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Spatial interpolation of gamma dose in radioactive waste storage facility

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Abstract. External radiation measurement for a radioactive waste storage facility in Malaysian Nuclear Agency is a part of Class G License requirement under Atomic Licensing Energy Board (AELB). The objectives of this paper are to obtain the distribution of radiation dose, create dose database and generate dose map in the storage facility. The radiation dose measurement is important to fulfil the radiation protection requirement to ensure the safety of the workers. There are 118 sampling points that had been recorded in the storage facility. The highest and lowest reading for external radiation recorded is 651 microSv/hr and 0.648 microSv/hour respectively. The calculated annual dose shows the highest and lowest reading is 1302 mSv/year and 1.3 mSv/year while the highest and lowest effective dose reading is 260.4 mSv/year and 0.26 mSv/year. The result shows that the ALARA concept along time, distance and shield 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 planning and the development of shielding design for the facility.

1. Introduction The first section in your paper

Radioactive waste storage facility is a controlled working area and the only radioactive waste storage facility in Malaysia under management of Waste Technology Development Centre Nuclear Malaysia. Low-level waste comes from reactor operations, medical, academic, industrial, and other commercial uses of radioactive materials [1]. The storage of radioactive waste must is provided in order to ensure that both human health and the environment will be protected, both now and in the future, without imposing undue burdens on future generations. Radiation monitoring should be conducted routinely to determine the external radiation levels and surface contamination levels inside the waste storage facility, along the boundaries of the storage facility and on the surface of waste packages [2]. It is compulsory to comply and fulfil the dose rate at the storage facility in order to apply Class G license (Storing waste, dispose of, dissolve milling installations) (LEM-SS-14 Class G) for new, amendment and renew license applications [3]. Rigorous and continuous radiation monitoring is important to ensure that environmental radiation remains within internationally agreed and legal safety limits. This monitoring will ensured that the organisation involved quickly aware of any change in environmental radiation and able to provide any health warnings and protection necessary advice to the public [4]. Dose limit criteria are divided into 2 categories which dose limit for public is 1mSv/year and radiation workers is 20mSv/year , where the maximum effective dose on the worker averaged over a period of five consecutive years shall not exceed 20 mSv [5].

Interpolation is a statistical technique potentially capable of generating the intermediate unknown points of independent variables for spatial data.[6] Inverse distance weighting estimates the variable of interest by assigning more weight to closer points. It is a simple technique that does not require prior information to be applied to spatial prediction. [7] IDW's general idea is based on the assumption that the attribute value of an unsampled point is the weighted average of known values within the neighborhood, and the weights are inversely related to the distances between the prediction location and the sampled locations.[8]

This study aims to measure external radiation doses received by the workers in radioactive waste storage facility. Spatial documentation of the dose rate is essential as a baseline. It is also important for radiation safety and environmental radiological monitoring programme. The information is important to assure workers wear proper personnel protective equipment in the facility. This study was conducted to measure external radiation data in the radioactive waste storage facility, establish local dosimetry database and to generate local dosimetry map. In addition, the result of the study can be used in planning and developing shielding and as additional supporting reference for storage facility licensing.

2. Material and method

The gamma radiation dose was measured using Ludlum Model 2241-3 and a probe 44-2 which is a 2.5 cm x 2.5 cm scintillation crystal. The scale of survey meter is 0.001 microSievert per hour to 9999 Sv per hour where it is suitable to measure low, intermediate and high radiation [9]. The survey meter has been calibrated at the Secondary Standard Dosimeter Laboratory at Nuclear Malaysia. Measurements were conducted at 1 m above the flat land surface [10, 11, 12].

Annual dose data obtained when every dose data were calculated using the following equation:

$$\text{Annual dose (mSv/a)} = \text{Dose } (\mu\text{Sv/hr}) \text{ x working hours/year} \tag{1}$$

where the annual doses for a working 2,000 hours in a year in such areas [13]. Effective dose values at indoor were determined by using annual dose times the indoor occupancy fraction where indoor occupancy fraction is 0.8[13]. The value of effective dose mSv/year were calculated using the following equation [13][14]:

$$\text{Effective dose (mSv/year)} = \text{Annual dose (mSv/year)} \times 0.80 \tag{2}$$

There were 118 sampling points that had been recorded in storage facility. The survey points were transferred to a basemap to create geodatabase. Site measurement provided an hourly dose rate value only at the sampling points. The map was plotted according to the following steps;

- The spatial information was created in the digital maps and the dose rate, annual rate and effective rates were recorded in the attributes.
- The IDW method, with dose rate data as the variable, was applied to the digitized map for projection of the contour based on interpolation.
- The value range were reclassified according to the following intervals;
  a. Hourly dose rate: below than 1, 5, 10, 15, 20, 50 and more than 100 microSv/hr.
  b. Effective dose and annual dose rate: below than 2, 5, 10, 15, 20, 50, 100 and more than 200 miliSv/year

3. Result and discussion

This study covered an area approximately 720 m^2 in the storage facility. Each sampling point reading showed different dose rate. Several part of the facility cannot be access due to the radioactive drum and device. Based on figure 1, the arrangement of the Disused Sealed Radioactive Sources (DSRS) and solid waste showed comprehensible visual dose on the map. Sealed radioactive sources (SRSs) were used extensively in agriculture, industry, medicine and various research areas. SRS that is no longer in used is termed as DSRS. DSRS located at the centre to the south of the building. The highest dose rate was located at south of the block which contained radium needle in the concrete shielded drum while the lowest dose rate was located to north of the block which contained radioactive solid waste. Mostly, solid wastes were below than 6 µSv/hr.

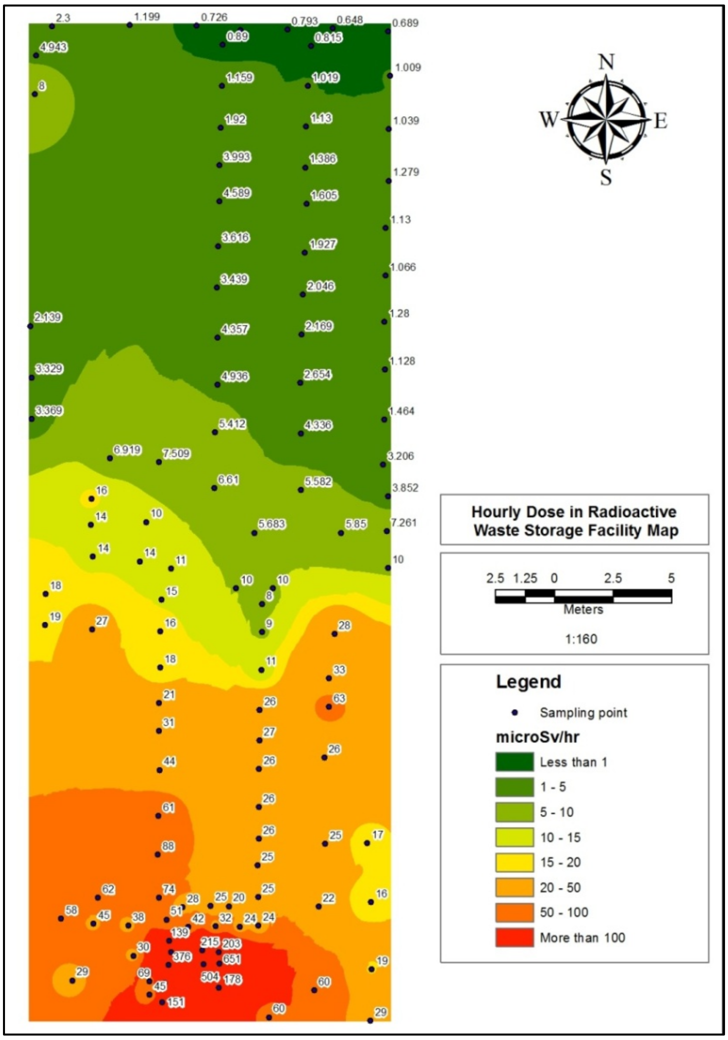

Figure 1. Hourly dose in radioactive waste storage facility.

Figure 2 and figure. 3 show the high dose value at the DSRS storage area; the workers shall received high dose if they work in long time at the specific area. Effective dose (mSv/year) is a calculation that considers the occupancy fraction which is 0.8. Effective dose showed wider area for dose ranging from15 to 50 mSv/year. Therefore,it is important to make the workers aware of the importnace to use approriate personnel protective equipment and personnel monitoring in the facility. The workers shall schedule and limit working time in the facility to reduce exposure to the external radiation dose.

The outcome of this study shows that distribution of high and low dose rate of radioactive waste in Block 33. The map is important as a visual guide for planning and development programme for personnel working in the controlled area. Planning using ALARA concept and safety principle is crucial in an area with radiation sources. Due to high dose in the working area, every personnel who has been given access to the controlled area shall comply with prevailing instructions applicable to the area issued. All workers must be provided with suitable and

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adequate personal protective equipment and personnel monitoring where the doses received during normal, operation, accidental exposure and emergency exposure recorded [7].

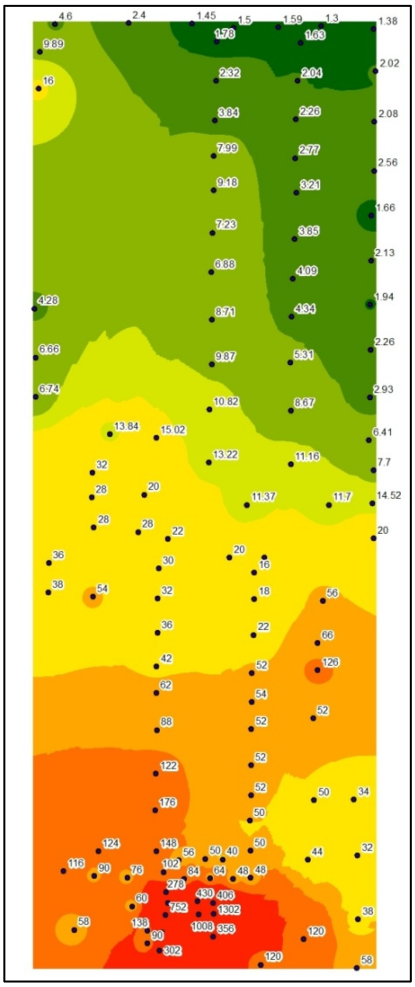

Figure 2. Annual dose in radioactive waste storage facility.

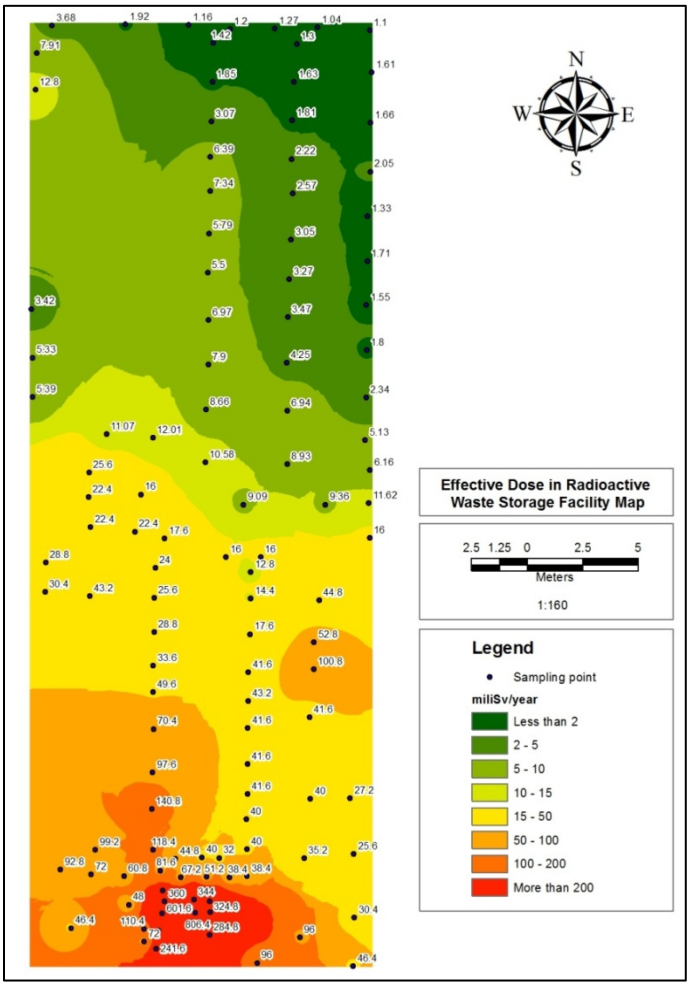

Figure 3. Effective dose in radioactive waste storage facility.

4. Conclusion

This study shows level and distribution of external radiation for public and workers concerned, in controlled working area such as the radioactive waste storage facility in Nuclear Malaysia. The annual and effective dose shows that workers shall adopt ALARA along time, distance and shield principles to that ensure the dose received by the workers is kept below dose limit regulated by AELB, which is 20 mSv/year for radiation workers. Ludlum survey meter can be used to measure external radiation level for monitoring workplace and environmental radiation. This study is important as a baseline for external radiation data, process and method to monitor environmental radiological effect in a controlled area in Nuclear Malaysia. It is also fulfils and comply the environmental radiological monitoring program for licensing purposes.

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