
Treatment of Radiological Medical Waste Using Concrete Cubic Molds

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Abstract: Concrete cubic molds were made and manufactured using a fixed percentage of cement and sand to be as a container for the radiological medical waste in order to prevent radiation during the transfer of radioactive waste from hospitals to their own landfill sites to preserve the safety of people and the environment from radiation pollution. The maximum dose rate was 173.744 $\mu\text{Sv/h}$ in NHTc2 sample measured using RAD EYE B20 dosimeter, which has a very high activity as a medical waste (28.568 μCi), while the lowest dose value 0.297 $\mu\text{Sv/h}$ and activity 0.041 μCi was for MCI4 sample, except the dead samples which less than detection limit for the NaI(Tl) system. Also, the efficiency calculations of manufactured molds with thickness 3 cm were done by using Ba-133 and Cs-137 as a point source, because of the energies of these sources are close to that for I-131 and Tc-99 m exist in the medical waste samples. The shielding percentages were calculated and have very high values with using concrete molds, and the dose rate decreases with increasing the sand in the mold. Measurement of resistivity to compression for the molds were done to acknowledgment the strength to hold radiological waste through transfers or store of these kinds of waste. We found that the increase of the cement percentage (chosen 10, 20 and 30%) leads to increasing the mold strength.

Keywords: Radiological Medical Waste, Concrete Molds, Dose Rate, NaI(Tl), Rad Eye B20

1. Introduction

Radioactive wastes from hospitals form one of the various types of urban wastes, which are managed in developed countries in a safe and organized way. In countries where growth of nuclear medicine services are envisaged, implementations of existing regulatory policies and guidelines in hospitals in terms of handling of radioactive materials used in the treatment of patients need a good model [1]. Although the comparison with other construction materials used in nuclear reactors, concrete has many advantages when it is utilized as a radiation shield, a set of conflicting requirements must be met in the selection of ingredients and mix proportions of concrete designed for the optimum attenuation of both gamma and neutron radiation. For efficient neutron shielding, concrete must contain some heavy elements, which are capable to slow down fast neutrons, and a sufficient quantity of hydrogen to slow down the intermediate and to absorb the slow neutrons. When

heavyweight concrete is mixed, placed and consolidated using conventional methods, particular attention should be given to the increasing tendency for mixes to segregate. Standard batching and mixing equipment can be used for high-density concrete. However, the batch sizes should be reduced inversely proportional to densities, as compared with the conventional structural concrete. Radiation shielding concrete must be consolidated to obtain its maximum potential density and to remain free from segregation and entrapped air [2]. Potentially harmful effects of irradiation on the properties of hardened concrete have been investigated for more than 50 years. Some of the results are non-conclusive and others conflicting. One of the reasons seems to be the difficulty of separating the effects of irradiation from the changes, which take place at high temperatures in concrete subjected to high-intensity radiation. Another possible reason is that the extent of damage for a similar exposure varies with the concrete aggregate type and mix composition [3]. when ordinary Portland cement 1 to 3

mortar, with a water-cement ratio of 0.45 was exposed to the $1012 \text{ cm}^{-2} \text{ sec}^{-1}$ neutron flux, there was strength reduction of about 30% after six months of irradiation. The temperature was maintained constant at about 500°C . However, further exposure of up to three years produced no additional loss of strength. Companion specimens stored in an oven at 2000°C produced a similar decrease in strength. Gamma radiation doses of up to 1010 rd [4]. seem to have no apparent effect on the compressive strength of concrete. In another study, at a gamma-ray dose of 1011 rd., reduction of between 25% and 60% in concrete strength was reported. Exposure to an integrated flux of between 3 and 8, $1019 \text{ cm}^{-2}\text{sec}^{-1}$, resulted in the 31% strength reduction in barytes mortar, and a 20% reduction in magnetite mortar [5]. The 100% leaded glass shields were used half as often (almost as consistently as the thin wall type) and received the highest ratings for a variety of syringe shield characteristics. Lead shield or wrapping with no viewing window was used the least and received the poorest ratings [6]. Technologists who use shields nearly all respondents agreed that shields do significantly reduce radiation exposure. Most agreed that any reduction in exposure is enough to warrant shield use and that shields should be used when injecting doses, preparing radio pharmaceutical, and drawing up doses. There was greater agreement about the use of syringe shields during injection than about their use during preparation and drawing up doses. This is probably because less manipulation of the shield (i.e., reading volumes, removing air bubbles, etc.) is required during injection [7]. However, we have found that higher exposures to the hand occur during preparation and drawing up doses than during injection [8]. Medical applications of radioactive isotopes form one of the important peaceful uses of atomic energy. Unsealed radioactive isotopes are used in hospitals for diagnostic and therapeutic applications in various health disorders. Safe use of radioisotopes in medical applications is the main issue in obtaining clearance from national regulatory authorities. The important issues are 1) safe custody of the received radioisotopes, 2) surveillance for their safe applications in the department and 3) the disposal of the radioactive wastes generated from human use of these radioisotopes. The issues relating to management of radioactive wastes, are very well formulated internationally, and guidelines for radioactive waste disposal are well documented [9-16].

2. Experimental Part

2.1. Templates Preparation

A number of molds in the shape of a cube have been prepared with fixed percentages of cement and sand in order to prevent radiation during the transfer of radioactive waste from hospitals to their own landfill sites to preserve the safety of people and the environment from radiation pollution. We classified all molds samples into three groups depending on the period of time for dry up the mixing of cement and sand as follows:

Group A: Cement was mixed with 10%, 20% and 30% of the amount of sand used, and 9 molds were made and left for 7 days.

Group B: cement was mixed with 10%, 20% and 30% of the amount of sand used and made of 9 molds and left for 14 days.

Group C: Cement was mixed with 10%, 20% and 30% of the amount of sand used and 9 molds were made and left for 28 days. As shown in the table 1 and figure 1.

These molds are designed with different percentages of cement to determine their effect on the blocking ratio. Periods of time are different to determine the resistance of molds to pressure when buried. Therefore, the compression of each group was measured in a laboratory located in the Ministry of Construction and Housing/Construction Section after the work of an important facilitation book to determine the resistance of each set of concrete blocks.

The concrete blocks or cubes have a weight: Cube 10% Cement =1827 gm, Cube 20% Cement =1866 gm and Cube 30% Cement =1887 gm.

Table 1. Classification of molds in three groups.

Periods of Time	10% Cement	20% Cement	30% Cement
Group a (7 days)	A11	A21	A31
	A12	A22	A32
	A13	A23	A33
Group B (14 days)	B11	B21	B31
	B12	B22	B32
	B13	B23	B33
Group C (28 days)	C11	C21	C31
	C12	C22	C32
	C13	C23	C33



Figure 1. The concrete pattern where ever measuring its resistance by the presses.

2.2. Dose Measurement in the Templates

The benefit of the molds is to block the radiation and reduce its rate. The molds were tested using two types of radioactive sources, namely cesium (Cs-137) and barium (Ba-133) because they have energies 81,365 and 662 which are near to that for I-131 and Tc-99 m used in the present work as a medical waste. Before and after the test, we measured the doses of the radioactive sources using a device Rad Eye B20. The thickness of the designed cube was 3 cm as shown figure 2.



Figure 2. Form of the template in which the dose measurements were done.

3. Results and Discussion

Table 2 shows the resistance and compressible of the molds designed to block the radioactivity leaking from the accumulated waste inside the medical center, which has a negative effect on the workers inside the hospitals. The amount of cementation depends on the percentage of cement involved in the manufacture of the concrete mold, using 10, 20 and 30% cement with sand has shown to be very sufficient in manufacturing cement-based cubes that can be

used for the isolation of radioactive waste. The 10% cement cubes achieved a compression strength of 55.4 N/mm² at 28 days, while 20% and 30% cement-based cubes gave a compression strength values of about 80.2 and 159.2 N/mm² respectively, which were considered to be above the minimum landfilling waste disposal requirements (NRC, 1991; EPA2014).

It was observed that the cement-based cubes reached about 65-75% of their maximum strength (Maximum strength is considered to be at 28 days). This goes along with the standard cement C-S-H development and matches many concretes and cement-based mixtures strength development patterns (Michael and John, 1999; Dale *et al.*, 2009). It was observed that the cubes which were manufactured using cement-based mortars can achieve a very solid structure with low permeability and with a rigid structure which can help in their use and utilization as an envelope capsule to contain and hold of different types of waste forms within the manufactured mold.

The 10% and 20% cement mold used for blocking of gamma radiation, has a low value comparing with 30% of the resistance to compression, therefore, we prefer the 30% cement mixture as optimal type as a function of strength, see the Figure 3.

Table 2. Compression of the concrete blocks depending on time.

Treatment	10% OPC	20% OPC	30% OPC
7 days	2.4	5.5	11
	2.1	5.2	11.2
	2.2	6.3	13.3
Ave.	2.2	5.7	11.8
14 days	21.1	41	107.8
	23.8	43	110.4
	25.8	45	115.3
Ave.	23.5	43	111.1
28 days	50.6	76.3	156
	56.3	80.8	159
	59.4	83.6	162.8
Ave.	55.4	80.2	159.2

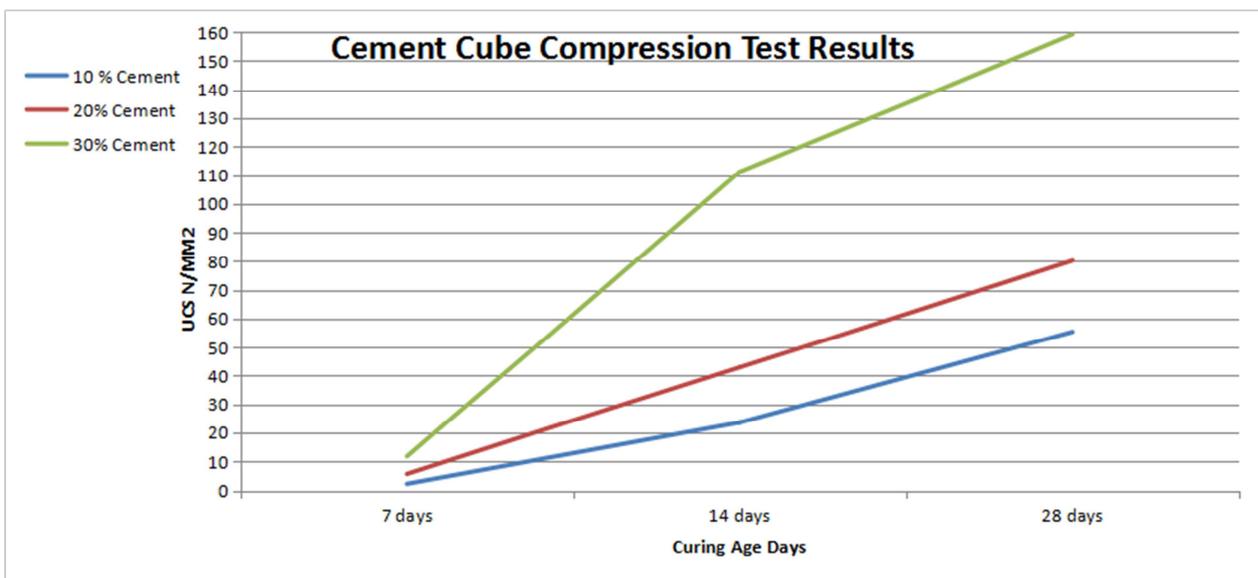


Figure 3. Comparison between different percentages of cement with the curing age.

Dose Measurement with Mold

To determine the efficiency of the molds in blocking the radiation, isotopes Ba-133 ($E_\gamma=365$ keV at $I=62\%$ and 81 keV at 33%) and Cs-137 ($E_\gamma=661$ keV at $I=85\%$) were used because of their energies close to the I-131 ($E_\gamma=364.5$ keV at $I=82\%$, 634 keV at 7.16% and 80.21 keV at 2.62%), while Tc-99 m ($E=140.5$ keV at $I=89\%$) for specific gamma energies.

Table 3 shows the efficiency of the molds in blocking the activity to reduce the radiation leakage from the accumulated radioactive waste. The Dose rate values when putting the barium and cesium isotope inside the molds and checked the dose rate outside as in touch with the mold for a distance of 3 cm (thickness of the mold) by using Rad Eye B20 dosimeter, were decreases to about 88.2%, 87.5% and 84.7% for barium

to the molds of 10, 20 and 30% cement percentage respectively, while it was decreased to 96.3%, 96.2% and 95.7% for cesium as a mean value for the three cement percentage, it's clear that the dose rate very decreased from the mean values of the dose rate without using the mold (4.24 and 59.2) $\mu\text{Sv/h}$ respectively for the same distance between the isotopes and dosimeter in the two cases, as shown in Figure 4. Also, we can find from the Figures 4 and 5 that the blockage of radiation dose rate using the molds were increases with a decrease in the cement percentage. That is because the sand consists of heavy chemical compounds heavier than the chemical compounds involved in cement synthesis. Sand is a mixture of Si oxides by 70% and the remainder is ($\text{Al}_2\text{O}_3, \text{Na}_2\text{O}, \text{Fe}_2\text{O}_3$) and others such as potassium and chlorine.

Table 3. Energy and effectiveness of barium and cesium inside and outside the molds.

Isotope	Activity (μCi)	Dose without molds ($\mu\text{Sv/h}$)		Cement rate	Dose outside molds ($\mu\text{Sv/h}$)		Shielding percentage (%)	
		Max	Mean		Max	Mean	Max	Mean
Ba-133	0.777	4.61	4.24	10%	0.60	0.50	87	88.2
				20%	0.71	0.53	84.6	87.5
				30%	0.75	0.65	83.7	84.7
Cs-137	3.456	63.9	59.2	10%	2.49	2.19	96.1	96.3
				20%	2.62	2.23	95.9	96.2
				30%	2.77	2.52	95.7	95.7

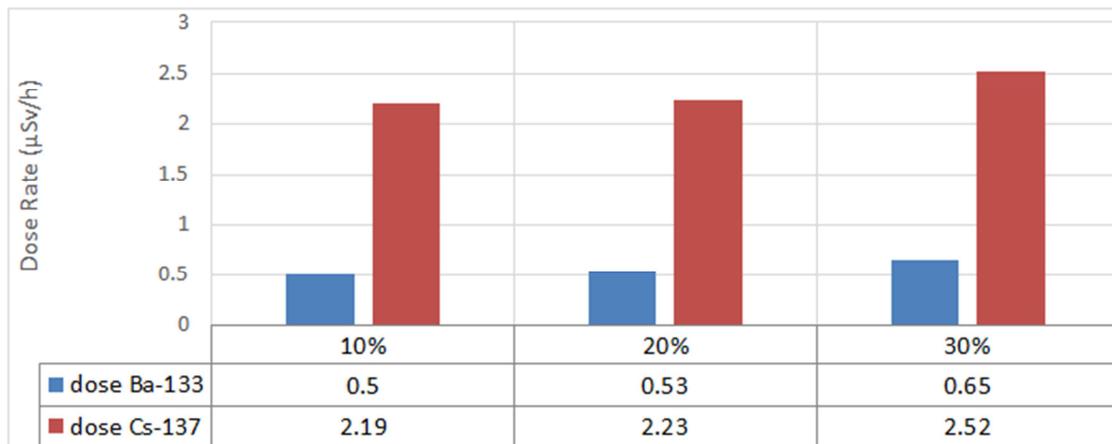


Figure 4. Comparison between the mean dose rate for Ba-133 and Cs-137 with the molds.

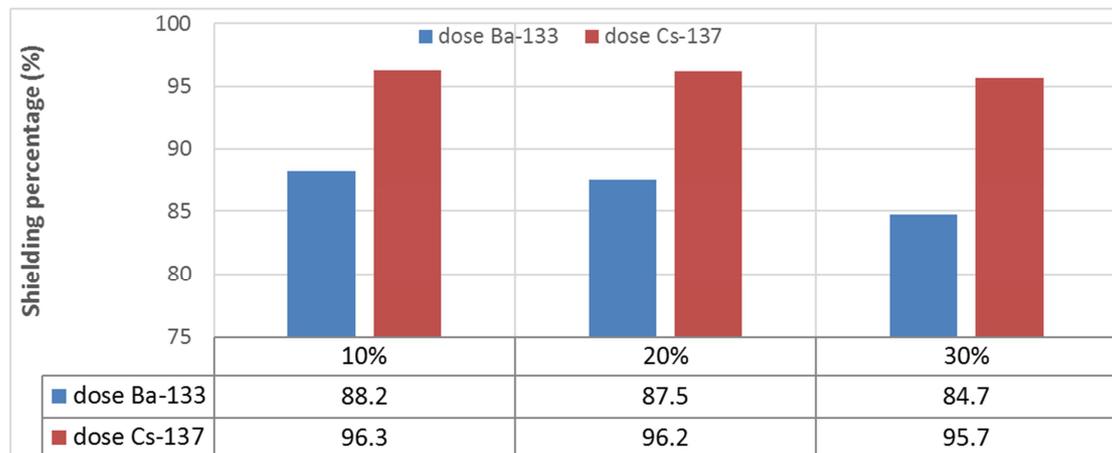


Figure 5. Comparison between the mean dose rate for Ba-133 and Cs-137 with the molds.

4. Conclusions

1. The concrete molds technique supposed in the present work was due to give an alternative treatment for the much radiological waste to less the dose rate at medical centers especially after few times from using to the patients.

2. The increasing in cement percentage in the mold manufactured in the present study gives more strength to the mold but cause a little decrease in the blocking of radiation.

3. The mold very useful to decrease the high amount of radiation and they can be sealed with safety and transport to another store or any other treatment.

5. Recommendations

We recommend that, they should be prevention the accumulate of radiological medical waste inside medical centers, specialized in the treatment of cancerous tumors using radioactive materials, due to they cause an increases in external of radiation doses because they contain a radioactivity, even if it is limited, These wastes should be transported to their landfill sites immediately after using, to lessen the side effect of radiation to the workers near the storage areas inside the medical center. Transportation using a concrete container instead of lead is a useful technique in this case because the activity for the waste is small, and the concrete mold is lighter and lessens in cost than lead.

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