REVIEW OF THE DIFFERENT ACCELERATOR BASED-BNCT FACILITIES WORLDWIDE AND AN ASSESSMENT ACCORDING TO THE ALARA CRITERION.

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Presently, there are a number of different facilities for Accelerator-Based BNCT (AB-BNCT) worldwide, some already working and even treating patients and some under development and construction. They range from high-energy 30 MeV cyclotrons (using the ^{9}Be(p,n) reaction), medium-energy RFQ-DTL accelerators (at 8 and 10 MeV using likewise the ^{9}Be(p,n) reaction), low-energy electrostatic, both Tandem and single-ended, and RFQ machines (working on ^{7}Li(p,n) at about 2.5 MeV), to a very low-energy electrostatic quadrupole accelerator (working on ^{9}Be(d,n) or ^{13}C(d,n) at 1.45 MeV). We shall briefly describe this last accelerator which is being developed at the National Atomic Energy Commission of Argentina.

In this presentation we will analyze and discuss these installations from the point of view of activation, both at the target and beamline (by the primary beam + neutrons) and also at the level of the Beam Shaping Assembly and other exposed materials in surrounding areas (by neutrons). Since these facilities are intended to work in hospital environments one of the guiding criteria should be the ALARA (As Low As Reasonably Achievable) one. We have followed the IAEA RS-G 1.7 Safety Guide, Application of the Concepts of Exclusion, Exemption and Clearance**,** which recommends limits on the specific activities produced (in Bq/g), to assess the long-term operation sustainability from the point of view of activation.

A thorough analysis using MCNP simulations on the basis of the existing data bases is made evaluating the residual radioactivity produced both by the primary beam and induced nuclear reactions at the target and beam line, and also by the generated neutrons in the surrounding areas like Beam Shaping Assembly, shielding materials and patient treatment room.

We have analyzed the production of residual radioactivity in a representative group of AB-BNCT facilities, mainly for two subsystems: 1. Activation of the target due to the primary beam (p or d). 2. Activation of the Beam Shaping Assembly (BSA).
In particular we present in Table 1 results for the induced target activity (accumulated over 1 year operation) due to primary nuclear reactions at the target.

TABLE 1. INDUCED RADIOACTIVITY IN THE RESPECTIVE TARGETS FOR THE LISTED REACTIONS AT INDICATED BEAM ENERGY AND CURRENT

^{7}Li+p 2.3MeV 30mA	^{9}Be+p 8MeV 10mA	^{9}Be+p 30MeV 1mA	^{9}Be+d 1.45MeV 30mA	^{13}C+d 1.45MeV 30mA
5.7TBq/y (7Be)	Only prompt radiation	1.2TBq/y(7Be) 51GBq/y (tritium)	54GBq/y (tritium)	9.3GBq/y (tritium) 8GBq/y (^{14}C)

There are other sources of residual radioactivity that have been analyzed here:

(a) Target Backing materials & target assembly: e.g., Copper. Several exothermic and low-threshold neutron-induced reactions generate intermediate and long-lived radionuclides (e.g., ^{64}Cu: $T_{½}$ =12.701 h, ^{63}Ni: T ½ =101.2 y, ^{60}Co: T ½ =5.272 y, etc.).

(b) Beamline and accelerator parts (especially for intermediate and high energy beams): Proton scattering on the residual gas. Beam energies are higher than Coulomb Barriers of several elements of the beamline leading to activation (e.g., Copper: ^{65}Cu(p,n)^{65}Zn, T ½ =243.93 d).

This paper contributes to an optimization and assessment of the sustainability of different facilities, particularly considering that they are intended to work in hospital environments.