budgetary purposes and fundamental to quality patient care and safety, but they are often also specified for practice accreditation purposes and professional credentialing. The estimation of reasonable staffing levels to support radiotherapy services has often been loosely based on patient population size, infrastructure, equipment availability and disease incidence. Retrospective subjective estimates based on existing practice are often the benchmark for predicting future staffing needs locally. Detailed measurements of how long each procedure and activity takes to perform are probably the most objective basic evidence required to estimate fulltime equivalent staffing levels [10–13]. Such measurements are logically more useful and valid if they are performed in a variety of clinics, for a range of services and applied to professionals with a wide range of experience. There is likely to be bias in these documents due to work practices that are shaped by national economic and cultural norms. Median values obtained from national surveys have been used extensively to support medical physics staffing levels in North America [10–12]. Multinational studies have also been published [14–16].

It is unlikely that accurate time estimations of every possible procedure and activity can be obtained, as this is clearly an onerous activity. Also, new procedures are developed all the time and new technology is being introduced at an increasing rate. The activities associated with each procedure are therefore recognized as very dynamic measurands. Consequently, any workload staffing survey will always lag behind emerging technological developments by a considerable degree. When time estimates are not available, benchmarking against similar activities is an alternative, and professional expert consensus is the next best option.

Often, activities need to be grouped because some activities can only be performed safely if they are attended to by more than one person, such as treatment delivery. In some cases, more than one type of professional may need to be in attendance during a single procedure. On the other hand, not all procedures involve professional activities that are directly linked to equipment utilization.

In order to produce a universal guideline, agreement is necessary on the respective roles and responsibilities of each member of the professional team. Skill sets and competencies can vary significantly in different Member States. For instance, treatment planning is performed by medical dosimetrists in North America, who are a recognized professional group in the region. There are only a few other countries that have adopted this profession within their workforce, so in other regions, the equivalent competencies are performed by medical physicists, radiation therapists or radiation oncologists. As a result, ‘services’ better describe the staffing needs.

Differences in the terms and conditions of service are other variables. The number of working hours per week, annual leave days and the number of public holidays, for instance, differ substantially between countries. As a result, the algorithm includes the ability to adjust the definition of fulltime equivalent staff to local conditions.

A radiotherapy service is provided primarily by three professional groups: radiation oncologists, medical physicists and radiation therapists with additional support services provided by radiation oncology nurses, mechanical and electrical engineers and information technology (IT) experts. Optimal radiotherapy is only delivered when these professionals work together as a team to achieve a seamless process. The roles and responsibilities of these professionals are defined elsewhere [2, 17].

This algorithm represents an activity based approach to defining staffing levels and attempts to capture all activities over the entire radiotherapy workflow: patient related activities (all clinical assessments including follow-up, external beam and brachytherapy activities, and indirect patient care such as tumour boards), equipment related activities (including quality control procedures), specific complex techniques, educational and other non-clinical activities. Each activity has a total activity time in hours per activity (column F in the spreadsheet) and is ultimately assigned a total number of person-hours (column AE). Each category of staff is assigned a factor of total activity time (*F*) which links their input to that activity. As many countries allocate more than two radiation therapists per EBRT treatment machine, cell N10 gives the possibility to choose between two and five radiation therapists per machine. This factor only applies to procedures on EBRT treatment machines. Total person-hours are the sum over all the professional categories assigned to an activity. The user defined number of working hours per day or per week accounting for annual leave (minus non-RT-treatment-related working hours — overhead) is used to define fulltime equivalence (FTE).

The individually identified procedures related to the workflow in a radiation oncology unit are listed vertically in column A. The personnel carrying out the activities have been categorized by service rather than profession as it is acknowledged that different professionals may carry out the same activity in different countries. In this way, the algorithm has been designed to offer maximum flexibility. The services defined are: radiation oncology, medical physics, radiotherapy, treatment planning, radiation oncology nursing, information technology, mechanical engineering and electronics engineering. The service group 'treatment planning' was introduced to provide flexibility for departments which recognize medical dosimetrists on the one hand, and for those in which radiation therapists or medical physicists perform this activity on the other.

Each activity has been defined in terms of an estimated total time frame within which it can be realistically completed based on best evidence or consensus based practice. The time has been further subdivided into the services typically attending to these activities. In this way, the time spent by each type of professional is estimated. The number of patients and the number of overall treatment sessions are entered by the user, and the entries indirectly reflect the technology and complexity level of the department practice. Estimates of time frame were taken from publications [12, 18–22] or expert advice.

The algorithm focuses on the routine practice found in most departments. Advanced technologies such as particle therapy, robotic radiotherapy, stereotactic radiosurgery and helical tomotherapy were not considered.

2.2. DESCRIPTION OF THE ALGORITHM

2.2.1. Therapeutic decision making and first consultation

This activity is carried out by the radiation oncologist, and may be carried out face to face or through a telephone discussion with the referring clinician. During this process, the radiation oncologist makes the decision as to whether radiotherapy is appropriate for the patient in question. Typically, the radiation oncology nurse assists at the first consultation in outlining the treatment process to the patient, and this activity is reflected in the algorithm.

During this activity, the radiation oncologist assesses the patient together with all available clinical, imaging and pathology data and decides on the best approach to treatment. The treatment options are then discussed with the patient and informed consent is obtained.

The input includes the total number of consultations per year, including the number of patients who only receive brachytherapy or those who are clinically assessed but do not receive radiotherapy or patients that are referred for a second course of treatment.

2.2.2. External beam radiotherapy (EBRT) technique: Imaging, planning and first set-up

It was found that many activities associated with patient preparation and treatment planning for external beam radiotherapy could be collapsed into one row based on the technique of radiotherapy offered. The procedures arising, commencing with the decision to prescribe radiotherapy, are dependent on the number of cases, and are included in this subsection. The user therefore decides what number of patients will receive 2-D, 2-D + TP (treatment planning), 3-D, IMRT or 4-D radiotherapy per year. The activities that are included in 2-D radiotherapy are conventional fluoroscopic simulation, field delineation on the subsequent images or clinical mark-up on the patient, the manual calculation of the treatment times and the first set-up. 2-D + TP includes the use of at least a single contour (manual or CT) in order to produce a basic isodose distribution and calculate the treatment times. It also includes treatment plan approval, simulation and verification of the treatment plan, and the first set-up. 3-D includes CT simulation, contouring of the volumes, treatment planning, treatment plan approval, simulation and verification of the treatment plan, and the first set-up. IMRT and 4-D include the same activities as 3-D;

however, the activity time is different. All activity times also include the independent check of the approved dose plan. 4-D may include an IMRT technique but patients should not be double counted under IMRT.

2.2.3. EBRT: Additional activities

2.2.3.1. Patient positioning and immobilization for EBRT

The optimum patient position and immobilization method to achieve the desired treatment goal is selected and the necessary reference marking completed. The algorithm divides this process into three categories: simple, using standard immobilization devices (e.g. breast board), customized (e.g. thermoplastic masks) and complex, which includes stereotactic fixation frames. The sum of these procedures may not necessarily be equal to the total number of cases; for example, clinical markups with no positioning or immobilization aids are already considered under the technique.

2.2.3.2. Additional image acquisition for EBRT and activities related to target volume definition

Since image acquisition and target volume delineation are included in the workflow during imaging, planning and first set-up, these procedures refer to the use of additional modalities in order to improve the target definition, for example, MRI and PET/CT studies.

2.2.3.3. Block cutting and accessories

This activity includes fabrication of treatment aids, construction of custom blocks, compensating filters and any other beam modifying devices as necessary. The total number of devices that are manufactured per year needs to be entered here.

2.2.3.4. Treatment delivery

Treatment delivery includes all activities that occur while a patient is on treatment. The activities have been listed separately in order to adapt the algorithm to local institutional policies and relate the workload to complexity.

A wide range of practices are in place for imaging during treatment and are dictated largely by locally available resources and policy. The most common methods currently in use are included, i.e. the number of portal imaging sessions per year and the procedures to follow daily image guidance procedures. For instance, the total number of imaging procedures from patients receiving daily imaging for the first week, followed by weekly imaging, would have to be averaged over all such patients in a year. There is no distinction made between different types of in-room imaging, for example portal imaging vs. kilovoltage (kV) radiographs vs. cone-beam CT. The fundamental difference in the algorithm between portal imaging sessions and daily image guidance procedures is the involvement of the radiation oncologist. It is assumed that the radiation oncologist will review and approve all in-room images but different factors are applied for portal imaging vs. daily image guidance. The number of in vivo dosimetry procedures per annum is then entered.

Three different treatment time slots (1, 2 and 3 slots or appointments) have been defined to capture the time that the patient is in the treatment room. In addition, 4-D and SBRT appear separately, noting that the session must only be counted once; for example, an SBRT patient may be receiving 4-D treatment and should then only be counted against a SBRT session, and vice versa. The product of the total number of fractions (treatment sessions) and the number of patients per annum must be entered against each type of appointment. One time slot is equivalent to 12 minutes and the presence of a minimum of two radiation therapists is mandatory at the external beam treatment units. The number of radiation therapists per treatment machine can vary between two and five.

Adaptive radiotherapy implies that there is regular monitoring of the patient with IGRT, which may result in re-optimization of the treatment plan during the course of treatment if there are significant changes in the patient or disease. In the spreadsheet, there is no separate procedure for this and the average number of additional sessions should be included in the imaging, planning, first set-up and treatment procedures.

‘Chart checks’ refers to the time taken for regular control of the treatment charts to confirm the delivered dose per fraction, the total dose to date, that quality control activities were performed, that patient review was carried out and that any changes that were made to the set-up or prescription have been considered.

‘Evaluation during treatment’ refers to the clinical evaluation of tumour response and assessment of the patient during a course of treatment. For in-patients, this may take place daily on ward rounds but for outpatients this is often performed as a weekly review consultation. It was found that the overall total time dedicated to on treatment review was the same for in- and out-patients [22].

2.2.4. Brachytherapy

Brachytherapy insertions have been defined in terms of their complexity ranging from a simple insertion with a rigid applicator for cervical cancer, for instance, to a complex procedure, to a permanent prostate seed implant. The time allocation is consistent with complexity.

Image acquisition is the same as for EBRT with the exception of the pre-insertion ultrasound, which is specific to permanent prostate seed implants. The most commonly used methods have been listed separately.

The times for treatment planning of brachytherapy procedures reflect the level of complexity of the procedure. In some instances, planning will be carried out simultaneously with the insertion procedure, as in the case of permanent prostate seed implant, which is called prostate pre- and post-plan.

HDR brachytherapy delivery is the average number of fractions multiplied by the number of patients per year. Applicator removal and patient recovery reflects the time spent by the radiation oncologist in removing the applicator. The patient recovery time in the radiotherapy area, including radiation oncology nursing support, is also calculated in this field. If the recovery area is in a ward with different nursing support, then the number of radiation oncology nurses must be reduced. It is assumed that patients receiving LDR treatment are not attended to by specialized oncology nursing services. For brachytherapy applications, it is assumed that one radiation therapist is present for all imaging procedures and is in attendance during the actual treatment.

2.2.5. Equipment (technology or areas)

The full range of equipment used in radiotherapy is included in this list. The activity hours per year related to each piece of equipment includes initial commissioning, all routine quality control, and maintenance activities. The time dedicated to these activities per year have been assumed to be the same regardless of the replacement interval of the equipment. Even though national recommendations for regular upgrading, updating or replacement of equipment (hardware and software) [23] may exist, it is assumed that older equipment will be subject to major breakdowns and therefore the annual medical physics and engineering support will remain the same overall. Only the number of medical physics, engineering and IT support staff are linked to the number of pieces of equipment. The number of individual pieces of equipment, systems, complements or areas is required as a user input. The number of rows has been collapsed when different equipment has similar total time and time per type of service.

2.2.6. Specific complex techniques

The input for highly complex techniques requires the actual number of procedures performed per year. Stereotactic radiosurgery (SRS) refers to a single fraction application and includes all activities including fitting the frame, treatment planning and calculation, machine specific QC, treatment delivery and patient support.

Total body irradiation (TBI) can be delivered as a single fraction or multiple fractions. Each patient session must be included. The time includes pre-treatment measurements and dosimetry calculations, treatment delivery and patient support.

Intraoperative radiotherapy (IORT) is limited to a smaller number of departments. The intraoperative radiotherapy unit may be housed in a dedicated treatment area or may be stored in an existing linear accelerator bunker and used at dedicated times during the week. The total activity time includes allocations for radiotherapy staff to attend theatre sessions outside the department, to carry out machine preparation, dose planning, calculations and treatment delivery.

Total skin electron treatment (TSET) is usually carried out in a limited number of specialist centres with the necessary expertise in this treatment. The input is the number of patients per annum (and not the number of fractions or sessions). The activity time allocated reflects the complexity of the dosimetry, patient preparation and treatment delivery.

2.2.7. Other factors

The input required is the maximum percentage of time dedicated to the activity by any single category or service. The factors in the spreadsheet are adjusted (between 0 and 1) to reflect the extent to which other categories of service are involved in that particular activity.

'Follow-up evaluations' refers to patient follow-up, both immediately following treatment and in the longer term. It does not refer to follow-up carried out by a non-radiotherapy professional such as the referring surgeon. Since most radiation oncologists dedicate a known number of hours to follow-up clinics, the input is most easily estimated as a percentage of their time. The assumption is that they are assisted by radiation oncology nurses.

Indirect patient care (including peer review and attendance at multidisciplinary clinics or tumour boards) refers to the multidisciplinary meetings attended primarily by the radiation oncologists where the initial treatment decision is taken. This can also refer to other interdisciplinary meetings where new patient plans are discussed prior to treatment, films are reviewed, morbidity and mortality is discussed, and so on, and such meetings would also be attended by medical physicists, treatment planners and/or radiation therapists [22].

Research and development work goes beyond the implementation of techniques developed by others and includes development of new clinical techniques, new technologies and new treatment protocols. This activity includes all the related activities associated with participation in a clinical trial. There will be a wide variation depending on the scope and complexity of the individual trials and the data to be collected. Where departments have data managers employed outside the professional disciplines listed, they should be added to the personnel. All centres may be involved in some level of research but it is anticipated that the workload will be higher in academic centres. Students may also be completing research projects associated with their education programmes and may require additional assistance and support. Medical physics staff may be involved in the development of specific software to be used in the department. Ideally, a measurement should be made of the percentage of time that is dedicated to this type of work. This may be an ongoing component of the medical physics service or it may be a one off activity.

Classroom teaching includes time allocated to education and training of students and residents/registrars. The number and the discipline of the attending students and residents/registrars will vary significantly between academic and non-academic centres. Teaching students and residents/registrars requires a substantial time commitment and this should not be underestimated when calculating workload and staffing levels. Education can include giving lectures, demonstrations or tutorials in an academic setting, and also the clinical education of students and residents/registrars on clinical placement in the department. If assessment of students or residents/registrars is also required, this can take significantly more time.

'Administration — management' (including internal audits) relates to additional administrative responsibilities held within the department. Where there is a designated manager with responsibility for an area, this is a specific position rather than an additional activity, but must be accounted for when calculating the overall staffing levels.

Internal audit should be a continuous activity with the aim of having significant parts of the overall audit programme covered once a year. Internal audit is useful to address a range of individual topics on an ongoing basis. It requires a significant time commitment from all disciplines, but especially from the medical physics service.

All staff should be encouraged to participate in continuing education and this has an additional impact on staffing levels, and the percentage of time allocated to this activity is used in the calculation. The percentage should consider the annual requirement for continuing education for maintaining national registration if applicable, or an approximation of the time needed to remain competent. An accurate assessment of the time involved is necessary to ensure that a full complement of staff is present at all times during normal working hours. Where staff are actively involved in developing or delivering continuing education courses or sessions, additional time should be factored in.

Radiation safety activities include attendance at radiation safety and quality assurance committee meetings, and radiation safety training. Attendance at radiation safety and quality assurance committee meetings is advisable for all staff and is essential to maintain a safe environment for both staff and patients. Time to attend these meetings and to carry out any subsequent activities are factored into the staffing calculations for all five professional services.

Radiation safety training is usually required for all staff working in a radiotherapy environment and the percentage of time allocated can be entered in this field. 'Other' refers to any non-patient contact activity that has not been captured above. This could include benefits that are specific to a region or country.

3. WORKED EXAMPLES

The algorithm has been tested by a number of centres and the feedback received was varied. Most respondents however, only compared their existing staffing levels with the output of the tool and therefore implicitly assumed that their local resources were a true reflection of optimal practice.

Clearly, the results for environments that require for instance, more than two radiation therapists to operate treatment or imaging equipment, will result in an underestimation of staffing. This was revealed in pilot tests performed on North American and United Kingdom facilities, for instance, where national skill sets, work practice and legislation are different in this respect. The option to modify the number of radiation therapists per teletherapy machine was introduced for this reason. In addition, when medical physicists perform some or all the treatment planning activities, their number will be underestimated and the number of treatment planners should be added to the medical physics staffing.

On the other hand, the medical physics annual hours dedicated to equipment are based on the measured median quality assurance effort time per year, assuming annual re-commissioning checks and a catastrophic failure event on the treatment units requiring complete re-commissioning every five years. The amortization and age of the equipment are therefore not embedded in the calculation. In some instances, this may overestimate the medical physics staffing levels, particularly if less intensive quality assurance programmes are maintained or if some quality control activities are delegated to the radiation therapists or engineers. However, it should be noted that medical physics service hours dedicated to both equipment and clinical activities as used by the algorithm are supported by most published evidence.

The basic radiotherapy service as defined in an IAEA publication on setting up a radiotherapy programme [2], consists of a single energy megavoltage unit, an orthovoltage unit, a conventional simulator and access to a CT scanner, a HDR brachytherapy service with a treatment planning system and a C arm, a 3-D treatment planning system for external beam treatment, a mould room, a workshop and a basic suite of dosimetry equipment. The centre is assumed to service 500 new patients per year, 40% of whom are treated using 2-D techniques; 50% of patients receive a simple plan based on a contour and a basic calculation. It is assumed that 10% of patients receive customized immobilization followed by 3-D CT-based treatment planning for conformal radiotherapy treatment, and 400 accessories are produced overall. Brachytherapy is received by 200 patients, in addition to teletherapy, and all brachytherapy is assumed to be delivered in 3 fractions (600 applications). External beam treatment is delivered in 5000 slots (appointments or visits) of 12 minutes and 5000 slots of 24 minutes each (resulting in approximately 1.5 shifts of 8 h each per day). It is assumed that all patients receive in vivo dosimetry once during their external beam treatment and that there are two portal imaging checks per patient. The detailed parameters input to the staffing algorithm for the basic radiotherapy service are given in the Appendix (in Table 4). The IAEA recommends staffing levels for this service to be 4–5 radiation oncologists, 3–4 medical physicists, 7 radiation therapists and 3 oncology nurses [2]. The staffing level is shown in Table 1. It is therefore evident that the tool provides reasonable results for resource constrained low and middle income countries.

TABLE 1. EXAMPLE OF A BASIC RADIOTHERAPY SERVICE

Staff group	Radiation oncology	Medical physics	Radiotherapy	Treatment planning
RT planning and treatment related working time	46%	73%	77%	76%
Fulltime equivalent	4.0	2.9	6.5	0.3

A large academic facility in a middle income country was also considered. The facility is assumed to consist of 4 dual modality linear accelerators (1 with multileaf collimator and 2 with electronic portal imaging devices), 2 cobalt teletherapy units, 1 orthovoltage unit, 2 conventional simulators, 1 CT simulator, 2 high dose rate brachytherapy units, each with a dedicated treatment planning system and C arm, a 3-D external beam treatment planning system with up to 10 workstations, an integrated record and verify system (Intranet), a mould room, a workshop and a more extensive set of absolute and relative dosimetry equipment compared to the low income example. It is assumed that 2500 new patients per annum were treated, 1200 of whom were treated using 2-D techniques, 600 with basic contouring, 690 with 3-D CT based planning techniques and 10 with IMRT. 2500 accessories are manufactured, while 700 patients receive customized immobilization devices, and there are 1800 in vivo dosimetry procedures. There are 6000 portal imaging sessions, 41 600 single slot treatments and 16 500 double slot treatments (approximately 1 shift of 8 h on each treatment unit). It is assumed that 2600 brachytherapy procedures are delivered using a simple 2-D technique in addition to external beam treatment (i.e. 800 patients received 3 fractions each). The detailed parameters input to the staffing algorithm for this example are given in the Appendix (in Table 5). The staffing level calculated for this setting is shown in Table 2. The calculated number of medical physicists is in close agreement with a previous Australasian recommendation [13]. The number of courses per radiation oncologist was found to be approx. 170, which is below the traditional recommendation of 200–250 courses per radiation oncologist [2]; however, the significant workload of brachytherapy in this example justifies the increased number of radiation oncologists.

TABLE 2. EXAMPLE OF A LARGE ACADEMIC FACILITY IN A MIDDLE INCOME COUNTRY

Staff group	Radiation oncology	Medical physics	Radiotherapy	Treatment planning
RT planning and treatment related working time	61%	70%	83%	78%
Fulltime equivalent	14.8	11.4	30.4	2.4

A large academic facility in a high income country was also considered. The facility is equipped with 9 megavoltage treatment units, servicing 4000 new patients per annum, over 50% of whom are treated with IMRT or 4-D techniques. Specialized services such as SBRT (150 patients per annum), total body irradiation (12 patients per annum) and permanent prostate seed implants (50 patients per annum) were included. 1200 HDR brachytherapy procedures are delivered with two afterloaders, of which 700 have 3-D plans, most of those based on CT or MR imaging. The detailed parameters input to the staffing algorithm for this example are given in the Appendix (in Table 6). The calculated staffing levels are shown in Table 3. The number of medical physicists is in reasonable agreement with the Ontario staffing model [10].

TABLE 3. EXAMPLE OF A LARGE ACADEMIC FACILITY IN A HIGH INCOME COUNTRY

Staff group	Radiation oncology	Medical physics	Radiotherapy	Treatment planning
RT planning and treatment related working time	61%	70%	83%	78%
Fulltime equivalent	19.5	20.7	53.7	12.0

Note that the calculated fulltime equivalent for all staff groups is highly dependent on the percentage of time allocated to non-radiotherapy treatment related activities (i.e. those activities identified in 'other factors' in the last block of the spreadsheet). Tables 1 to 3 show the percentage of time for each staff group allocated to radiotherapy planning and treatment considered in the three worked examples. Departments should carefully consider the weighting of these other factors when applying the staffing algorithm.

4. GUIDANCE

Calculation of staffing levels based on the time needed to perform all activities in the radiotherapy department is preferable to the use of estimations based only on the number of patients per annum, especially when advanced and specialized techniques are used. The same applies to algorithms which only consider the number of treatment machines. Transition from simpler to advanced technologies does not necessarily result in a pro rata increase in staffing. Use of the staffing algorithm requires a certain level of understanding of radiotherapy practice because of the amount of detail required in inputting relevant parameters. The community would benefit from more evidence based time keeping studies as this would enhance the accuracy and reliability of the algorithm, especially in advanced technologies. This is a highly dynamic environment, however, and therefore a lag in evidence is to be expected.

Appendix

NON-ZERO INPUT PARAMETERS FOR EXAMPLE FACILITIES

TABLE 4. NON-ZERO INPUT PARAMETERS TO THE STAFFING ALGORITHM FOR THE EXAMPLE OF A BASIC RADIOTHERAPY SERVICE

Parameter	Value	Parameter	Value
Working hours per day	8	kV therapy — Co-60 — MV single energy	2
Working days per week	5	X ray — C arm	1
Annual leave (working days) + public holidays	40	Brachytherapy HDR — LDR	1
Number of consultations/y	500	Fluoroscopic sim — CT option on simulator — CT sim — CT option on LINAC	2
Number of cases/y: 2-D	200	3-D treatment planning system up to 10 workstations	1
Number of cases/y: 2-D + TP	250	Absolute dosimetry equipment	2
Number of cases/y: 3-D	50	Relative dosimetry equipment	1
Patient positioning/immobilization for EBRT: simple	250	Survey and monitoring equipment	1
Patient positioning/immobilization for EBRT: customized	50	In vivo dosimetry	1
Block cutting / accessories	400	Automatic/manual block cutter	1
Portal imaging sessions	1 000	Workshop (patient accessories, devices, etc.)	1
In vivo dosimetry	500	Follow-up evaluations	25%
Total No. fractions: 1 slot	5 000	Indirect patient care (tumour boards, etc.)	20%
Total No. fractions: 2 slots	5 000	Administration — management (incl. internal auditing)	5%
Chart check	2 000	Continuing education	4%
Evaluation during treatment	2 000	Radiation safety activities	6%
Brachytherapy insertion: simple	600		
Image acquisition brachytherapy: 2-D sim — CT sim 3-D	600		
Treatment planning brachytherapy: 2-D + (films)	600		
Brachytherapy delivery HDR	600		
Applicator removal / patient recovery	600		

TABLE 5. NON-ZERO INPUT PARAMETERS TO THE STAFFING ALGORITHM FOR THE EXAMPLE OF A LARGE ACADEMIC FACILITY IN A MIDDLE INCOME COUNTRY

Parameter	Value	Parameter	Value
Working hours per day	8	kV therapy — Co-60 — MV single energy	3
Working days per week	5	X ray — C arm	2
Annual leave (working days) + public holidays	40	MV multiple energies/modalities	4
Number of consultations/y	2 500	Complements (multileaf collimator, electronic portal imaging devices)	3
Number of cases/y: 2-D	1 200	Brachytherapy HDR — LDR	2
Number of cases/y: 2-D + TP	600	Fluoroscopic sim — CT option on simulator — CT sim — CT option on LINAC	3
Number of cases/y: 3-D	690	3-D treatment planning system up to 10 workstations	1
Number of cases/y: IMRT	10	R&V (record and verify) network / Intranet	1
Patient positioning/immobilization for EBRT: simple	1 800	Absolute dosimetry equipment	8
Patient positioning/immobilization for EBRT: customized	700	Relative dosimetry equipment	2
Additional image acquisition for EBRT: MRI and PET/CT	20	Survey and monitoring equipment	1
Addition activities related to treatment volume definition: Image fusion (PET/CT, MRS, etc.)	20	In vivo dosimetry	1
Block cutting/accessories	2 500	Automatic/manual block cutter	2
Portal imaging sessions	6 000	Workshop (patient accessories, devices etc.)	1
In vivo dosimetry	1 800	Total skin electron treatment	5
Total No. fractions: 1 slot	41 600	Follow-up evaluations	10%
Total No. fractions: 2 slots	16 500	Indirect patient care (tumour boards, etc.)	10%
Chart check	11 250	Research and development work	5%
Evaluation during treatment	11 250	Classroom teaching	5%
Brachytherapy insertion: simple	2 600	Administration — management (incl. internal auditing)	5%
Image acquisition brachytherapy: 2-D sim — CT sim 3-D	2 600	Continuing education	4%
Treatment planning brachytherapy: 2-D + (films)	2 600	Radiation safety activities	6%
Brachytherapy delivery HDR	2 600		
Applicator removal / patient recovery	2 600		

TABLE 6. NON-ZERO INPUT PARAMETERS TO THE STAFFING ALGORITHM FOR THE EXAMPLE OF A LARGE ACADEMIC FACILITY IN A HIGH INCOME COUNTRY

Parameter	Value	Parameter	Value
Working hours per day	8	Treatment planning brachytherapy: 2-D + (films)	500
Working days per week	5	Treatment planning brachytherapy: 3-D	700
Annual leave (working days) + public holidays	40	Treatment planning brachytherapy: Prostate pre- + post-plan	50
Number of consultations/y	4 000	Brachytherapy delivery HDR	1 200
Number of cases/y: 2-D	500	Applicators removal/patient recovery	1 200
Number of cases/y: 2-D + TP	500	kV therapy — Co-60 — MV single energy	4
Number of cases/y: 3-D	1 000	X ray — C arm	2
Number of cases/y: IMRT	1 800	MV multiple energies/modalities	6
Number of cases/y: 4-D	200	Complements (multileaf collimator / electronic portal imaging devices)	20
Patient positioning/immobilization for EBRT: simple	2 300	Fluoroscopic sim — CT option — CT sim — CT option on LINAC	8
Patient positioning/immobilization for EBRT: customized	1 000	Brachytherapy HDR — LDR	2
Patient positioning/immobilization for EBRT: complex	400	Fluoroscopic sim — CT option on simulator — CT sim — CT option on LINAC	3
Additional image acquisition for EBRT: MRI and PET/CT	200	3-D treatment planning system up to 10 workstations	2
Addition activities related to TV definition: Image fusion (PET/CT, MRS, etc.)	200	4-D treatment planning system up to 10 workstations	1
block cutting/accessories	1 500	MRI, PET/CT, 4-D CT Sim, SPECT-CT	2
Portal imaging sessions	16 000	R&V network/Intranet	1
Daily image guidance	3 000	Absolute dosimetry equipment	10
In vivo dosimetry	4 000	Relative dosimetry equipment	4
Total No. fractions: 1 slot	26 000	Survey and monitoring equipment	2
Total No. fractions: 2 slots	26 000	In vivo dosimetry	4
Total No. fractions: 3 slots	20 000	Automatic/manual block cutter	2
Total No. fractions: 4-D excluding SBRT	4 000	Workshop (patient accessories, devices, etc.)	1
Total No. fractions: SBRT	150	Total body irradiation	12

TABLE 6. NON-ZERO INPUT PARAMETERS TO THE STAFFING ALGORITHM FOR THE EXAMPLE OF A LARGE ACADEMIC FACILITY IN A HIGH INCOME COUNTRY (cont.)

Parameter	Value	Parameter	Value
Chart check	16 000	Follow-up evaluations	10%
Evaluation during treatment	16 000	Indirect patient care (tumour boards, etc.)	10%
Brachytherapy insertion: simple	1 000	Research and development work	5%
Brachytherapy insertion: complex	200	Classroom teaching	5%
Brachytherapy insertion: permanent prostate	50	Administration and management (incl. internal auditing)	5%
Image acquisition brachytherapy: 2-D sim – CT sim 3-D	700	Continuing education	4%
Image acquisition brachytherapy: MRI and PET/CT	500	Radiation safety activities	6%
Image acquisition brachytherapy: pre-insertion ultrasound	50		

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Planning National Radiotherapy Services: A Practical Tool, IAEA Human Health Series No. 14, IAEA, Vienna (2010).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Setting Up a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA, Vienna (2008).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement, Quality Assurance Team for Radiation Oncology (QUATRO), IAEA, Vienna (2007).

[4] EUROPEAN COMMISSION, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, UNITED NATIONS ENVIRONMENT PROGRAMME, WORLD HEALTH ORGANIZATION, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, IAEA Safety Standards Series No. GSR Part 3, IAEA, Vienna (2014).

[5] AMERICAN SOCIETY FOR RADIATION ONCOLOGY, Safety is No Accident: A Framework for Quality Radiation Oncology and Care, ASTRO, Fairfax, VA (2012).

[6] BENTZEN, S.M., et al., Towards evidence-based guidelines for radiotherapy infrastructure and staffing needs in Europe: The ESTRO QUARTS project, Radiother. Oncol. **75** (2005) 355–365.

[7] SLOTMAN, B.J., et al., Overview of national guidelines for infrastructure and staffing of radiotherapy. ESTRO-QUARTS: Work package 1, Radiother. Oncol. **75** (2005) 349–354.

[8] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Preventing Accidental Exposures from New External Beam Radiation Therapy Technologies, ICRP Publication No. 112, Elsevier, Oxford (2009).

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Lessons Learned from Accidental Exposures in Radiotherapy, Safety Reports Series No. 17, IAEA, Vienna (2000).

[10] BATTISTA, J.J., et al., Medical physics staffing for radiation oncology: A decade of experience in Ontario, Canada, J. Appl. Clin. Med. Phys. **13** (2012) 3704.

[11] ABT ASSOCIATES, The Abt Study of Medical Physicist Work Values for Radiation Oncology Physics Services: Round III, Abt Associates, Bethesda, MD (2008).

[12] ABT ASSOCIATES, The Abt Study of Medical Physicist Work Values for Radiation Oncology Physics Services: Round II, Abt Associates, Bethesda, MD (2003).

[13] OLIVER, L., FITCHEW, R., DREW, J., Requirements for radiation oncology physics in Australia and New Zealand, Australas. Phys. Eng. Sci. Med. **24** (2001) 1–18.

[14] ROUND, W.H., et al., AFOMP Policy statement No. 2: Recommended clinical radiation oncology medical physicist staffing levels in AFOMP countries, Australas. Phys. Eng. Sci. Med. **33** (2010) 7–10.

[15] THE EUROPEAN FEDERATION OF ORGANISATIONS FOR MEDICAL PHYSICS, Criteria for the Staffing Levels in a Medical Physics Department, Policy Statement No. 7, EFOMP, York (1997).

[16] BELLETTI, S., et al., Quality assurance in radiotherapy: The importance of medical physics staffing levels. Recommendations from an ESTRO/EFOMP joint task group, Radiother. Oncol. **41** (1996) 89–94.

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Roles and Responsibilities, and Education and Training Requirements for Clinically Qualified Medical Physicists, IAEA Human Health Series No. 25, IAEA, Vienna (2013).

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, El físico médico: Criterios y recomendaciones para su formación académica, entrenamiento clínico y certificación en América Latina, IAEA Human Health Reports Nº 1, IAEA, Vienna (2010).

[19] KLEIN, E.E., A grid to facilitate physics staffing justification, J Appl. Clin. Med. Phys. **11** (2010) 2987.

[20] THOMAS, S.J., VINALL, A., POYNTER, A., ROUTSIS, D., A multicentre timing study of intensity-modulated radiotherapy planning and delivery, Clin. Oncol. **22** (2010) 658–665.

[21] HOLMBERG, O., McCLEAN, B., A method of predicting workload and staffing level for radiotherapy treatment planning as plan complexity changes, Clin. Oncol. **15** (2003) 359–363.

[22] CANADIAN ASSOCIATION OF RADIATION ONCOLOGY, Canadian Radiation Oncologists Manpower Study Report CARO, Markham, ON (1999).

[23] NATIONAL RADIOTHERAPY ADVISORY GROUP, Radiotherapy: Developing a World Class Service for England, Report to Ministers from National Radiotherapy Advisory Group, Association of Healthcare Technology Providers for Imaging, Radiotherapy and Care, London (2007).

CONTRIBUTORS TO DRAFTING AND REVIEW

Alfonso, R.	International Atomic Energy Agency
Beardmore, C.	Society of Radiographers, United Kingdom
Christofides, S.	European Federation of Organisations for Medical Physics — International Organization for Medical Physics
Coffey, M.	St. James's Hospital, Ireland
Healy, B.	International Atomic Energy Agency
Holmberg, O.	International Atomic Energy Agency
Lievens, Y.	Ghent University, Belgium
Meghzifene, A.	International Atomic Energy Agency
Mills, M.	Brown Cancer Center, United States of America
Rosenblatt, E.	International Atomic Energy Agency
Scalliet, P.	Cliniques Universitaires St. Luc, Belgium
van der Merwe, D.	International Atomic Energy Agency
Van Dyk, J.	International Atomic Energy Agency
Zubizarreta, E.	International Atomic Energy Agency

Consultants Meeting

Vienna, Austria: 31 January–4 February 2011

Technical Meeting

Vienna, Austria: 31 October–4 November 2011

IAEA
International Atomic Energy Agency

No. 23

ORDERING LOCALLY

In the following countries, IAEA priced publications may be purchased from the sources listed below or from major local booksellers.

Orders for unpriced publications should be made directly to the IAEA. The contact details are given at the end of this list.

AUSTRALIA
DA Information Services
648 Whitehorse Road, Mitcham, VIC 3132, AUSTRALIA
Telephone: +61 3 9210 7777 • Fax: +61 3 9210 7788
Email: books@dadirect.com.au • Web site: http://www.dadirect.com.au

BELGIUM
Jean de Lannoy
Avenue du Roi 202, 1190 Brussels, BELGIUM
Telephone: +32 2 5384 308 • Fax: +32 2 5380 841
Email: jean.de.lannoy@euronet.be • Web site: http://www.jean-de-lannoy.be

CANADA
Renouf Publishing Co. Ltd.
5369 Canotek Road, Ottawa, ON K1J 9J3, CANADA
Telephone: +1 613 745 2665 • Fax: +1 643 745 7660
Email: order@renoufbooks.com • Web site: http://www.renoufbooks.com

Bernan Associates
4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4391, USA
Telephone: +1 800 865 3457 • Fax: +1 800 865 3450
Email: orders@bernan.com • Web site: http://www.bernan.com

CZECH REPUBLIC
Suweco CZ, spol. S.r.o.
Klecakova 347, 180 21 Prague 9, CZECH REPUBLIC
Telephone: +420 242 459 202 • Fax: +420 242 459 203
Email: nakup@suweco.cz • Web site: http://www.suweco.cz

FINLAND
Akateeminen Kirjakauppa
PO Box 128 (Keskuskatu 1), 00101 Helsinki, FINLAND
Telephone: +358 9 121 41 • Fax: +358 9 121 4450
Email: akatilaus@akateeminen.com • Web site: http://www.akateeminen.com

FRANCE
Form-Edit
5 rue Janssen, PO Box 25, 75921 Paris CEDEX, FRANCE
Telephone: +33 1 42 01 49 49 • Fax: +33 1 42 01 90 90
Email: fabien.boucard@formedit.fr • Web site: http://www.formedit.fr

Lavoisier SAS
14 rue de Provigny, 94236 Cachan CEDEX, FRANCE
Telephone: +33 1 47 40 67 00 • Fax: +33 1 47 40 67 02
Email: livres@lavoisier.fr • Web site: http://www.lavoisier.fr

L'Appel du livre
99 rue de Charonne, 75011 Paris, FRANCE
Telephone: +33 1 43 07 50 80 • Fax: +33 1 43 07 50 80
Email: livres@appeldulivre.fr • Web site: http://www.appeldulivre.fr

GERMANY
Goethe Buchhandlung Teubig GmbH
Schweitzer Fachinformationen
Willstätterstrasse 15, 40549 Düsseldorf, GERMANY
Telephone: +49 (0) 211 49 8740 • Fax: +49 (0) 211 49 87428
Email: s.dehaan@schweitzer-online.de • Web site: http://www.goethebuch.de

HUNGARY
Librotrade Ltd., Book Import
PF 126, 1656 Budapest, HUNGARY
Telephone: +36 1 257 7777 • Fax: +36 1 257 7472
Email: books@librotrade.hu • Web site: http://www.librotrade.hu

INDIA
Allied Publishers
1st Floor, Dubash House, 15, J.N. Heredi Marg, Ballard Estate, Mumbai 400001, INDIA
Telephone: +91 22 2261 7926/27 • Fax: +91 22 2261 7928
Email: alliedpl@vsnl.com • Web site: http://www.alliedpublishers.com

Bookwell
3/79 Nirankari, Delhi 110009, INDIA
Telephone: +91 11 2760 1283/4536
Email: bkwell@nde.vsnl.net.in • Web site: http://www.bookwellindia.com

ITALY
Libreria Scientifica "AEIOU"
Via Vincenzo Maria Coronelli 6, 20146 Milan, ITALY
Telephone: +39 02 48 95 45 52 • Fax: +39 02 48 95 45 48
Email: info@libreriaaeiou.eu • Web site: http://www.libreriaaeiou.eu

JAPAN
Maruzen Co., Ltd.
1-9-18 Kaigan, Minato-ku, Tokyo 105-0022, JAPAN
Telephone: +81 3 6367 6047 • Fax: +81 3 6367 6160
Email: journal@maruzen.co.jp • Web site: http://maruzen.co.jp

NETHERLANDS
Martinus Nijhoff International
Koraalrood 50, Postbus 1853, 2700 CZ Zoetermeer, NETHERLANDS
Telephone: +31 793 684 400 • Fax: +31 793 615 698
Email: info@nijhoff.nl • Web site: http://www.nijhoff.nl

SLOVENIA
Cankarjeva Zalozba dd
Kopitarjeva 2, 1515 Ljubljana, SLOVENIA
Telephone: +386 1 432 31 44 • Fax: +386 1 230 14 35
Email: import.books@cankarjeva-z.si • Web site: http://www.mladinska.com/cankarjeva_zalozba

SPAIN
Diaz de Santos, S.A.
Librerias Bookshop • Departamento de pedidos
Calle Albasanz 2, esquina Hermanos Garcia Noblejas 21, 28037 Madrid, SPAIN
Telephone: +34 917 43 48 90 • Fax: +34 917 43 4023
Email: compras@diazdesantos.es • Web site: http://www.diazdesantos.es

UNITED KINGDOM
The Stationery Office Ltd. (TSO)
PO Box 29, Norwich, Norfolk, NR3 1PD, UNITED KINGDOM
Telephone: +44 870 600 5552
Email (orders): books.orders@tso.co.uk • (enquiries): book.enquiries@tso.co.uk • Web site: http://www.tso.co.uk

UNITED STATES OF AMERICA
Bernan Associates
4501 Forbes Blvd., Suite 200, Lanham, MD 20706-4391, USA
Telephone: +1 800 865 3457 • Fax: +1 800 865 3450
Email: orders@bernan.com • Web site: http://www.bernan.com

Renouf Publishing Co. Ltd.
812 Proctor Avenue, Ogdensburg, NY 13669, USA
Telephone: +1 888 551 7470 • Fax: +1 888 551 7471
Email: orders@renoufbooks.com • Web site: http://www.renoufbooks.com

United Nations
300 East 42nd Street, IN-919J, New York, NY 1001, USA
Telephone: +1 212 963 8302 • Fax: 1 212 963 3489
Email: publications@un.org • Web site: http://www.unp.un.org

Orders for both priced and unpriced publications may be addressed directly to:

IAEA Publishing Section, Marketing and Sales Unit, International Atomic Energy Agency
Vienna International Centre, PO Box 100, 1400 Vienna, Austria
Telephone: +43 1 2600 22529 or 22488 • Fax: +43 1 2600 29302
Email: sales.publications@iaea.org • Web site: http://www.iaea.org/books

15-15271

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA
ISBN 978–92–0–156715–4
ISSN 2412–2955