Assessment of the engineering barriers shielding effectiveness from radioactive waste disposed of in an industrial waste disposal facility at Ignalina NPP

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Keywords: Radioactive waste, specific clearance, industrial waste disposal facility, radiation

Introduction:

Industrial waste (IW) generated during operation of Ignalina Nuclear Power Plant (Ignalina NPP) was disposed of in an IW disposal facility (dumps). The facility is located inside the controlled area of the Ignalina NPP. The IW disposal was stopped in 2014 when approximately 20 000 t of the waste was already placed. At the time of disposal, according to the Soviet Union regulations, the waste was considered as non-radioactive waste. Due to changes in the regulatory requirements, part of the waste was reclassified to very low-level radioactive waste. Development of specific clearance levels is required for the waste clearance and conversion of the IW disposal facility into a conventional waste disposal facility [1]. It is also important to evaluate shielding effectiveness of the existing engineered barriers and necessity for their upgrading.

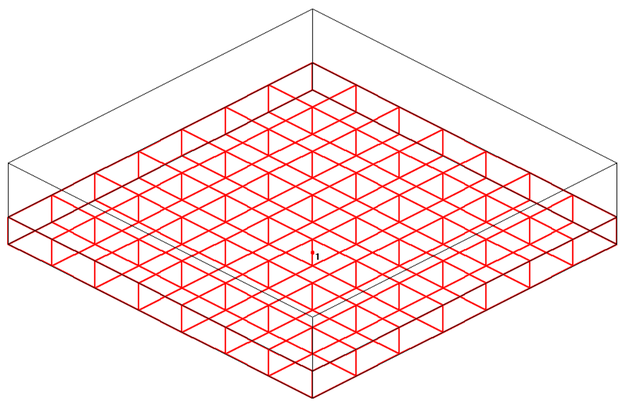

Fig. 1 The 3D model of IW layer (49 IW elements) with protective layer

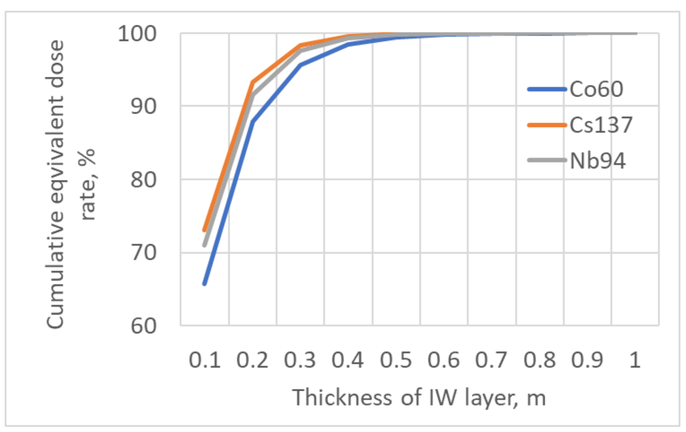

Fig. 2 The influence of the thickness of the IW layer

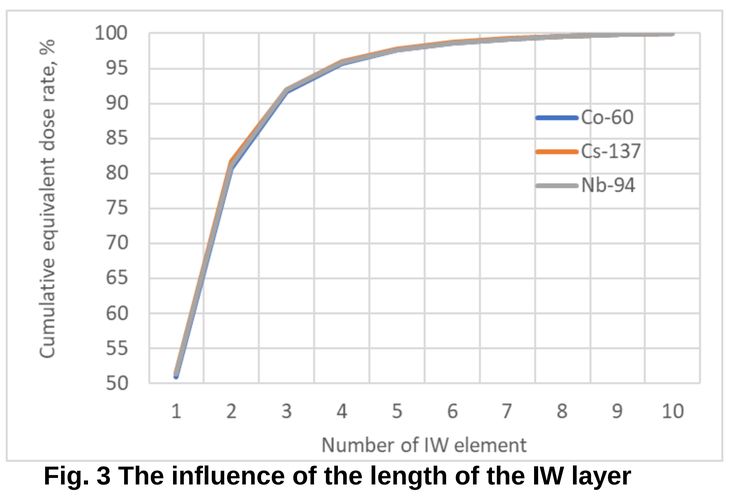

Fig. 3 The influence of the length of the IW layer

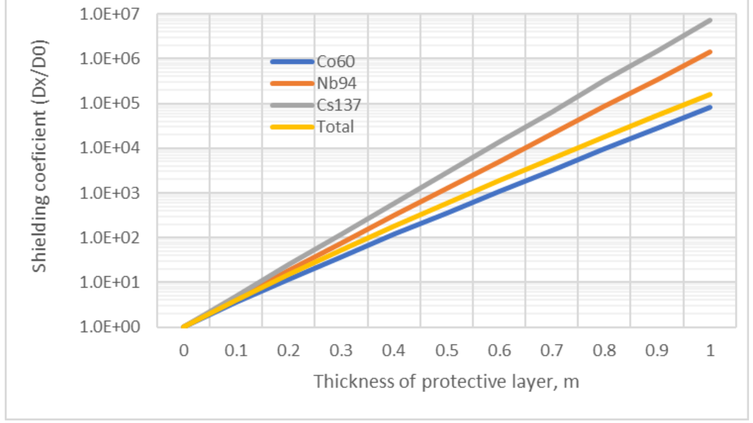

Fig. 4 Results of the shielding using protective soil layer

The waste:

The largest part of the Ignalina NPP industrial waste, consists of various construction waste types (concrete, soil, stones, bricks, tiles, glass, etc.). Metals (aluminum, iron, steel, cables etc.) make the second significant part the waste mass. The disposed of waste is mixed with the filling material sand and loam.

Radiological characterization of the waste defined activities of 18 radionuclides. Radionuclides determining external exposure are Co-60, Nb-94 and Cs-137. They account for about 99.6% of the total value of the effective dose.

Methods:

The computer program VISIPLAN 3D ALARA PLANAVIMO TOOL [2] is used to estimate the dose rate of gamma radiation. This program evaluates the dose rate of gamma radiation using a 3D modeling. Calculation of the dose rate from ionizing radiation sources in this program is done by the point-kernel method.

The assessment of the shielding effectiveness of engineered barriers against IW disposed of in an IW disposal facility was carried out in several stages. The first stage was to create optimization models in order to determine the optimal number of IW elements in the shielding effectiveness model:

1. The influence of the thickness of the IW layer for self-shielding was analyzed. In this case, a 3D model of IW layers consisting of 10 elements (1x1x0.1 m) was created. The elements were stacked vertically, each 0.1 m thick.
2. The influence of the length of the IW layer. In this case, a 3D model of IW layers consisting of 10 elements (1x1x0,5 m) was created. The elements were placed horizontal next to each other.

In the second stage, the optimization results have been used for the creation of a 3D model of the IW with a protective layer (see Fig. 1). The influence of the thickness of the protective layer was analyzed. The thickness of the layer was variated from 0 to 1 m by step 0.1 m.

Results:

Optimization modeling results show that a 0.5 m thick IW layer (5 separate elements of IW) shields 99.4-99.9% of the total radiation dose from the deeper located IW layers (see Fig. 2). Up to 7 m long IW layer is accounting for 99 % of the total radiation dose (see Fig. 3). The results of a 3D model of the IW (7x7x0.5 m from 49 elements) with a protective layer are presented in Fig. 4. Comparing the obtained results with the effective dose rate values given in FGR-15 [3] for irradiation from "infinite depth" (i.e., more than 0.3 m deep) contaminated soil (without a protective layer), the values obtained by the VISIPLAN program are 1.4 - 1.9 times are more conservative depending on the radionuclide.

Requirements for new engineered barriers:

After conversion of IW disposal facility into a conventional waste disposal facility which is not subject to radiation protection requirements, the annual effective dose received by the worker maintaining it or the resident visiting it must be 0.01 mSv/year or less. The dose assessment without consideration of the IW shielding show that the established dose limit is exceeded and will be exceeded after the end of decommissioning of the Ignalina NPP (in 2038). Hence, it is necessary to reduce the annual effective dose to a resident or worker by using engineered barriers (protective layers).

As can be seen from Fig. 4, the 0.2 m thick protective soil layer reduces the gamma radiation dose rate of radionuclides Co-60, Nb-94 and Cs-137 by more than 10 times. A 0.4 m thick protective soil layer reduces the gamma radiation dose rate of radionuclides Co-60, Nb-94 and Cs-137 by more than 100 times. The engineering geological studies of the IW disposal facility showed that the thickness of the protective soil layer covering the wastes of the IW disposal facility is in most cases 0.7 - 1 m, so this thickness of the protective layer is sufficient to ensure radiation safety and there is no need to install additional protective layers.

Conclusions:

Assessment of the shielding effectiveness of engineered barriers against radioactive waste disposed of in an industrial waste disposal facility at Ignalina NPP shows that the existing protective soil layer (0.7-1 m) is sufficient to protect residents and workers against harmful effects of ionizing radiation.

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