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Measurements of Recycling Steel Slug at Qatar Steel Using Low-level Gamma-ray Spectrometry and Calculation of Risk Factors

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Steel slugs are final by-products in the steelmaking process which may pose an environmental hazard for workers in the vicinity of slag dumps. The objectives of this study are: 1. Using high resolution low-level gamma-ray spectrometry to measure natural occurring radioactive material (NORM) as well as of the artificial isotope 137Cs, in 4 types of steel slug such as Steel Slag loss aggregate, Asphalt Mix (100% steel slag with 4% Bitumen), slag, 50% Gabbro with 4% Bitumen, and Concrete cube (50% steel slag, 50% gabbro. The value of NORM material is reduced when they mixed with gabbro. 2. Calculation of hazard indices such as gamma absorbed dose rate, radium equivalent, external and internal hazard index, annual effective dose equivalent Outdoor), annual effective dose equivalent (indoor), and excess lifetime cancer risk. The values obtained were compared with their corresponding world permissible values, and found to be below the standard limits. 3. Mixing steel slag, with 50% of Gabbro and 4% of Bitumen with asphalt to be used as road base in the construction of 200 m road in Mesaieed city in Qatar. The mechanical and stress-strain measurements were conducted by specialists in civil engineering, then 5 core from the surface to the bottom of road was used to measure (NORM) radioactivity. The measured activity and hazards indices in asphalt mixing with slag lies within the world permissible values. Thus, the use of recycling steel slug can replace aggregates in highway construction and concrete.

Keywords: Steel slugs, Gamma spectrometry, NORM, Hazard indices, Dose equivalent, Core samples.

INTRODUCTION

Slags are generated as waste materials or byproducts in the iron and steelmaking process. About 150- 200 kg of slag per 1 ton of steel occur, so 162 million tons of steel slag are produced annually worldwide, from this only 12 million tons are produced in Europe. Significant quantities of slag are generated as by-product from steelmaking process that usually contain quantities of materials that can be recovered by physical or chemical processing such as crushing, grinding, magnetic separation. Recovered slug can be used as road basement and building materials or to produce complying grade steel aggregates (SSA) one good option to decrease waste damping, develop win–win solutions.

The steel slag is considered as waste if they are not reused, so it is essential to dispose this waste properly to reduce the human and environmental impact. The disposal and handling of this waste is money and risk consuming, thus it is essential to utilize this waste through the recycling process. Steel slag is used in different applications, such as a raw material for cement, a road base course material, for civil engineering work. Recycling of these wastes is important in conserving natural resource such as stone, minimize the extraction of primary aggregates thereby protecting more of natural resources, and manufacturing new products to protect people and the environment. Many useful materials can be used as a low-cost substitute in many processes and also as a secondary source of steel.

Slags usually contain considerable quantities of important materials that can be used for road construction (1) and other applications that include its use in granular base, highway shoulder, and mix with asphalt, and used as a building material because of its high density, durability, high resistance to abrasion and impact, as well as a high compressive strength. Use of slag refers to Aristotle, who used slag as a medicament as early as 350 B.C (2). Nowadays, 64% of granulated blast

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furnace slag is used in cement production, and 32.6% of crystalline blast furnace slag is used in road base and sub-bases. Since the beginning of steel industry in Qatar, steel slag generated from Electric Arc Furnaces was considered as a waste material and was dumped in slug yard forming huge stockpiles of approximately 1 million tons. Research work at the Ministry of environment with cooperation of Qatar steel and Environmental building Material Qatar (EBMQ) was initiated in 2011 in order to recycle this waste and used in road concentrations and in concrete.

SAMPLING

The iron slag was collected from Qatar steel yard at Mesaieed industrial city and was subjected to magnetic separation in order to remove the iron, then grinding, sieving, and finally kept in marked plastic bags.

The samples were transferred to the Ministry of environment radiation laboratory in Doha-Qatar. These samples were crushed in a mill to the grain size below 1 mm and 1 kg of homogeneous sample were transferred to sealed Marnille beaker, dried at 378 K for 24 hrs and stored in fridge for 30 days in order to allow all the decay products in secular equilibrium. Five cores of asphalt mixed with steel slug and gabbro used as base road were prepared for gamma ray spectroscopy.

THEORY

Radiation Hazard Indices Calculation

Many recent studies have used radiation health hazard indices to assess the radiation hazards and the health impacts on people and the environment (3), these indices are:

The gamma absorbed dose rate D (nGy/ h)

Expresses the absorbed dose rate at a height of 1 m above the ground surface due to natural radioactivity. The dose imply the radiation risk to people from the steel slug in damping area or after using it as road base or building materials. The dose rate D is calculated using equation (1) sited in reference (4)

$$D = 0.427C_{Ra} + 0.662\ C_{Th} + 0.043\ C_K \quad nGy/h \quad ----1$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg/, respectively.

Using the conversion factor of 0.042 nGy/ h / Bq/ kg for ^{40}K, 0.462 nGy/ h / Bq/ kg for ^{226}Ra, and 0.604 nGy/ h / Bq/ kg for ^{232}Th (5). The published maximal permissible dose rate for soil is 51nGy/h.

The external hazard index H_{ex}

This is an index used to evaluate the indoor radiation dose rate due to the external exposure to gamma radiation from the natural radionuclides defined by Beretka and Mathew (6) as in Eq (2);

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \leq 1 \quad ----2$$

The values of this index must be less than one in order to limit the radiation dose to the admissible annual dose equivalent limit of 1 mSv/y and corresponds to the upper limit of Ra_{eq} (370Bq/Kg).

The internal hazard index (H_{in})

Hazards of this index due to inhalation of radon that can lead to respiratory diseases like cancer. This index is given as in Eq (3), (6).

$$H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4810 \leq 1 \quad ----3$$

H_{in} should be less than one for the radiation impacts to be negligible.

The Radium equivalent (Ra_{eq})

In any sample, the distribution of ^{226}Ra, ^{232}Th and ^{40}K is not uniform, but the uniformity of these radionuclides with respect to radiation exposure has been given in terms of radium equivalent activity (Ra_{eq}).

(Ra_{eq}), usually used as radiological hazard index that is related to the external gamma dose and internal dose due to radon and its daughter from any materials that contains Ra-226, Th-232 and K- 40 in Bq/ kg, respectively, which is, defined on the assumption that 370 Bq/ kg of ^{226} Ra, 259 Bq /kg of ^{232} Th and 4810 Bq/ kg of ^{40} K produce the same γ dose rate, or defined on the assumption that 1Bq/kg of 226Ra, 0.7Bq/kg of 232Th, and 13Bq/kg of 40K produce the same radiation dose rates. (9) used equation (4) to calculate R_{aeq}

$$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.077\ C_K \quad ------ 4$$

Where C_{Ra}, C_{th}, C_k are the radioactivity concentration in Bq/kg of 238U, 232Th, and 40K. The Ra_{eq} index, is useful to compare the specific activity of samples containing different activities of ^{226}Ra, ^{232}Th and ^{40}K, and maximum value of Ra_{eq} must be less than 370 Bq/kg that equivalent to the annual dose equivalent of 1.5 mSv/y, the maximum permissible dose to human and discouraged to avoid radiation hazards (7)

Annual Gonadal Equivalent Dose (AGED)

The gonadal dose is directly proportional to absorbed dose in air. The AGED results from the use of a material with a given activity concentration of 226Ra, 232Th and 40K is calculated by Ibrahim, F.A. and Mohammad (8), using the equation 5;

$$AGED\ (Sv/yr) = 3.09\ C_{Ra} + 4.18\ C_{th} + 0.314\ C_k \quad ---- \quad 5$$

Annual effective dose in and outdoor (AED in, AED out)

Calculation of annual effective dose in the outdoor, must be taken into account. The conversion coefficient from absorbed dose in air to human effective dose (0.7 Sv/Gy), and the occupancy factor which is the fraction of time spent in that location, indoors and outdoors occupancy factor is 0.8 and 0.2, respectively (4). The annual effective doses are determined as Follows -Rohit Mehra, et al (4):

Outdoor Annual effective Dose (AEDE μSv/y) = Absorbed dose (nGy/h) × 8760 h × 0.7Sv/Gy × 0.2 × 10^{-3} -----------6

Indoor Annual effective Dose (AEDE μSv/y) = Absorbed dose (nGy/h) × 8760h × 0.7Sv/Gy × 0.8 × 10^{-3} -------------7

Excess Lifetime Cancer Risk (ELCR)

This is the probability of developing cancer over a lifetime due to given exposure level, which represents the number of extra cancers expected in a given number of people on exposure to a carcinogen at a given dose. Excess lifetime cancer risk (ELCR) is given as (12):

ELCR=AEDE×DL×RF = AEDE x 70 x0.05 = AEDE x3.5 --- 8

Where, AEDR is the Annual Equivalent Dose (outdoor), DL is the average Duration of Life (estimated to be 70years), and RF is the Risk Factor (S/v), = 0.05 for the public.

Gamma Index (I_γ)

This index is used to assess exceeding of action levels and was calculated from activity concentration measurements of (^{226}Ra), (^{232}Th), (^{40}K) and ^{137}Cs from fallout (9). It is a screening tool for identifying materials that might become of health concern when used for construction (10). Values of Iyr ≤ 1 corresponds to an annual effective dose of less than or equal to 1mSv, while Iyr ≤ 0.5 corresponds to annual effective dose less or equal to 0.3mSv (11). If the activity indices $I_{\gamma1}$, $I\gamma_2$, $I_{\gamma3}$, and $I_{\gamma4}$ is 1 or less than 1, the material can be used, so far as radioactivity is concerned, without restriction. The activity index $I_{\gamma1}$ for materials used in building construction is:

$$I_{\gamma1} = \frac{C_{Th}}{200} + \frac{C_{Ra}}{300} + \frac{C_K}{3000} \quad \text{-----9}$$

The activity index $I_{\gamma2}$ for materials used in road (asphalt), street, and related construction is:

$$I_{\gamma2} = \frac{C_{Th}}{500} + \frac{C_{Ra}}{700} + \frac{C_K}{8000} + \frac{C_{Cs}}{2000} \quad \text{--- 10}$$

The activity index $I_{\gamma3}$ for materials used in mounding, landfill and landscaping (Steel slag aggregates) is:

$$I_{\gamma3} = \frac{C_{Th}}{1500} + \frac{C_{Ra}}{2000} + \frac{C_K}{20000} + \frac{C_{Cs}}{5000} - - - - - 11$$

The activity index $I_{\gamma4}$ for materials used in Handling of Slag (Steel slag)

$$I_{\gamma4} = \frac{C_{Th}}{3000} + \frac{C_{Ra}}{4000} + \frac{C_K}{50000} + \frac{C_{Cs}}{10000} - - - \; 12$$

Where: C_{Th}, C_{Ra}, CK and C_{Cs} are the activity concentration values of ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs, expressed in Bq/ kg

MEASUREMENTS

Gamma ray system calibration

Measurements were conducted by Gamma ray spectroscopy system equipped with CANBERRA detector of high-purity germanium (HPGe). The detector system was calibrated using prepared standards so that their matrixes resemble to that of steel slug matrix. The detector has a resolution of 2.5 keV and relative efficiency of 30% for 1.332 MeV gamma energy of 60Co.

The output of the detector is connected to PC. The spectral data is analyzed using the “Genie 2000 Gamma Analysis Software package”. The detector has a graded shielding made of lead of 10 cm thick shield to reduce the background radiation level of the system, and lined inside with 1mm copper sheets to minimize the X-rays emitted due to interaction of cosmic radiation with lead.

The absolute photo-peak efficiency calibration of the system were carried out using standard source of 152Eu in Marinelli beaker because of its suitable half-life and the wide range of gamma ray energies produced during its decay process.

The specific radioactivity of 226Ra under the peak energy of 186.21 keV is the sum of 235U under the peak energy of 185.7 keV and peak energy of 226Ra alone. Thus the radioactivity of 226Ra alone calculated by subtracting the specific radioactivity of 235U which is calculated from the peak energy of 143.76 keV from the total specific radioactivity. Or 226Ra activities can be calculated from the weighted mean of the activity of the 609.4 keV peak of its 214Bi progeny and 351.9 keV peak of its 214Pb progeny. 232Th activities were determined from the average concentrations of 238.6 keV peak of its 212Pb progeny and 911.1keV peak of its 228Ac progeny or by 208TI gamma-ray emission probability corrected for 212Bi α decay branching ratio of 35.94 %. Activities of 40K were calculated from the 1,460.7 keV peak, activities of 137Cs were calculated from the 661.6 keV peak in the samples.

Activities of 238U were calculated from the 235U activities, assuming the 235U/238U activity ratio (13) of 0.046. 235U activities were calculated from the 186 keV peak, after subtraction of the overlapping 226Ra peak, which was previously calculated from 214Bi.

Limit of detection (LD) or (MDA) which is the minimum detectable activity was calculated according to Currie (14) method at 95% confidence level and was estimated at the base of known efficiency, counting time, energy intensity and sample mass.

RESULTS AND DISCUSSION

Table 1 presents the activity concentration of natural radionuclide of ^{238}U and ^{232}Th, series (Bq/kg) and their daughter products and Cs isotopes present in the investigated slug samples. The average values of ^{226}Ra, ^{238}U, ^{228}Ra, ^{232}Th, ^{40}K, and ^{137}Cs are 324.6, 147.5 , 112.3 , 111.7 ,10, and < 1.03 Bq/kg respectively. The activity concentration of ^{226}Ra and ^{238}U was higher than the world average value 35 Bq/kg, for ^{228}Ra and ^{232}Th also higher than the world average value 30 Bq/kg for and for ^{40}K was below the world average value of 400Bq/kg, (UNSCEAR, 2000).

The activity measurements of steel slug and associated risk. Extensive field and laboratory investigation were conducted in Qatar to assess the suitability of steel slag aggregate in road construction; to replace the natural crushed aggregate in the asphalt concrete mixes. Our trails to recycling steel slug was based on Saudi Arabia’s utilization of steel slag since 1994 that resolved several environmental of high ambient temperatures that cause major problems in asphalt surfaces (15).

Table 2 shows the measured radioactivity of natural isotopes in Asphalt and Concrete cube samples mixed with different proportion of steel slug, and gabbro. The results indicate that ^{226}Ra activity of steel slag loss aggregate (392 Bq/kg), and asphalt mix contain 100% steel slag with 4% Bitumen (331 Bq/kg) were more than exempted value (185 Bq/kg) of Qatari regulation. As 50% of gabbro was mixed with asphalt or concrete the ^{226}Ra activity (82, 75 Bq/kg) were reduced to less than exempted value and cane be safe from radiation side.

Table 1. Radioactivity of natural and manmade isotopes in steel slug samples from Qatar Steel damping area.

ID	^{226}Ra	^{238}U	^{228}Ra	^{232}Th	^{40}K	^{137}Cs
1	257±20	120±10	110±5	110±5	10±2	< 1.0
2	399± 121	170±41	99±27	98±14	8± 2	< 0.8
3	328± 66	166±30	122 ±20	120 ±19	14±3	< 1.1
4	297±29	130±18	118±8	119±7	9 ±2	< 1.0
5	345 ± 66	169±35	128 ±25	127 ±23	11±3	< 1.2
6	379± 111	165 ±31	97±26	96±13	9± 3	< 0.9
7	267±19	122±12	114±7	113±6	11±2	< 1.1
8	299±32	135±18	120±8	119±7	10 ±3	< 1.2
9	390± 120	168 ±41	95±27	94±14	7± 2	< 0.9
10	267±24	130±11	120±6	121±5	11±3	< 1.1
Average	324.6	147.5	112.3	111.7	10	< 1.03

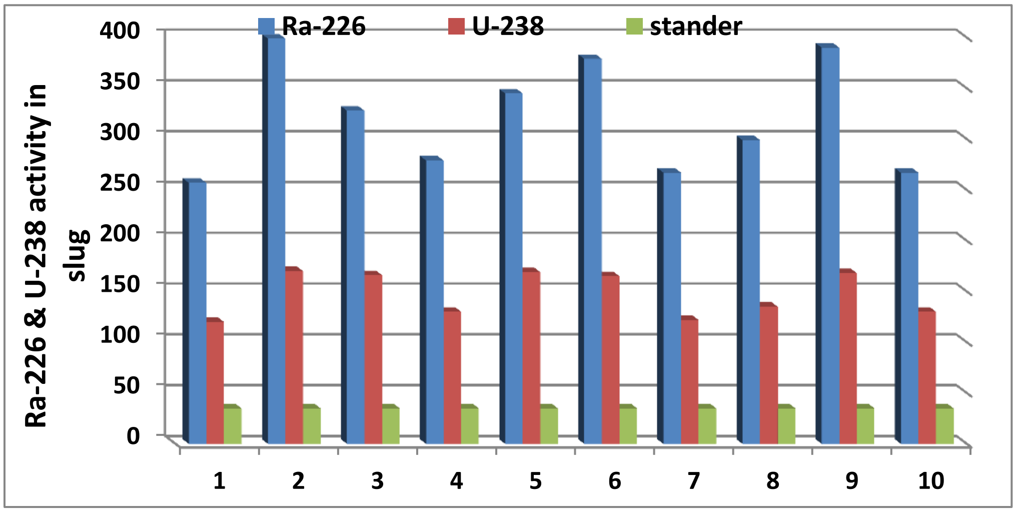

Fig -1. Radioactivity of Ra-226 & U-238 in steel slug samples from Qatar Steel damping area.

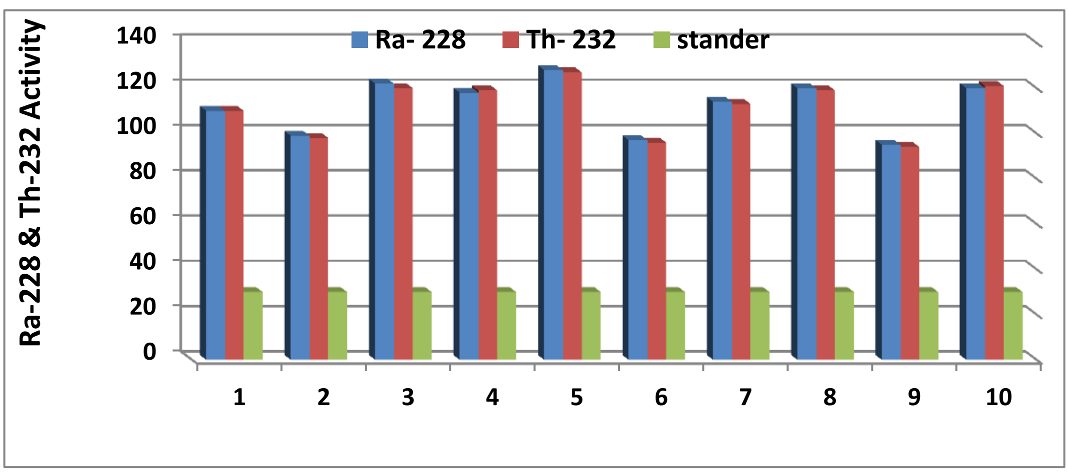

Fig -2. Radioactivity of Ra-228 & Th -232 in steel slug samples from Qatar Steel damping area.

Table 2. Radioactivity of natural and manmade isotopes in asphalt and concrete cube samples mixed with different proportion of steel slug, gabbro, from Qatar Steel damping area

ID	Sample	^{226}Ra	^{238}U	^{228}Ra	^{232}Th	^{40}K	^{137}Cs
1	Steel Slag loss aggregate)	392± 121	168±41	93±27	93±14	< 7	< 0.9
2	Asphalt Mix(100% steel slag with 4% Bitumen)	331± 69	170±31	89±18	93±11	16±7	< 1.1
3	Asphalt Mix(100% steel slag, 50% Gabbro with 4% Bitumen)	82± 4	72±6	72±6	41±2	36±3	< 1.4
4	Concrete cube (50% steel slag, 50% Gabbro	75± 6	37±3	23±1	22 ±1	215 ±2	< 0.6

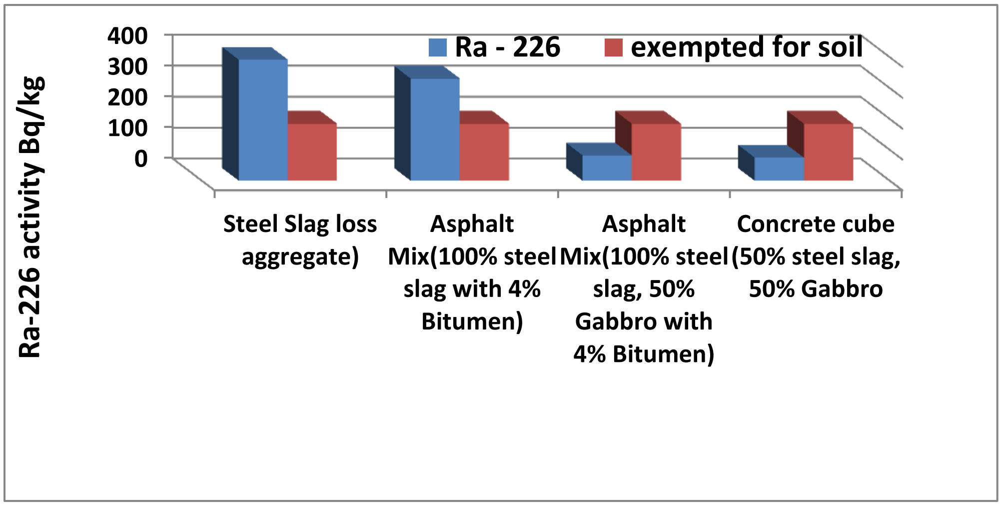

Fig -3. Radioactivity of Ra-226 in steel slug samples with different mixing quantities of gabbro and bitumen that was used in paving experimental road

Table 3. Average natural radioactivity in asphalt mixing with different proportion of steel slag, Gabbro and Bitumen that was used in paving experimental road

Nuclide	Activity-Asphalt Bottom layer (Bq /kg)	Activity of Asphalt Mid Layer (Bq /kg)	Activity of Asphalt Top Layer (Bq /kg)	Activity of concrete
K-40	24±2.2	18±2.2	16±2.8	133 ±6.5
Tl-208	8.1±0.4	2.1±0.4	1.4±0.2	1.9 ± 0.5
Pb-212	21.8±1	21.8±1	4.1±0.3	5.4 ±0.4
Bi-214	50.8±1.4	21.8±1.4	9.2±0.6	23±1.5
Pb-214	54±1.2	12±1.2	10±0.6	26 ±1.3
Ra-226	41±19.6	20±9.6	17±4.4	24 ±1.6
Ra -228	23.8±1	5.5±1	4.5±0.8	5.2 ±1.4
Pa-234m	56.3±17	22.3±2	N .D	38 ± 17
Th-234	41.8±2.6	12.8±2.6	10.9±2.5	4.7 ± 0.8
U-235	2.8±1	1.1±0.1	0.8±0.1	1.8 ± 0.8
Th-232	22.8±1	5.8±1	4.3±0.4	5.3±0.4

Table 3 shows the average of natural radioactivity in asphalt mixing with different proportion of steel slag, Gabbro and Bitumen were used in paving an experimental 200 - meter road at Mesaieed city in Qatar for the purpose of measuring its mechanical, strain and stress measurements, then 5 core at that road contain surface, mid, and bottom layers to measure natural radioactivity. The average radioactivity of 226Ra in asphalt mix with steel slag and gabbro at bottom, mid, and top layers and concrete cube are 91.5 ,41,17, and 54 Bq/kg respectively, and for 228Ra 44.8, 23.8 ,4.5 and 29 Bq/kg, both of them less than exempted level sited by Qatari regulation for NORM.

Tables 4 shows the calculated health hazard indices from equations 1- 12. The mean gamma absorbed dose rate D (nGy/ h), for asphalt – Bottom, mid, top layers of road, and concrete (38, 22.1,10.8, and 19.5 nGy/h respectively) were lower than the published maximal permissible value 51 nGy/h for steel Slag it was higher, Fig (5).

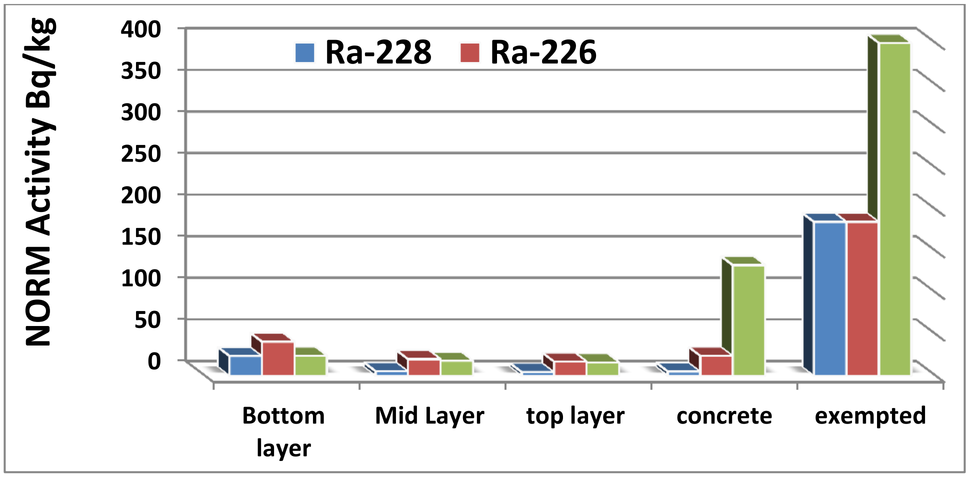

Fig-4. NORM activity of Ra-226 & Ra-228 in steel slug samples and concrete in different layers of paving experimental road

Table 4. Risk factor indices in steel slug samples and concrete in different layers of paving experimental road & concrete cube

Sample	D nGy/h	H_{ex}	H_{in}	Ra_{eq} Bq/kg	AGED (μSv/y)	AED in μSv/y	AED out μSv/y	ELCR $x10^{-3}$
Steel Slag	213	1.31	2.18	485.1	1473	1045	261	0.9
Asphalt Bottom layer	38.3	0.20	0.31	75.4	229.5	188	47	0.16
Asphalt Mid layer	22.1	0.08	0.13	29.7	91.7	78.8	19.7	0.068
Asphalt Top layer	10.8	0.06	0.11	24.4	75.5	53	13.2	0.06
Concrete	19.5	0.11	0.18	23.0	138.0	95.7	23.9	0.08
World Standard values	51	1.0	1.0	370	300	70	450	0.29

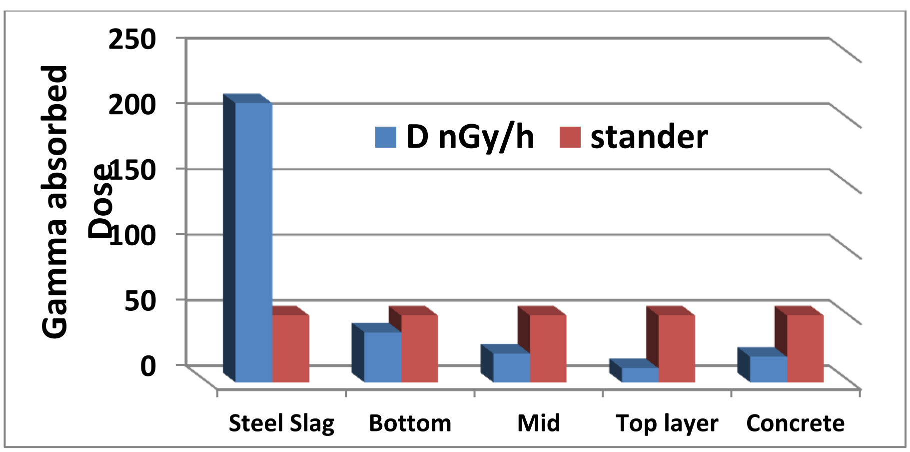

Fig-5. Gamma absorbed dose in steel slug samples and concrete in different layers of paving experimental road and concrete cube.

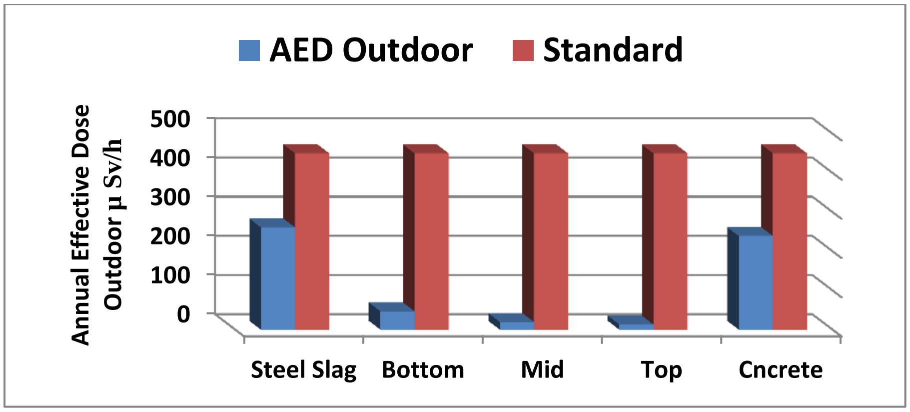

Fig-6. Annual effective doses outdoor in steel slug samples and concrete in different layers of paving experimental road & concrete cube

Table 5. Activity Index for different use of steel slag for different use

Meterial used	Activity Index	Test result					
		100% slag	90% slag	80% slag	70% slag	60% slag	50% slag
Material used in road asphalt	$I_{\gamma 1} = \frac{C_{Th}}{500} + \frac{C_{Ra}}{700} + \frac{C_K}{8000} + \frac{C_{cs}}{2000}$	0.69	0.59	0.52	0.46	0.40	0.33
Material used in landfill and landscaping (Steel slag aggregates	$I_{\gamma 2} = \frac{C_{Th}}{1500} + \frac{C_{Ra}}{2000} + \frac{C_K}{20000} + \frac{C_{cs}}{5000}$	0.23	0.13	0.11	0.10	0.09	0.07
Handling of Slag (Steel slag)	$I_{\gamma 3} = \frac{C_{Th}}{3000} + \frac{C_{Ra}}{4000} + \frac{C_K}{50000} + \frac{C_{cs}}{10000}$	0.11	0.063	0.056	0.05	0.04	0.035

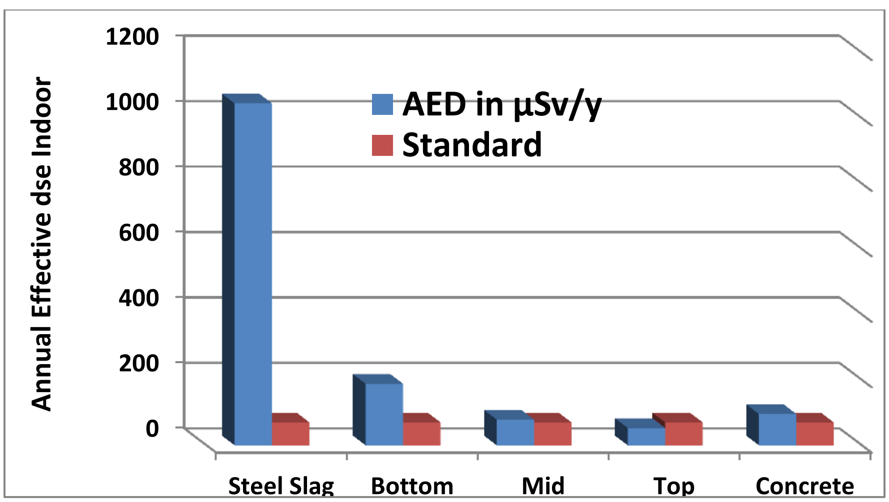

Fig -7. Annual effective doses indoor in steel slug samples and concrete in different layers of paving experimental road & concrete cube

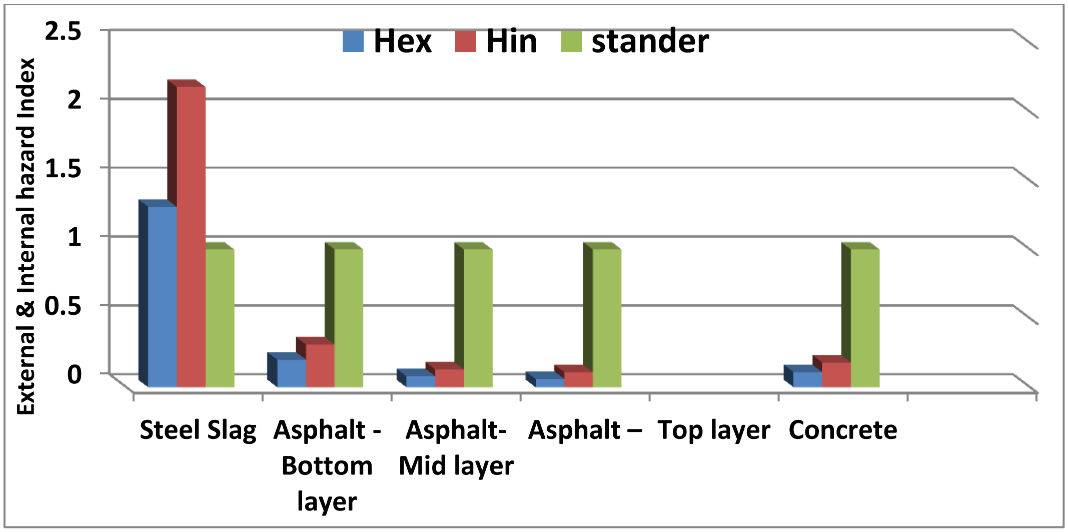

Fig-8. External & Internal Hazard index in steel slug samples and concrete in different layers of paving experimental road & concrete cube

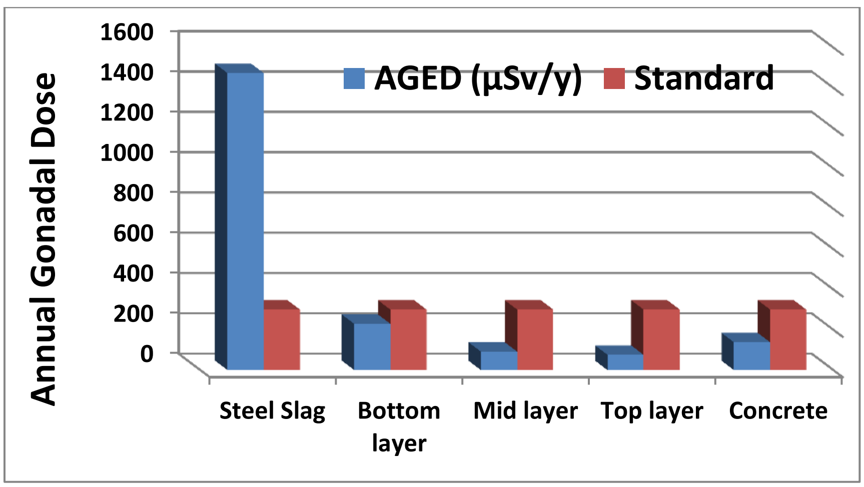

Fig-9. Annual gonadal Doses in steel slug samples and concrete in different layers of paving experimental road and concrete cube

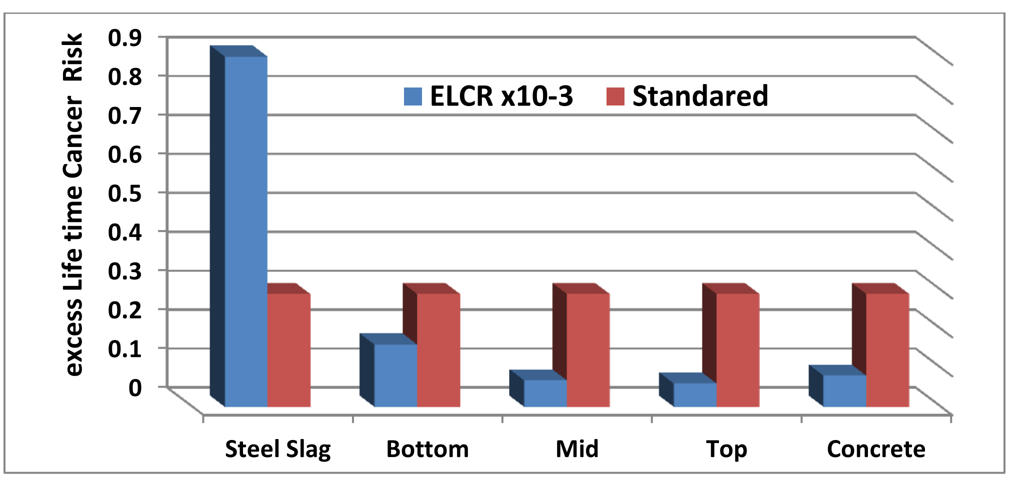

Fig-10. Excess Life time Cancer Risk in steel slug samples and concrete in different layers of paving experimental road & concrete cube.

The Outdoor Effective dose (μSv/yr) for Steel slag, asphalt Bottom, mid, top layers and concrete was lower than published maximal permissible value (450 μSv/yr) Fig (6).

The indoor Effective dose (μSv/yr) for Steel Slag, concrete, asphalt Bottom, and mid layers were higher than the published maximal permissible value (70 μSv/yr) Fig (7).

The external hazard index, internal hazard index and representative gamma index for asphalt used in road, steel slag aggregates used in landfill and landscaping, and handling of steel slag Table (5) are less than the world permissible value of unity (Fig 8). This indicates that the values will not lead to respiratory cancer and other external radiation diseases such as erythema, skin cancer and cataracts.

The annual gonadal equivalent dose (AGED) for asphalt – Bottom, mid and top layers and concrete cube were less than the published maximal permissible value 300 μSv/y (Fig 9).

Excess Lifetime Cancer Risk (ELCR) for asphalt Bottom, Mid, top layers and concrete, were lower than published maximal permissible value (0.29 x10^{-3} μSv/yr), for steel slag it was higher Fig 10).

DISCUSSION

The average natural radionuclide isotopes present in our investigation show that these radioactivity concentration values are higher than the world average value. This means that the natural radioactivity is enhanced in slug samples, so it contain NORM. The activity of 226Ra in the investigated samples were more than exempted value (185 Bq/kg) set by Qatar regulation, this implies that it will pose a significant health threat to human and the environment.

Measured radioactivity of natural isotopes in Asphalt and Concrete cube samples mixed with 50% or less were less than Qatari exempted value and can be used in paving road or concrete without posing any health hazard effect on the public and environment. The results of these measurements indicate that the radition risk level when the iron slug used in paving road or added to concrete slitly increased.

The values for risk indices for iron slug were higher than world permissible values so this material will pose a significant hazard to human lives and the environment, for asphalt mixed with 50% of gabbro used in paving road were safe and the recycling of steel slug thereby protecting more of natural resources and very good option to be used in road or building materials. The annual gonadal dose equivalent is below the permissible values. This implies that the gonadal values pose no threat to the bone marrow of the human being and the environment.

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REFERENCES

1. Ziauddin A. Khan, Rezqallah H. Malkawi, Khalaf A. Al-Ofi, and Nafisullah Khan. 2002Review of steel slag utilization in Saudi Arabia, The 6th Saudi engineering conference KFUPM Dhahran
2. The European Slag Association (2006) Legal Status of Slags, Position Paper
3. Agbalagba, E.O. and Onoja, R.A., 2011. Evaluation of natural radioactivity in soil, sediment and water samples of Niger Delta (Biseni) flood plain lakes, Nigeria. Journal of Environmental Radioactivity 102: 667-671.
4. Rohit Mehra, Surinder Singh, and Kulwant Singh, Assessment of the average effective dose from the analysis of Ra-226, Th-232 and K-40 in soil samples from Punjab, India,. (2011) Geochemical Journal,. 45 ,497 – 503
5. UNSCEAR (200) Sources and Effects of Ionizing Radiation Report of United Nations Scientific Committee on the Effect of Atomic Radiation. United Nations, New York.
6. Beretka, J. and Mathew, P.J., Natural radioactivity of Australian building materials, industrial wastes and byproducts.. Health Phys., 1985. 48: 87-95.
7. Sam, A.K and Abbas, N., 2010. Assessment of radioactivity and associated hazards in local and imported cement types used in Sudan. *Radiation Protection Dosimetory 88,225-260, 2000s*
8. Ibrahim, F.A. and Mohammad I. A. (2009). Soil radioactivity levels and radiation hazard assessment in the highlands of northern Jordan. *Radiation Measurements,44*: 102-110.
9. STUK, GUIDE ST 12.2 / 17 December 2010, The radioactivity of building materials and ash
10. Tufail, M., Akhtar, N., Jaried, S. and Hamid, T. (2007). Natural radioactivity hazards of building bricks fabrication from soil of two districts of Pakistan, *Journal of radiological protection 27: 481-492*
11. Turhan, S. and Gunduz, L., (2007). Determination of specific activity of 226Ra, 232Th and 40K for assessment of radiation hazards from Turkish plumice samples. *Journal of environmental radiation doi: 10:1016/j.jenvrad.2007.08.002*
12. Taskin, H.M, Karavus, P., Ay, A., Touzogh, S., Hindiroglu and Karaham, G., (2009) Radionuclide concentration in soil and lifetime cancer risk due to the gamma radioactivity in Kirklareli, Turkey. Journal of environmental radioactivity, 100: 49-53.
13. Murray, A.S. and Aitken, M. J.: Analysis of low-level natural radioactivity in small mineral samples for use in thermoluminiscence dating, using high resolution gamma spectrometry. International of Applied Radiation Isotope, 39,1998, 145-158
14. Currie, L.A.: Limits for Qualitative Detection and Quantitative Determination. Analytical Chemistry, 40,1968, 586-593
15. Ziauddin A. Khan, Rezqallah H. Malkawi, Khalaf A. Al-Ofi, and Nafisullah Khan, Review of steel slag utilization in Saudi Arabia, The 6th Saudi engineering conference KFUPM Dhahran December 2002