Conversion Factor of Radioactivity Measurements Counts per Second (cps) into Dose Rates in Aqaba-Jordan Phosphogypsum disposal piles

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Abstract-Jordan occupies the fifth rank among the global producers of phosphate, where more than 8 million metric tons from Al Hasa, Al Abiad and the Esh shidiya areas are exported per annum. The alteration products of fertilizer industry from phosphate rocks produce Phosphogypsum, where it is containing rare earth elements (REE) that may contribute natural radionuclides in Aqaba area, where accumulated piles near the Red Sea shorelines. The volume of phosphogypsum piles evaluated as more than 100 million metric tons. The gamma ray spectrometry was used to measure the average activity concentrations of radioactive materials, the recorded measurements in the field of the study area were ranged between 300 and 550 counts per second (cps). This study is recommended in order to clear the effect of the assumed radioactive materials in the constituent of phosphogypsum in Aqaba and then to suggest a suitable solutions.

KEYWORDS- Phosphogypsum piles, Radioactivity, Geiger Mueller Counter, Dose assessment, Conversion Factor, Aqaba-Jordan.

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1 INTRODUCTION

Phosphate rocks in Jordan contain the rare radioactive elements such as uranium (U), the U during the phosphate up grading process sticks to the mineral Francoise and behaves similar to calcium (Ca) and apatite (P_2O_5) [1]. In general the concentrations uranium (U) in the phosphate rocks samples from Esh-Shidiya and Al-Hisa mines, where ranged from 40–60 and 70–80 mg/kg respectively [2]. These constituents are consequently found in different percentages in the alteration phosphogypsum side product of the phosphate fertilizer industries.

The rainfall on these phosphogypsum pile are absorbed in a huge amounts as far as one molecule of Anhydrite combine 2 molecules of water, then in the hot summer the gypsum loose the water molecules and convert to Anhydrite, this cycle continues almost every year. The released water inflows to the Red Sea loaded by the leached minerals and elements originally accompanying with phosphogypsum. The harmful substances may cause an extreme danger to the marine environment and its creatures.

The reading of the Gama rays insitu measurements determined by the Gama emanation detector revealed 300-550 count per second (cps). While, samples showed the value ranges from zero to 45 cps.
The United States Environmental Protection Agency (1990) has excluded most applications of phosphogypsum with a radium-226 concentration of greater than 10 picocurie per gram (400 Bq/Kg). As a result, phosphogypsum which exceeds this limit is stored in large stacks [3].

2 SAMPLING METHOD

The piled deposits show an artificial mountain as in Figure (1). The whole area was spatially discretized into three main vertical zones, the lower (Lo), the middle (Md) and the upper zone (Up). The samples were collected from each zone in a random manner. The samples where distributed laterally in each zone. The 45 collected samples were numbered systematically started from SPG1 to SPG45 were tested via XRF technique. The spatial distribution of the sites of the collected samples from the piled disposals of the phosphogypsum in Aqaba are considered a representative for both lateral changes which reflect the percentage changes in the product of the same period of time, while the vertical sampling reflects the changes of percentage in the products in different time stages of production. This variation in the constituents is also depends on the differences of the mother bed rocks from where the phosphate were quarried.
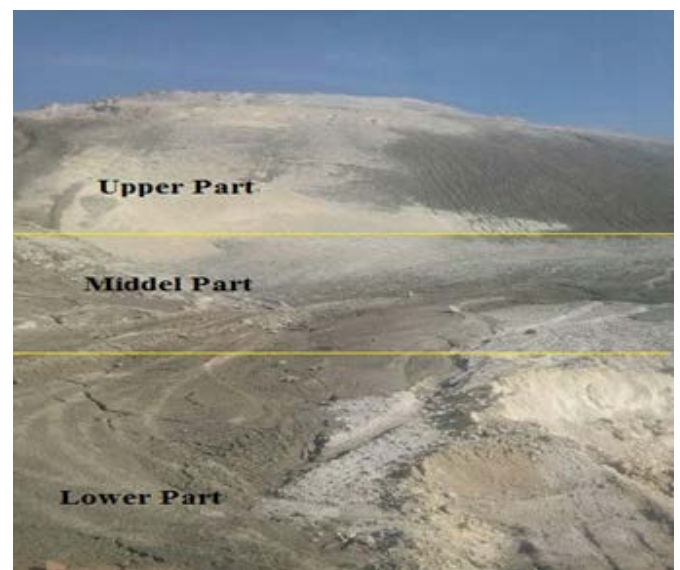
Figure (1) Photo of the artificial mountain of piled disposals phosphogypsum in Aqaba

3 PHOSPHOGYPSUM CHEMICAL COMPOSITIONS

This study was conducted to characterize the composition of Phosphogypsum samples and the chemistry of pour water released from Aqaba site stockpiled phosphogypsum. The samples collected from the water squeezed out under the hot summer with temperature exceeds 45°C were gypsum release its water and converted to anhydrite, then chemical analyses were conducted and presented in Table (1). The water samples shows an elevated total content of Ca, Mg, Na, Mn, Al, Fe, K and some of the rare earth elements such as Cr and V. The concentrations of Al, Fe, Mn, Na, and Zn exceeded drinking water standards in tested water samples.

Table (1) the ICP analysis of the rain waters leached phosphogypsum constituents in Aqaba (ppm).

ID.	Cu	Ca	K	Mg	Mn	Na	Ni	Pb	Zn	As	Cr	V	Al	Fe
Sw1	ND	7176	5.38	459	121	2100	1	1	9	2	0.3	0.5	451	212
Sw2	0.2	8704	6.54	633	167	3138	0.4	ND	14	1	0.3	9	595	280

Phosphogypsum is a side-product from the production of phosphoric acid by treating phosphate ore (apatite) with sulfuric acid according to the following reaction [4]:
$$Ca_5 (PO_4)3X + 5H_2SO_4 + 10H_2O \rightarrow 3H_3PO_4 + 5CaSO_4\ 2H_2O + HX$$
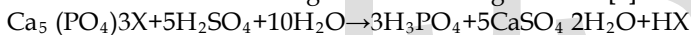
Where, X may include OH, F, Cl, or Br.
Stockpiled Phosphogypsum in Aqaba area is mainly composed of Gypsum ($CaSO_4 \cdot 2H_2O$) and Anhydrite ($CaSO_4$). It contains accessory minerals, trace elements, and radionuclides. The analyses presented in table 2 are based on the x-ray spectrometric (XRF) analysis of lime & limestone according to ASTM c1271-12 LOI according to ASTM c25-11 section19.
The results indicate that the SO_3 and CaO Oxides are forming the bulk components of phosphogypsum samples, where there average percentages found to be 39.28 and 28.13 respectively. Other Oxides (Fe_2O_3, TiO_2, K_2O, P_2O_5, SiO_2, Al_2O_3, MgO, and Na_2O) are detected in the collected samples. Cl and F were detected in some samples table 2.
The oxides are not regularly distributed in the disposal piles this is; possibly attributed to leaching process may take place in different stages. U reached less than 40 ppm, and disappears from many of the random spatial distributed samples; this is due to leaching processes during and after manufacturing of phosphate fertilizers.

Table (2) the chemical analysis of phosphogypsum (XRF) in wt%, the samples with no U and/or Cl, F were omitted

ID	Fe₂O	TiO₂	CaO	K₂O	P₂O₅	SiO₂	Al₂O₃	MgO	Na₂O	SO3	Cl	F	U
SPG1	0.21	0.019	23.6	0.036	9.25	4.17	0.38	0.33	0.82	36.4	0.35	-	ND
SPG2	0.21	0.02	21.1	0.061	10.6	3.95	0.3	0.37	0.54	28.2	0.18	-	ND
SPG3	0.11	0.018	30.8	0.022	5.03	4.11	0.18	0.23	1.24	43.3	0.25	-	ND
SPG4	0.03	0.008	12.7	0.043	1.09	10.2	0.09	0.17	8.82	18.8	0.34	14.2	ND
SPG5	0.26	0.016	20.6	0.016	14	2.2	0.71	0.29	0.33	29.2			33.5
SPG6	0.18	0.021	30.8	0.014	5.7	3.65	0.44	0.21	0.37	43.5			24.7
SPG10	0.15	0.02	23.9	0.03	10.14	4.61	0.26	0.28	0.34	34.8			24.7
SPG14	0.24	0.03	23.4	0.045	16.9	4.17	0.33	0.35	0.46	33.6		-	37.6
SPG15	0.06	0.015	13.9	0.053	1.9	10.3	0.15	0.17	8.04	21.1		10.3	ND
SPG16	0.24	0.023	24.8	0.054	9.1	4.38	0.39	0.33	0.81	35		1.01	19.8
SPG17	0.21	0.022	32	0.015	5.65	5.63	0.6	0.21	0.26	42.4			26.5
SPG18	0.19	0.021	31.1	0.007	6.48	5.23	0.55	0.2	0.22	42.2			33
SPG19	0.13	0.021	34	0	2.82	5.32	0.53	0.17	0.16	48.4			22.2
SPG20	0.2	0.022	29.4	0.01	8.02	4.25	0.66	0.22	0.25	40			22.8
SPG21	0.16	0.022	34.4	0.061	1.85	4.74	0.51	0.22	0.31	47.6			36.9
SPG22	0.17	0.026	36	0.017	1.83	3.89	0.22	0.17	0.12	50.4			21.7
SPG25	0.16	0.024	28.9	0.028	8.4	5.28	0.17	0.24	0.35	38.9			34.2
SPG26	0.16	0.029	29.6	0.023	7.87	5.24	0.16	0.23	0.27	39.7			38.3
SPG27	0.22	0.019	29.6	0.015	8.29	3.03	0.35	0.22	0.24	41.2			26.3
SPG28	0.22	0.015	21.6	0.01	13	2.47	0.42	0.27	0.33	32.4			22.6
SPG29	0.08	0.014	35.3	0.027	1.76	3.74	0.31	0.24	0.19	46.8			11.4
SPG33	0.21	0.026	30.3	0.029	3.85	4.98	0.18	0.263	0.11	42.7		-	16.7
SPG34	0.43	0.068	33	0.077	3.96	5.9	0.52	0.28	0.18	46.9		-	18.2
SPG35	0.14	0.013	18.5	0.04	17.2	2.9	0.14	0.25	0.82	22.6			20.1
SPG36	0.17	0.021	34	0.009	5.28	3.91	0.14	0.17	0.12	46.8			39
SPG37	0.2	0.023	28	0.033	10.4	3.79	0.16	0.22	0.48	36.6			40
SPG38	0.25	0.019	20.7	0.022	16.71	2.47	0.64	0.33	0.37	30.6			25
SPG39	0.18	0.025	30.7	0.01	5.18	7.79	0.31	0.22	0.05	43.2			23
SPG40	0.17	0.025	31.3	0.005	4.83	7.97	0.23	0.18	0.05	44.3			32
SPG41	0.21	0.024	29.8	0.01	7.54	6.19	0.26	0.22	0.16	42.8			31.5

The results of the analyzed samples using ICP-MS techniques listed in table (3) indicated that; the minor constituents found in phosphogypsum are not regularly distributed in the disposal piles this is; possibly attributed to leaching process may take place under different conditions.

Table (3) the ICP analysis of phosphogypsum samples from Aqaba pile stocks (ppm).

ID.	Cu	Cd	Sr	B	La	Ce	Ni	Zr	Be	Pb	Zn	Ba	Y	Cr	V	W
SS1	0.6	ND	261	ND	7	10	ND	238	ND	5	4	128	ND	ND	7	27
SS2	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	15	ND	ND	ND	9
SS3	23	21	322	20	3	4	ND	58	<1	ND	302	45	18	187	115	15
SS4	2	ND	129	ND	ND	2	ND	3645	ND	ND	9	114	ND	4	14	12
SS5	ND	ND	862	ND	6	7	ND	849	ND	89	ND	97	13	4	10	ND
SS6	9	ND	879	7	8	9	21	15	<1	53	95	125	27	79	115	12

SS7	6	1	1122	25	15	12	ND	16	<1	32	144	122	35	92	74	19

Obviously, the main available elements detected in the samples are Strontium (Sr), Barium (Ba) and Vanadium (V). The other elements are found in the water samples analyzed from the collected rainfall water. The elements detected in the analyses are possibly due to leaching process.

4 PHYSO-MECHANICAL PROCEDURE

The physical properties of the REE are useful in separating different elements. The Bromoform Hydrometer separation method which depends on the differential specific gravity (SG) for each compound is used to precipitating heavy minerals, because the low density materials as silicates and carbonates float at the surface of the Bromoform ($CHBr_3$) which has the density of 2.89 g/L. The sink substances are collected and washed by distilled water, then dried in an oven for 24 hours at 150 – 200 °C. The dried sample is grind as a very fine size powder and thereafter, the powder is treated by mercury (Hg) hydrometer which has the specific gravity (SG) equal to 13.6, then the noticeable small amounts sink soils through the hydrometer are treated by the magnetic separation method to get rid of the magnetic materials as iron and other ferric substances. Then the gathered remained materials are expected to have the heavy rare earth elements (REE), these powder soils are used partially to extract the heavier minerals from phosphogypsum by separation using their electrical charge characteristics.

The alternative method is the chemical methods directly used in extracting REE. Since the use of the precipitating agent in the aqueous extracting phase makes it possible to minimize the volume ratio of the U to other elements, it will be easy to use the Electro- static Valentes on the different ions to separate them.

5 RADIOACTIVE MEASUREMENTS

Radiation levels are not stable and changes through any time interval and space, and can be transported via particles dependent on number of causes as blowing winds, other radiation moves as waves in straight path where it penetrates even through a wall. Large variations in levels can also occur within only a few metres of each other. The radiation level is measured by different instrument types and expressed in a unit called Sieverts per hour of exposure. The measurement of ionizing radiation associated with the detection of gamma particles is a rate of counts per unit time, where counts per second (cps) are commonly used. However, for gamma ray dose measurements a unit such as the Sievert is normally used.

The radioactive decay measurements must not be confused with disintegrations per unit time (dpm), which represents the rate of atomic disintegration events at the source of the radiation. Consequently, count rate does not universally equate to dose rate, the conversion calculation is dependent on the radiation energy levels, the type of radiation being detected and the radiometric characteristic of the detector [5].

The investigated gamma levels for radiation activities in the collected samples were ranging between 00.00 and 49 cps. The gamma radiation levels in the piles sites were ranging between 300 and 550 cps. The obtained and calculated results are listed in table (4).

The Geiger-Mueller (GM) detector is not intended to measure the concentration of Radon ^{222}Rn which is most stable isotope a radioactive noble gas, occurring naturally as a decay product of radium. Radon is formed as one intermediate step in the normal radioactive decay chains through which thorium (Th) and uranium (U) slowly decay into lead (Pb), [3].

There is no simple conversion factor from the Geiger-Mueller count rate into radon; therefore, calibrations can be conducted exceptionally for a uniform volume source. David, 2011, claimed that [6];

1 Becquerel (Bq) = 1count per second (cps) …….. eq (1)

For a uniform volume it was calculated that;

64 cpm = 1.15 Bq ……….. eq (2)

This means that

55.65 cpm = 1 Bq ………... eq (3)

The Becquerel (Bq) is defined as the activity of a quantity of radioactive material (soil, air, water, etc.) in which one nucleus decays per second. That's why usually there's a quantity indicated: Becquerel per liter (Bq/L), per kilogram (Bq/Kg), per square meter (Bq/m^2), per cubic meter (Bq/m^3), etc. [7]. The SI unit of radioactivity is Becquerel (Bq); it is equivalent one disintegration per second (dps), which is the number of atoms that have decayed in one second, but not the number of atoms that have been measured as decayed [8];

1 Becquerel (Bq) = 60 dpm ……… eq (4)

Therefore,

55.65 cpm = 60 dpm ……….. eq (5), or;

1 cpm = 1 Bq = 1.0781 dpm ………... eq (6)

That is the number (1.078) is the conversion factor from Geiger-Mueller (GM) detector into the radiation dose unit Bq.

Subsequently, this gives the explanation of why we can't simply convert Bq measurements into dose rates in microseviert per hour (μSv/h).

Radiation doses are often calculated in the units of rad (abbreviated from **r**adiation **a**bsorbed **d**ose). One rad is 100 ergs/gram, in other words, 100 ergs of energy absorbed by one gram of a given body tissue. One erg is one-ten-millionth of a joule. One hundred rad equals one Joule/kilogram (J/kg), which also equals one Gray (Gy), the standard international unit for measuring radiation dose. Suppose time is involved? Then we are talking about dose rate (or dose per unit time). An example of the units for dose rate is millirad/hour. In everyday terms, a joule (and even more so, an erg) is a rather small amount of energy. But in terms of ionization potential of molecules or elements, a joule is a huge amount of energy. One joule of ionizing radiation can cause tens of thousands of trillions of ionizations [9].

Physically speaking, the most elementary way to measure the effect of radiation is to measure the amount of energy deposited in a given weight of material. However, the deposition of energy is only one aspect of the potential of radiation to cause biological damage. The damage caused per unit of deposited energy is greater when it is deposited over a shorter time. Hence an alpha particle, which would deposit its entire energy over a very short time, causes far more damage per unit of energy than a gamma ray, which deposits its energy

over a longer period. The weight of biological matter in which the energy is deposited is also important. The sensitivities of different organs also vary. The concept of relative biological effectiveness (RBE) has been created to try to capture the relative efficiency of various kinds of radiation in producing biological damage [10].

In 1977 the rem was redefined by the ICRP as 0.01 Sv or 0.01 J/kg, with the goal that the Sievert would come to replace the rem [11]. The International Committee for Weights and Measures (CIPM) adopted the Sievert in 1980, but never accepted the use of the rem [12].

Currently, the quality factor for alpha is 20 (multiply rad of alpha radiation by 20 to get rem. We say "currently" because the quality factor for alpha radiation has changed over the years. The current quality factor generally used for neutrons is 10. The following conversion indicated by Makhijani 1997 is used to convert the (rad) units into erg/g units [9].

1 rad = 100 erg/g

Other basic conversions are given as follows [6]:

1 gray (Gy) = 100 rad

1 Sievert (Sv) = 100 rem

1 Becquerel (Bq) = 1 count per second (cps)

For gamma rays, 1 rad = 1 rem = 10 mSv

The most important units and conversions of the gained values of the tested sample are done by the author and listed in table 4. Please note that the samples with Zero cps values were omitted.

Table (4) measured and calculated radioactivity samples from Aqaba piles

ID	CPS	mSv/h	mSv/y	Bq	Bq/kg	rem=rad	Gy/y	J/Kg	Nots
SPG1	18	0.000108	0.947	19.40	15.65	9.467	0.001	0.001	Up
SPG2	5	0.00003	0.263	5.39	4.35	2.630	0.000	0.000	Up
SPG4	38	0.000228	1.999	40.96	33.04	19.986	0.002	0.002	Up
SPG5	15	0.00009	0.789	16.17	13.04	7.889	0.001	0.001	Up
SPG6	20	0.00012	1.052	21.56	17.39	10.519	0.001	0.001	Up
SPG7	22	0.000132	1.157	23.71	19.13	11.571	0.001	0.001	Up
SPG8	20	0.00012	1.052	21.56	17.39	10.519	0.001	0.001	Up
SPG9	12	0.000072	0.631	12.93	10.43	6.312	0.001	0.001	Up
SPG10	38	0.000228	1.999	40.96	33.04	19.986	0.002	0.002	Up
SPG11	38	0.000228	1.999	40.96	33.04	19.986	0.002	0.002	Up
SPG12	15	0.00009	0.789	16.17	13.04	7.889	0.001	0.001	Md
SPG18	25	0.00015	1.315	26.94	21.74	13.149	0.001	0.001	Md
SPG19	45	0.00027	2.367	48.50	39.13	23.668	0.002	0.002	Md
SPG20	49	0.000294	2.577	52.81	42.61	25.772	0.003	0.003	Md
SPG21	20	0.00012	1.052	21.56	17.39	10.519	0.001	0.001	Md
SPG22	10	0.00006	0.526	10.78	8.70	5.260	0.001	0.001	Md
SPG23	15	0.00009	0.789	16.17	13.04	7.889	0.001	0.001	Md
SPG24	20	0.00012	1.052	21.56	17.39	10.519	0.001	0.001	Md
SPG26	5	0.00003	0.263	5.39	4.35	2.630	0.000	0.000	Md
SPG27	25	0.00015	1.315	26.94	21.74	13.149	0.001	0.001	Md
SPG28	18	0.000108	0.947	19.40	15.65	9.467	0.001	0.001	Md
SPG29	5	0.00003	0.263	5.39	4.35	2.630	0.000	0.000	Md
SPG30	18	0.000108	0.947	19.40	15.65	9.467	0.001	0.001	Md
SPG31	15	0.00009	0.789	16.17	13.04	7.889	0.001	0.001	Lo
SPG32	15	0.00009	0.789	16.17	13.04	7.889	0.001	0.001	Lo
SPG33	18	0.000108	0.947	19.40	15.65	9.467	0.001	0.001	Lo
SPG34	5	0.00003	0.263	5.39	4.35	2.630	0.000	0.000	Lo
SPG35	7	0.000042	0.368	7.54	6.09	3.682	0.000	0.000	Lo
SPG36	30	0.00018	1.578	32.33	26.09	15.779	0.002	0.002	Lo

The comparison of cps results encountered for the tested 49 samples are shown in figure (2). The figure indicated that the new disposals have higher rates of radiation; this may be attributed to the fact that most of the radioactive materials are soluble in water; therefore, it is leached and recharged to the Red Sea with the rainfall runoff waters, or with the squeezed waters from the alteration process where gypsum is converted into anhydrite.
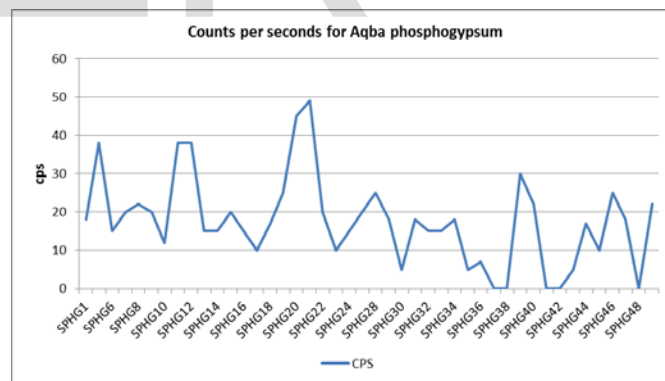

Figure (2) comparison of the radiation in different samples.

6 RADIOACTIVE RISKS

Natural Radiation is mostly gamma and electromagnetic, along with Radium, Radon, Uranium, Tritium. ICRP (1966) has confirmed that natural radiation is harmful [13]. The SI derived unit of radiation absorbed dose rate is microsieverts per hour (µSv/hour). The Sievert (Sv) is the SI derived unit of equivalent radiation dose, effective dose, and committed dose. 1 Sievert is the energy absorbed by one kilogram of biological tissue, which has the same effect as one gray of the absorbed

dose of gamma radiation. Therefore the Sievert can be expressed in terms of other SI units as 1 Sv = 1 J/kg. Therefore, 1 J/kg/s = 1 Sv/s = 3.6 * 107 μSv/hour.

Another set of units used as rad which cannot be exactly calculated as it is a unit of absorbed radiation dose but as a rough guide;

1 rad = 1 rem = 0.01 Sv = 10 mSv = 10 mGy = 0.01 Gy (gray).

Radiation levels are generally measured in millisievert (mSv) and many other international variants are converted one to each other. Table 5 briefly summarized the most common conversions from one unit to another, where different measure has a specific application. The most basic dosages can be easily compared with each other.

Table (5) radiation units and equivalent conversions

Sv	mSv	μSv	rem	mrem	rad	mGy	Gy	J/kg
1	1000	1,000,000	100	100,000	100	1000	1	1
0.1	100	100,000	10	10,000	10	100	0.1	0.1
0.01	10	10,000	1	1,000	1	10	0.01	0.01
0.001	1	1,000	0.1	100	0.1	1	0.001	0.001
0.0001	0.1	100	0.01	10	0.01	0.1	0.0001	0.0001
0.00001	0.01	10	0.001	1	0.001	0.01	0.00001	0.00001
0.000001	0.001	1	0.0001	0	0.0001	0.001	0.000001	0.000001

In relation to the health damage caused by natural radiation for the bulk of the world's population is a risk of sixth order (1 to 10 dead per million per rad / gray), in a few areas with high natural background radiation the risk fifth order, what means, 10 to 100 dead per million per rad/ (gray). In the same context, ICRP (1977) said that in this sense, regional differences of the natural radiation are so regarded, that the corresponding differences include the damage [11].

ICRP (1991) lowered the standard from 5 mSv /y to 1 mSv/y: and dose limit averaged over defined periods of 5 years for the lens of the eye to 20 mSv/y, with no single year exceeding 50 mSv [14], until 1990 ICRP said it is not necessary to evacuate people, as long as the radiation does not exceed 500 mSv.

Because every single radionuclide has a chance to get collected in the soil, therefore, our fruits, plants, vegetables grow (eaten by us and animals). The radionuclides from contaminated areas can be transported up to hundreds of km where it contaminating the soils, the affinity factors are increases as for example growth time and depth of the roots and ability of absorption [15].

Radiation exposure intensity over X time can vary the outcome of possible health risks and the information below is merely an average guide. Breathing in radiation or eating contaminated food/drink is a lot worse than direct body exposure [10].

Dangerous limits of radiation are still controversial, some people will say no amount is safe, but that doesn't really help in understand the relative dangers. Here are some basic num-

bers to use as a guide of the received dosages per year, according to US standards [16], where it is measured in micro Sieverts (μSv), table 6.

Table 6 US standards guide of dosages per year measured in micro Sieverts (μSv)

μSv/y	US standards guide of dosages per year
10	The average radiation you received today
40	The radiation you receive by a flight from New York to Los Anglos
100	The radiation you receive during a dental x-ray
800	Total radiation dose at Three-Mile Island for the duration of the accident
3000	Radiation dose from a mammogram
3600	Average radiation a US citizen receives in a year from all sources
50000	Maximum allowable yearly occupational dose (U.S.A.)
100000	Lowest yearly dose likely linked to increased cancer risk
2000000	Severe radiation poisoning (sometimes fatal)

7   NUCLEAR RADIATION SURVIVAL DANGERS

During a nuclear disaster the serious accumulative radiation danger level you are looking for is 1 Sv (1000 mSv). This is the point where you will become ill and risk serious health issues or latent death [17]. Remember that 100 mSv/hour for 10 hours will give you 1000 mSv total - the maximum risk level. The maximum hours or days that anyone can survive before he reach 1000mSv are shown in table (7).

Table (7) the possible survival time for exposure dose rate

Sv/h	mSv/h	μSv/h	rem/h	Survival time
1	1000	1000000	100	≤ 1 h
0.5	500	500000	50	2
0.25	250	250000	25	4
0.125	125	125000	12.5	8
0.0625	62.5	62500	6.25	16
0.0416	41.5	41666	4.16	1 day
0.02	20.8	20883	2.08	2 day
0.01	10.4	10416	1.04	4 day
0.005	5.2	5208	0.52	8 day
0.002	2.6	2604	0.26	16 day
0.0013	1.3	1302	0.13	32 day
	0.228	228	0.022	6 month

The radiation is an accumulative process [17], therefore the extreme levels of accumulative radiation over any period of time is given in table (8).

Table (8) extreme levels of accumulative radiation per year of any time period

Sv	mSv	rem	Accumulative radiation /year
1-2	1000-2000	100-200	Minor Nausea, Minor Headache - 5% death in 1 month otherwise non-fatal (2-6hr onset for 24hr)
3-6	3000-6000	300-600	Mod Vomiting, Mild Headache, Mod Fever, Cognitive Impairment 6hr - 5-50% death in 7-28 days (1-2hr onset for 48hr)
6-8	6000-8000	600-800	Vomiting, Mod Headache, High Fever, Cognitive Impairment 20hr - 50-100% death in 7days (10-60min onset for <48hr)
8-30	8000+	800+	Severe Vomiting, Severe Headache, Severe Fever, Incapacitated - 100% death rate (>10min onset for <48hr)
30+	30,000+	3,000+	100% death with immediate effect

The radiation level differs with respect to topographic elevations. It is clear that the radiation amounts increases upward the fact represents the influence of the atmosphere protection from these natural radiations, the topographic elevations and the corresponding radiation levels [18] are represented in table (9).

Table (9) the radiation levels at different topographic elevations

mSv/y	mrem/y	Elevation
0.26	26	Living at Sea Level
0.02	2	Up to 1000 ft
0.05	5	1000-2000 ft
0.09	9	2000-4000 ft
0.21	21	4000-5000 ft
0.29	29	5000-6000 ft
0.40	40	6000-7000 ft
0.70	70	8000-9000 ft
2.40	240	Natural radiation in the human body
0.01	1	For each 1000 mile airplane flight

The given risk values in table 10, shows the radiation doses in millisieverts (mSv/h) and microsieverts (μSv/h) per hour. Most dosimeters (the handheld Geiger counters that measure your body's "Dose") operate in these units. It's quite a simplified chart, and it helps to know that radiation gets more dangerous, the more your body gets. If you get a big amount of radiation in an hour, it's more hazardous than getting the same amount over an entire year. This table is measured in an hourly dose [17].

Table (10) the risk of different radiation levels

mSv/h	μSv/h	Health Risk
10,000	10,000,000	Organ failure and death within hours
1,000	1,000,000	Sever: Vomiting / 1: 20 risk of cancer
100	100,000	Sever: Radiation poising
1	1,000	High danger: Evacuation immediately
0.1	100	High danger: heightened sickness risk
0.02	20	High danger: Sickness risk
0.01	10	Danger: Relocate now
0.005	5	Elevated risk: Relocate as soon as possible
0.002	2	Elevated risk
0.001	1	Safe: Short-term habitation only
0.0005	0.5	Safe: Medium to long term habitation
0.0002	0.2	Safe: Long-term habitation (normal live)

8 AQABA PHOSPHOGYPSUM CASE STUDY

The results indicate that the maximum radiation (2.577 mSv/y) of the collected samples according with US standards guide of dosages per year approaching the value of radiation dose from a mammogram which is equal 3000μSv, table 6. The recorded maximum radiation per hour was (0.000294 mSv/h) which is one thousand time less than any dangerous according to the possible survival time related to exposure dose rate mentioned in Table 7. Discursively, this is less ten times than the lowest value of danger resulted from exposure levels for complete one day, table 7. The extreme levels of cumulative radiation per year are four times less than the lowest danger radiation per year, table 8. The radiation level with respect to different elevations, as in table 9, falls within normal Atmospheric radiation (Primarily Radon), while, this radiation level regarding the topographic elevation indicate the risk of different radiation levels 0.294 μSv/h is a very slight higher than the Safe Long-term habitation for normal live, equal to 0.2 μSv/h, table 10.

In reference with the fact that the Potash Company trucks transport the potash material to Aqaba port for exports, it can return loaded with the phosphogypsum instead of return back empty. Then a small mixer with pumping machines can be used to make suitable slurry to forward it to the bottom of the Dead Sea.

The advantages of this process is that the Dead Sea has no living creatures to be influenced, and the total amount of one hundred million metric tons, as far as the average specific gravity is 2.5, therefore, the total amount will convert into 40 million cubic meters. Regarding the fact that the Dead Sea water budget is about 145 billion cubic meters, with a bottom area about 611.7 Km² [19], it is clear that the phosphogypsum percentage will integrated to 0.276 per thousand. This is a tiny percentage, and may form a layer of phosphogypsum not exceeding 6.539 cm thick. One should not exclude the fact that the only continuous precipitating material from the Dead Sea hypersaline water is gypsum.

9 CONCLUSIONS

1-   The physical properties of the radioactive elements

can be useful characters to separate them from other light weight materials.

2-   The cps records of phosphogypsum samples collected from Aqaba stockpiles ranges between Zero and 49 count per second.

3-   The related mSv/y revealed that the radiation intensity in the area were the collected samples are gathered is still not harmfully, and the corresponding dosages are beyond the allowable limits.

4-   The radioactivity measurements revealed that there are no restrictions to use the phosphogypsum as a road construction materials and filling materials.

5-   It is possible to get rid of these materials for safer and seriously safer by through them into the Dead Sea bottommost.

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