Radiological Characterization of Destroyed Nuclear Reactor Tammuz-2 at Al-Tuwaitha Site

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Abstract

In-situ measurement, sampling and analysis of destroyed nuclear reactor Tammuz-2, were implemented using portable monitors to determine the external exposure dose rates. The quantity and quality of radionuclides were determined using gamma spectrometry techniques. Results indicated that the maximum dose rates at bottom of reactor core were 10.8 mSv/h; many of the soil samples were contaminated by Cs-137and Co-60. Therefore, the workers, general public and environmental will be subjected to the principles of the optimization of radiation protection according to ALARA (As Low As Reasonable Achievable) principle during all phases of decommissioning nuclear reactor Tammuz-2 as recommended by International Atomic Energy Agency (IAEA).

Keyword: Decommissioning, Iraqi Decommissioning Program (IDP), Radiation Safety

التوصيف الاشعاعي لمفاعل تموز-2 المدمر في موقع التويثة

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خلاصة

لغرض تصفية مفاعل تموز -2، تم اجراء قياسات حقلية باستخدام الاجهزة المحمولة لتحديد مستوى التعرض الاشعاعي الخارجي لبناية المفاعل المدمرة وقد دلت نتائج المسح الاشعاعي الحقلي ان اعلى مستوى تعرض اشعاعي كان في حوض المفاعل والقنوات الافقية رقم 2 و 3 حيث وصل حوالي 10.8 ملي سيفرت/ساعة في قعر الحوض. كذلك تم اجراء التحليل الطيفي لعينات التربة الماخوذة من مناطق مختلفة من بناية المفاعل المدمرة باستخدام منظومة التحليل الطيفي لاشعة كاما. دلت النتائج ان بعض العينات ملوثة بنظيري السيزيوم -137 والكوبلت-60. عليه يجب اتخاذ الاجراءات الوقائية الازمة لتامين سلامة العاملين والناس والبيئة اثناء مراحل التصفية للمفاعل وحسب مبدا الآرا (تقليل مستوى التعرض الاشعاعي الى اقل قدر ممكن) الموصى بة من قبل الوكالة الدولية للطاقة الذرية.

Introduction

Decommissioning is the final phase in the life-cycle of nuclear facilities, after siting, design, construction, commissioning and operation. It is a complex process involving activities such as decontamination, dismantling, demolition of equipment and structures, and management of resulting waste, while taking into account aspects of health and safety for the workers and the general public, as well as protection of the environment. The ultimate objective of decommissioning is unrestricted release or reuse of the site [1-8]. The decommissioning strategy for nuclear reactors can vary from case to case. Therefore the planning and implementation of decommissioning strategies for the destroyed nuclear facilities are very complex process. Characterization is an initial step in the decommissioning process and requires a logical approach in order to obtain the data necessary for planning a decommissioning program [8-10]. Characterization involves a survey of existing data, calculation, in-situ measurement and/or sampling and analysis. Using this database the decommissioning planner may assess various options and their consequences [4, 7], considering:

- techniques; decontamination processes, dismantling procedures ,
- radiological operating protection of worker, general public and environment;
- Waste classifications; and resulting costs;
- Comparison and optimization of these factors will lead to the selection of a decommissioning strategy.

TAMMUZ-2 NUCLEAR REACTOR

Tammuz-2 nuclear reactor is located at Al-Tuwaitha site about (20 Km South of Baghdad), GPS Coordinates (North= 33°12.194″, East= 44°31.079″), it is a part of the nuclear complex built by France [1] , which consists of five facilities[1]:

1. Tammuz-1 reactor (40 MW) which was destroyed by Israel in 1981,
2. Tammuz -2 reactor (500 KW),
3. Radioactive Waste Treatment Station (RWTS),
4. Laboratory Workshop Building (LWB) and,
5. Lamma facility (LAMA).

Tammuz-2 reactor was operated in 1980, and destroyed in 1991. Tammuz Complex occupies service area of (270 m^2).Tammuz -2 reactor is utilized:

- As an exact mock – up of Tammuz -1 reactor for measurements on core characteristics (reactivity, control rods, efficiency, power calculation, flux measurement), and measurements on experimental devices, neutron source for neutrongraphy and various studies with neutrons. Primarily designed as a neutron mock-up, it offers the same operating facilities as Tammuz-1:

- Pool type with direct access to the core, Easy change of core configuration, Layout and easy handling of devices inside and outside core caisson, Post irradiation examination devices: neutrongraphy, hot cells. It is connected to the channels making easy underwater transfers between Tammuz-2 andTammuz-1 pools and hot cells [1].

OBJECTIVES

The objective is to determine the exposure dose rates and information on quantity and quality of radionuclides, their distribution in the building of destroyed nuclear reactor Tammuz-2, and for the purpose of protection the workers, general public and environment against radiation risks.

Material and Methods

For the purpose of determination the external exposure dose rates of the destroyed nuclear reactor Tammuz-2, the background was determined using different types of portable monitoring, then compare the results of measurements, with the result of measurements of Tammuz-2 reactor.

The background was determined, as in Table-1 by using hand held monitors type:

- Ludlum type for measuring Gamma (γ) dose rate, unit (μSv/h).Gamma Scintillation detector type NaI crystal size (5cm x5.1cm).

- Radiagem type for measuring high (γ) dose rates, unit (μSv/h), water proof, GM detector.

Surface soil samples were collected from building of Tammuz-2 reactor, crushed by grinding machine, sieved through a (1) mm mesh sieve, then dried in an oven at (80 – 100)^{0}C for 12 hours. Weight one kilogram and packed in marinelli beaker, closed and tightly sealed using parafilm and store about one month to allow U-238 and Th-232 decay series to reach radioactive equilibrium with it short live progeny. Gamma spectrometer (Canberra) system was used for measurements and analyses of samples, which consists of a detector, preamplifier and pulse-height analyzer (DSA 2000),lead shield, using vertical high purity germanium (HpGe) detector of efficiency 40 %, and resolution (2.0 keV) , based on the measurement of 1.332 MeV gamma ray photo peak of Co-60 source and Multichannel analyzer (MCA) with 8192 channel is used , Both high voltage supply and amplifier device are compact in one unit (DSA 2000), A detector shield are with a cavity adequate to accommodate large samples. Shield has walls 10 cm lead, thick lined inside with graded absorber of Cd ~ 1.6 mm Cu ~ 0.4 mm [11-13].

Calibration and efficiency of the system are carried out using multi – gamma ray standard source (MGS-5, Canberra) of Marinelli beaker geometry. A library of radionuclides which contained the energy of the characteristic gamma emissions of each nuclide was analyzed and their corresponding emission probabilities were built from the data supplied in the software (Genie-2000). The activity concentrations of Ra-226 was evaluated from the gamma ray 609 keV of Bi-214 peak indicated for U-238, while 911 keV gamma line of Ac-228 or 238.6 keV of Bi-212 indicated for Th-232, k-40 activity was determined from peak at 1460.8 keV and Cs-137 was determined from gamma line 661.6

keV peak. Data on activity concentrations of radionuclides ($Bq.kg^{-1}$) (assuming secular equilibrium between U-238 and their progenies) [13-16] the activity concentrations of Ra-226, Th-232 and k-40 in soil sample are given in table (10).

MEASURMENTS

Background Measurements (B.G)

Table-1 B.G dose rates measurements, GPS: N= 33 12 158, E= 44 31 106.

No.	Ludlum monitor (μSv/h) at hight 1m
1	0.080
2	0,066
3	0.089
4	0.070
5	0.079
6	0.077
7	0.073
8	0.080
9	0.079
10	0.072
11	0.075
12	0.071
13	0.078
14	0.080
15	0.078
16	0.077
17	0.079
18	o.o78
19	0.079
20	0.076
Min	**0.070**
Max	**0,089**
Average	**0.0771**

Table 2. Dose rates around Tammuz-2 building(Ludlum monitor).

N0.	Location	Dose rate at 1m height (μSv/h)
1	Office building entrance	0.085
2	10m from entrance	0.084
3	building Corner near chimney	0.094
4	Near reactor chimney	0. 101
5	15m from chimney at the edge of the road	0. 118
6	10m from office building chimney side	0.098
7	10 from hot shop building(h.s.b) gate	0.099
8	At hot shop building gate	0.107
9	10m from h.s.b in front of the cells	0.097
10	10m to the wall at end of h.s.b	0.097
11	20m from h.s.b wall near sewerage	0.087
12	10m from gallery	0.088
13	10m from the end wall of gallery	0.085
14	10m from the end wall ofTZ-1 building	0.090
15	10m from the middle of TZ-1 office	0.094
16	10m from the in front side of TZ-1 office	0.088
17	10m from the in front side of h.s.b	0.086
18	Near storage tanks	0.082
19	10m from the wall of TZ-2 in front side of offices building	0.086
20	10m from office corner	0.088

Table 3. Dose rates in Tammuz-2 buildings level 0.0 offices and reactor hall (Ludlum monitor)

No.	Location	Dose rate at 1m hight µSv/h
1	Entrance in side office building	0.070
2	Room 1 on left	0.068
3	Room2 on left	0.088
4	Entrance of reactor hall	0.064
5	Laboratory 1 on the right	0.046
6	Laboratory 2 on the right	0.052
7	Dark room	0.092
8	Inside reactor hall	0.098
9	Pool edge wall no3	6.84

Table 4. Dose rates inside reactor facility +3.80m office building (Ludlum monitor)

No.	Location	Dose rate at 1m µSv/h
1	Hot Shop Building(H.S.B) entrance	0.110
2	Near channel 3	0.096
3	Near channel 2 beside hot cells	0.083
4	H.S.B. near cell B	0.071
5	H.S.B. near middle hall	0.065
6	H.S.B. wall of cell B	0.076
7	H.S.B. the wall in the middle of the two cells	0.075
8	H.S.B. wall of cell A	073
9	Area in front of H.S.B	0.070

Table 5. Dose rates insideTammuz-2 buildings level -4m offices and reactor hall (Ludlum monitor)

No.	Location	Dose rate at 1m hight µSv/h
1	Entrance of the (-4 m) offices	0.080
2	Left side rooms	0.083
3	First room on Right side rooms	0.081
4	Second room on Right side	0.080
5	Third room on Right side	0.081
6	Last room on Right side	0.082

Table 6. dose rates inside hot shop building (H.S.B.)(Ludlum monitor)

No.	Location	Dose rate at 1m hight µSv/h
1	Area near air condition	0.068
2	Inside air condition room	0.096
3	Touch to smoke detectors	2.18
4	Room 1 on the right	0.065
5	Laboratories	0.070
6	Storage room near different irradiate objects	8.0
7	Primary cooling circuit and purification	0.051

Table 7. Dose rates at different levels of Channel No. 3 (Radgaim monitor).

No.	Location	Dose rate µSv/h
1	Edge of wall no3	0.456
2	Edge of wall no2	3.222
3	-4m inside Channel No 3	10.6
4	-5m inside Channel No 3	14.2
5	-6m inside Channel No 3	18.5
6	-7m inside Channel No 3	15.7

Table 8. Dose rates at different levels of Channel No. 2 (Radgaim monitor)

No.	Location	Dose rate μSv/h
1	Edge of wall no1	0.102
2	Edge of wall no4	0.081
3	-4m inside Channel No 2	0.24
4	-5m inside Channel No 2	0.23
5	-6.5m inside Channel No 2 near irradiated rod	5.8

Table No (9) dose rates measurements at different levels of reactor core chimney (Radgaim monitor).

No.	Location	Dose rate μSv/h
1	+1m above Edge of wall no3	3.35
2	+1m above pool stage	7.24
3	0.0 level at pool stage	6.16
4	-1m inside reactor pool near chimney	10.6
5	-2 m inside reactor pool near chimney	15.2
6	-3 m inside reactor pool near chimney	30.9
7	-4 m inside reactor pool near chimney	56.9
8	-5 m at the edge of top of reactor core beside chimney	141
9	-5.5 m reactor core beside chimney	751
10	-6m reactor core beside chimney	8990
11	-6.5m reactor core beside chimney -7 m reactor core beside chimney	6080 10800

Table 10. Gamma spectroscopy results (S= Soil, SC = mixed Soil and Concrete, BDL = Below Detection Limit)

No	Sample type	Location	Th^{232} Bq/kg	U^{238} Bq/kg	K^{40} Bq/kg	Cs^{137} Bq/kg	Co^{60} Bq/kg
1	S	Office building	42.5±8.1	22.3±5.9	682.6±72	BDL	BDL

		entrance					
2	S	Near chimney	14.7±1.8	9.4±5.9	434.6±42	BDL	BDL
3	S	10 m from chimney	31.3±5.2	28.2±4.2	584.8±56	7.8±1 .5	BDL
4	S	10 from hot shop building(H.S.B) gate	20±2.4	17±4.3	596.7±58	BDL	BDL
5	S	10m from H.S.B. in front of the cells	30±4.5	24±4	546.3±54	BDL	BDL
6	S	20m from H.S.B. East	34.4±9.3	14.8±3.8	369.4±46	BDL	BDL
7	S	H.S.B. entrance	15.4±5.6	19.2±4.1	582.4±58	4.2±2 .7	BDL
8	S	Near channel- 3	16.2±3.4	28.4±4.5	388±52.6	27.3± 2.7	BDL
9	S	Near channel- 2 beside hot cells	13.7±7.8	20±6.2	520.2±69	18.5± 2.7	BDL
10	S	In front of reactor building	17.8±2.3	15±3	529±54	BDL	BDL

11	S	20m from reactor building	18.9±7.6	18.5±3.5	488.9±50	3±0.9	BDL
12	S	10m from gallery	32.2±5.2	17.1±4.5	541.4±56	BDL	BDL
13	S	20m in front of H.S.B. near sewerage	22±2.6	29.8±3.5	622.1±61	BDL	BDL
14	SC	Inside reactor hall level 0.0m	24±8.6	25.6±2.4	350±44	15.6±1.9	BDL
15	S	Level -4m primary cooling room	25.4±4.8	7.7±2.1	318.7±42	17.8±2	BDL
16	S	H.S.B near cell B	18.4±4.8	19±4.1	414.3±50	15.5±2	63.3±3.4
17	SC	H.S.B near middle hall	23.4±2.1	26.7±4.4	430±51	19.7±2.2	BDL
18	SC	H.S.B near middle hall	24.4±8.9	24.6±3.8	486±54.4	18.1±2.2	BDL

RESULT AND DISCUUSIONS

The results of gamma-dose rate levels of reactor core, channel (2&3) and the area around are found in excess of the background radiation levels ,while the maximum dose rates at the reactor core at depth (-7m) about 10.8 mSv/h. The activity concentrations of collected soil samples indicated that the area around reactor core and channel (2&3) are contaminated with Cs-137&Co-60. Individual doses expected from dismantling of the reactor pool are sufficiently high as compared with the occupational dose limit and the individual exemption dose criterion, warrant regulatory action, and must be subjected to the principles of the optimization of radiation protection safety according to ALARA principle as recommended by(IAEA).Access to this area should be controlled and restricted [3, 8].Radiation doses derived from the building debris/rubbles are considered "trivial" for the individuals involved in the management of these materials [10,1 1]. The building debris and rubbles can be handled without causing significant doses to the workers. All activities in the Tammuz-2 reactor decommissioning program have been proposed as generally acceptable/tolerable hazard", with the exception of the dismantling of the reactor pool, which has been proposed [12-15], as high hazard risk.

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