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Risk Assessment from Fire Accidents at Radioactive Waste Management Facility

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1. Introduction

Radioactive sources had a wide range of applications including medicine, industry, agriculture, research and education. Majority of them were manufactured in sealed forms in which the radioactive substances were strongly encapsulated into suitable containers [1]. Although these sealed radioactive sources were very small in size, most of them had very high activities of radionuclides which required strong and heavy shielding containers. When the radioactive source was unable to perform its intended application, it was termed as disused. Although one might term them as disused, but they might still find other applications by different users [2]. It was a regal requirement for owners of radioactive waste facilities to have a policy or strategy for managing the radioactive waste that would provide optimization of protection and safety to the public and environment [3]. For radioactive waste, it was important to extend the safety assessment to take into account a probabilistic analysis of the risk to the most exposed group at some varying time in future, assuming that the engineered barriers might fail in the future [4]. Therefore, during the storage of disused sealed radioactive sources, radiological risk might be of concern especially for high activity sources. This study was conducted to assess the radiological risk to the public associated with the release of radionuclide in the atmosphere due to fire incident in the radioactive waste management facility.

2. Materials and Methods

2.1. Study Area

The Central Radioactive Waste Management Facility (CRWMF) in Tanzania is located in Arusha City, in Njiro area within a compound of Tanzania Atomic Energy Commission. It is around 12 km from town center.

2.2. Model Description

Hotspot software code of National Atmosphere Release Advisory Center Lawrence Livermore National Laboratory was used to assess the total effective dose equivalent, TEDE. The model assessed the atmospheric dispersion of radionuclides from the accident involving nuclear and radiological facilities. This model estimated the short-range of less than 10 km, downwind radiological impact following the release of radioactive materials during a short-term release (less than a few hours). It contained some libraries of ICRP 30, ICRP60 and Acute for addressing any radionuclide or mixture. In this study, ICRP60 was used (Hotspot FGR-13 Option). FGR-13 provided dose coefficients using the new ICRP66 lung model and ICRP series 60/70 [5].

2.3. Model Input Parameters

In order to assess the radiation dose using Hotspot software code, the inventory of the Radioactive Waste Management Facility was used to provide the source term. Material at risk containing mixed radionuclide sources were used with an effective height of 0 m and deposition velocity of 0.3 m/sec. For the meteorology data, a wind speed of 3m/s at 10 meters was used and stability class B was chosen. The wind direction was 270 (wind from west). For the receptor window, the default values were selected for the specific downwind locations for the Hotspot table output. These locations indicated the distances in kilometers from the source. Also in this window, the receptor height was chosen to be 1.5m which represented the normal breathing zone near the ground service [5]. Under the setup table the standard terrain was selected because it estimated higher potential doses, and the wind reference height and sample time used were 10 meters and 10 minutes, respectively.

Table I: Summary of input parameters

Parameter	Value
Source term (10%)	Mixed radionuclides
Wind speed at 10 meters	3m/s
Wind direction	270(wind from the west)

Stability class	B
Receptor height	1.5 meters
Wind height	10 meters
Sample time	10 minutes

2.4. Scenario Description and Pathway Analysis

In this study, the critical receptor was chosen to be a resident living near the facility including employee working at Tanzania Atomic Energy Commission main building which was the building close to this waste management facility. It was assumed that general fire accident occurred in the facility which contained an inventory of disused sealed sources. Due to this fire the radionuclides were dispersed into the atmosphere. It was assumed that only 10 percent of the source term was involved in exposure. The exposure pathways which were considered in this scenario include ground shine (external dose rate) and resuspension (inhalation). The exposure duration was 4 days.

3. Results and Discussion

The results of this study were presented in TEDE plot and TEDE graph as follows.

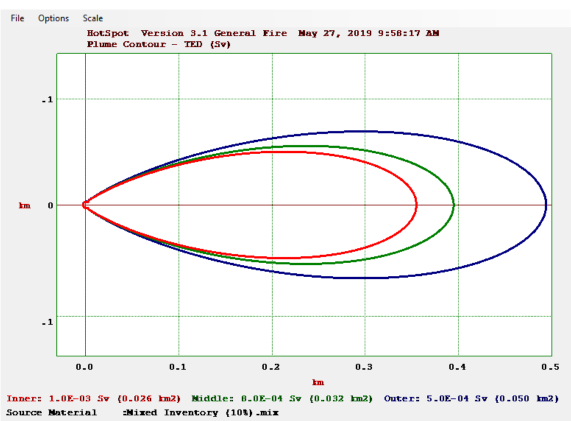

Fig. 1. Representing plume contour- TEDE (Sv)

From the results in the plot above, the inner zone (red zone) which represented the hotter zone (danger area) was 350 meters. This meant that the dispersion of radioactive material had a maximum value in this area which implied maximum dose to an individual situated within this distance from the source of explosion. The maximum dose (TEDE) was 1.1 Sv for a close distance (less than ten meters from the source) and the dose decreased with increase in distance from the source of explosion. The dose at 100 meters and 1 kilometer were 14 mSv and 0.1 mSv, respectively, as shown in Fig. 2.

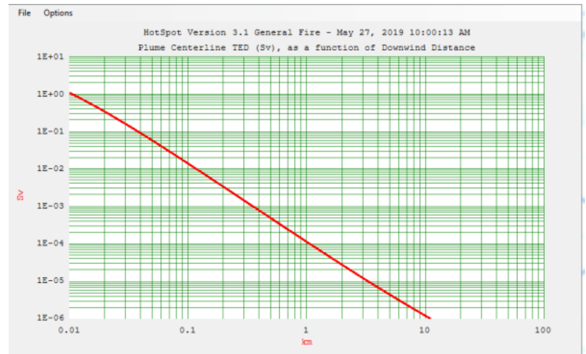

Fig. 2. Plume centerline TEDE (Sv) as a function of downwind distance.

The TEDE dose showed that up to the distance of 300 meters from the source, the dose was higher than the recommended value of 1 mSv per year for the member of public. The dose inside inner diameter ranged between 160 mSv at 30 meters and 1.4 mSv at 300 meters as shown in Table II. The variations of dose with distance was also represented.

Table II: Dose variation with distance and time

DISTANCE km	T E D (Sv)	RESPIRABLE TIME-INTEGRATED AIR CONCENTRATION (Bq-sec)/m3	GROUND SURFACE DEPOSITION (kBq/m2)	GROUND SHINE DOSE RATE (Sv/hr)	ARRIVAL TIME (hour:min)
0.030	1.6E-01	4.7E+07	6.0E+04	1.2E-04	<00:01
0.100	1.4E-02	5.2E+06	5.0E+03	9.7E-06	<00:01
0.200	3.3E-03	1.4E+06	1.1E+03	2.2E-06	00:01
0.300	1.4E-03	6.1E+05	4.7E+02	9.2E-07	00:01
0.400	7.8E-04	3.5E+05	2.6E+02	5.0E-07	00:02
0.500	4.9E-04	2.2E+05	1.6E+02	3.1E-07	00:03
0.600	3.3E-04	1.6E+05	1.1E+02	2.1E-07	00:03
0.700	2.4E-04	1.2E+05	7.7E+01	1.5E-07	00:04
0.800	1.8E-04	8.9E+04	5.7E+01	1.1E-07	00:04
0.900	1.4E-04	7.1E+04	4.5E+01	8.7E-08	00:05
1.000	1.1E-04	5.8E+04	3.6E+01	6.9E-08	00:06
2.000	2.8E-05	1.5E+04	8.2E+00	1.6E-08	00:12
4.000	6.9E-06	4.0E+03	2.0E+00	3.8E-09	00:24
6.000	3.2E-06	1.9E+03	8.8E-01	1.7E-09	00:37
8.000	1.8E-06	1.1E+03	5.0E-01	9.8E-10	00:49
10.000	1.2E-06	7.7E+02	3.3E-01	6.4E-10	01:02
20.000	3.5E-07	2.3E+02	9.0E-02	1.7E-10	02:04
40.000	1.1E-07	7.6E+01	2.7E-02	5.2E-11	04:08
60.000	5.7E-08	4.0E+01	1.4E-02	2.8E-11	06:13
80.000	3.6E-08	2.5E+01	9.0E-03	1.8E-11	08:17

As the distance increased, the doses decreased accordingly, that is to say, from 0.78 mSv at 400 meters to 0.1 mSv at 1 kilometer from the source. In this scenario, the evacuation zone could be designed beyond 500 meters from the source of explosion, if this accident occurred. However, inside area with higher dose the likely individuals to be exposed were the Tanzania Atomic Energy Commission (TAEC) employees since the TAEC building was around 200 meters from the waste management building. However, the exposure dose and the red zone distance might increase depending on the activities of the sources and evacuation distance might be extended.

4. Conclusion

This study was conducted to assess the radiological risk associated with the release of radionuclide in the atmosphere due to general fire situation in the waste management storage facility. The results of this study indicated that in a short range of distance from the source of exposure, there was slightly higher dose than the recommended exposure dose to the member of public. Although there was higher dose inside the red zone, the dose did not approach deterministic doses. The results of this study could be used not only to the radioactive waste storage facilities but to any facility containing radioactive sources, helping to plan for mitigation of likely fire accidents and to plan for evacuation areas if such accidents should occur. Also, these results suggested the isolation of radiological facilities from the public domain, taking into consideration the strength of the sources.

Acknowledgement

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