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Measurement of natural radioactivity in Al-Dora Refinery by using (HPGe) detector

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ABSTRACT

In the present work, we have measured the specific activity and the radiation hazard indices in fifteensamples, which include five for solid sample and ten for Liquid samples from different locations inside Al-Dora refinery by usinga high-purity germanium (HPGe) detector. For solid samples, the results have shown that the specific activity, for ^{238}U ranged from(32.62±5.71 Bq/kg) in D4to(9.39±3Bq/k g) in D13, for ^{232}Th was ranged from (26.56±5.15 Bq/kg) in D6 to (6.28±2.51Bq/kg) in D13, for ^{40}K was ranged from (277.59±16.66 Bq/kg) in D6 to (51.22±7.16 Bq/kg) in D13, for ^{137}Cs was ranged from(3.05±1.75 Bq/kg) in D6 to (B.D.L) in D13. In addition, for liquid samples, the specific activity, for ^{238}U was ranged from (35.04±5.92 Bq/l) in D8to (1.59±1 .26 Bq/l) in D11, for ^{232}Th was ranged from (35.47±5.96 Bq/l) in D11 to (3.27±1.81Bq/l) in D14, for ^{40}K was ranged from (422.28±20.55 Bq/l), in D15 to (14.16±3.76 Bq/l) in D10, for ^{137}Cs was ranged from (11.16±3.34 Bq/l), in D10 to (1.17±1.08 Bq/l) in D3. But regarding the radiation hazard indices in (both solid and liquid) ,for Radium Equivalent Activity(Raeq) was ranged between (5.21-79.84Bq/kg,Bq/l),for Absorbed Gamma Dose Rate (Dγ) was ranged between (37.53-2.49)nGy/h, for indoor (AEDE) ranged from (0.012-0.184)and for outdoor (AEDE) ranged from(0.003-0.046)in mSv/y, for internal hazard index (H_{in}) ranged from (0.025-0.079) and for external hazard index(H_{ex})ranged from(0.014-0.216),respectively. The present results show that specific activity and the radiation hazard indices in all samples are less than the recommended by the worldwide average. Therefore, the study shows that all the studied sites in Al-Dora refinery do not pose any significant source of radiation hazard and are safe for use.

Keywords:Crude oil, Petroleum, NORM, natural radioactivity, Radiation hazard indices.

INTRODUCTION

The presence of naturally-occurring radioactive materials (NORM) in oil field equipment was first observed as early as 1904, in Canada [1]. In later years, in many other countries all over the world, NORM concentrations were observed in different parts of oil production facilities. However, it was not until the 1980s that NORM was first considered a health and safety concern in the oil industry [1] [2].

Natural radionuclides from uranium and thorium series are present everywhere in the environment. They are part of soil, rocks, water, and food and can also be detected in the human body. Uranium-238 and thorium-232 are parents of two complex series of radioactive elements, with lead being the last (stable) element in both series.Naturally-occurring radioactive materials (NORM) are present in several industries, including the petroleum industry. NORM can be present in petroleum reservoirs, in oil and gas production, and in processing facilities. In some industrial processes, these natural radionuclides can be concentrated or accumulated, originating the TENORM (Technologically Enhanced Naturally-Occurring Radioactive Material) [3]. Most of the radionuclides that appear in oil and gas stream belong to the U-238 and Th-232 natural series, and K-40. Emphasis was given to the quantification of Ra-226, K-40 since these radionuclides are responsible for most of the external exposure in such facilities [4].

Human beings are exposed to ionizing radiation from natural sources throughout their lifetime, and sometimes from man-made sources. Therefore, the knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogenic sources [5]. Natural sources of radiation constitute almost 80% of the collective radiation exposure of the World's population [6]. Terrestrial background radiation represents the main external source of irradiation of the human body. Human beings are exposed also naturally from sources outside their bodies; mainly cosmic rays and gamma ray emitters in soil, building materials, water, food and air [5]. A significant amount of man-made radionuclides 137Cs, ^{131}I and ^{90}Sr may also present in the environment as a result of testing of nuclear weapons in the atmosphere, accidents such as the Chernobyl accident and the Japan nuclear power plant disaster, and the routine discharge of radionuclides from nuclear installations [7].

The aim of the present work is to measure the natural radioactivity levels and to estimate the hazard indices; radium equivalent activities, representative level index, external and internal hazard index, absorbed dose rate and effective dose rate in crude oil, soil and sludge/sediment in AL-Dora Refinery by using the Gamma spectrometry system.

MATERIALS AND METHODS

Description of study area

Al-Dora refinery which is one of the refineries operated by the Midland Refineries Company (MRC), Itis situated in the south eastof Baghdad governorate with the following geographical coordinates:latitudes 33°15'38"N and longitudes 44°25'28"E, just 4 Km from the city center of Baghdad, close to the western bank of the Tigers riveras shown in fig.(1) [8]

It occupies an area with nearly (1,011,714 m2). Al-Dora refinery is the oldest and largest one in Iraq and marks the true beginning of the modern oil refinery industry [9].It was constructed in 1953 by major oil companies, like Fortes Wheeler, M. W. Kellog and Exxon research and engineering. The refinery was developed and expanded from 1956 to 2004 by many companies, such as the Italian, Japanese, Yugoslavian, Germany and American companies to include different new units and plants. About more than 5000, workers work in different departments of the refinery[8].

Table 1:Shows the sample code,state, types and location of all samples inside AL- Dora refinery.

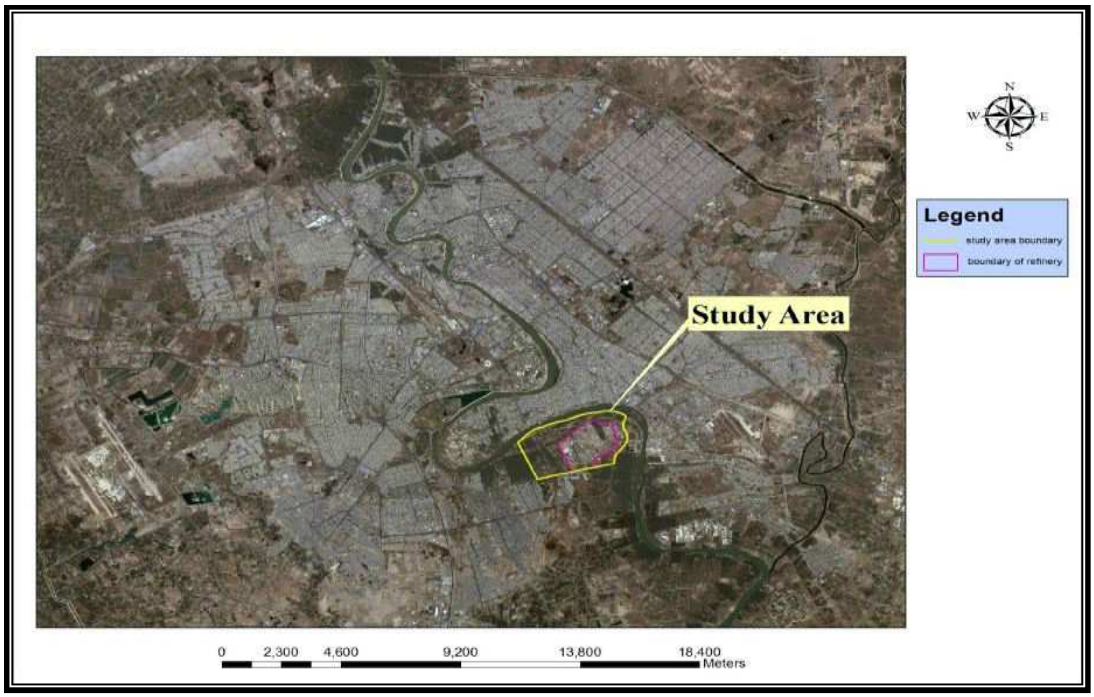

Figure (1): Study Area Location in Baghdad [8]

Table (1) : The sample code, state-Types and location of all samples inside AL- Dora refinery

Sample code	State –Type	Location of samples
D1	Liquid -Crude oil	The outstretched crude oil from Kirkuk.
D2	Liquid -Crude oil	The outstretched crude oil from Bijie.
D3	Liquid -Crude oil	Reduce crude oil (RC).
D4	Solid –soil	Contaminated dust in the line stretching to Basra
D5	Solid –soil	The fourth station around the pipe (skimmer).
D6	Soild–soil	The fifth station (unit for drying).
D7	Soild–soil	Reduce crude oil (RC).
D8	Liquid –sludge	The oil waste from Operated units
D9	Liquid –Gasoline	Oil refining stage (ORS)
D10	Liquid -Full oil	The waste oil
D11	Liquid -Gas oil	Oil refining stage(ORS)
D12	Liquid –Kerosene	Oil refining stage(ORS)
D13	Soild–Scale	The oil waste from (heavy products).
D14	Liquid -Motor oil	Oil refining stage(ORS)
D15	Liquid -Crude oil	The outstretched crude oil from Basrah.

Processing of Liquid Samples

The liquid samples were collected from ten locations inside Al-Dora refinery.Marinelli type beakers (1liter capacity) were used to process and measure the liquid samples.The net weights of the samples were found from the difference of weights of a sample-filled and empty beakers. Finally, the beakers filled with samples were closed by caps, wrapped with thick vinyl tape about their caps and kept for one month for achieving the secular equilibrium between gaseous and non-gaseous decay products of naturally-occurring radioactive series.

Processing of Solid Samples

The soil samples were collected from five locations inside Al-Dora refinery. These samples were crushed into small pieces then to fine powder by using an electrical mill and passed through a sieve of mesh size of (630 μm). The samples were dried at (60 °C) for one hour and they were packaged in a cylindrical plastic containers with a volume (lkg).the weight of all the samples were taken by an electronic balance. Finally, the plastic containers were closed by caps and wrapped with thick vinyl tape about their necks to seal the containers tightly. The samples were then stored for about one month before measurements in order to achieve the secular equilibrium between the ^{238}U and ^{232}Th series and with their respective progenies.

Experimental techniques (detection system set-up) :

The detection and measurement of radionuclides in the samples were carried out by gamma spectrometry technique using a vertical coaxial cylindrical coaxial hyper pure germanium (HPGe) detector of sensitive volume of (3×3) inch was used and of 20% relative efficiencyas shown in fig. (2). The p-type HPGe detector supplied by ORTEC (Model-GEM20-70) .The correct energy resolution of HPGe detector is 1.77 keV at 1332 kev^{60}C gamma-ray line.The detector was coupled to a 16,400 channel multichannel analyzer (MCA).

The spectra of all samples were perfectly analyzed using Maestro (ORTEC GEM20-70,USA) spectra analysis software (which matched various gamma energy peaks to a library of possible radionuclides) to calculate the concentrations of ^{238}U, ^{232}Th and ^{40}K . The detector was surrounded by a Pb cylindrical shield to eliminate the contribution of naturally-occurring background

radionuclides in the environment .All the samples were counted over a period of of (7200 s.). Prior to the measurement of samples, the environmental gamma background of the laboratory site was determined with an identical empty Marinelli beaker and plastic container used for the sample measurement.

Figure(2) :Photographic picture of system measurement.

The energy calibration of of the germanium detector system was found by using some standard radioactive sources with known energies. These sources should be counted for a long enough period in order to produce well-defined photopeaks and then calibrated according to their energies [10]. In the present work, the point source (^{60}Co) with a period of (300 s.) was used in thesystem calibration, the Gamma-ray spectra for this source as shown in fig. (3).

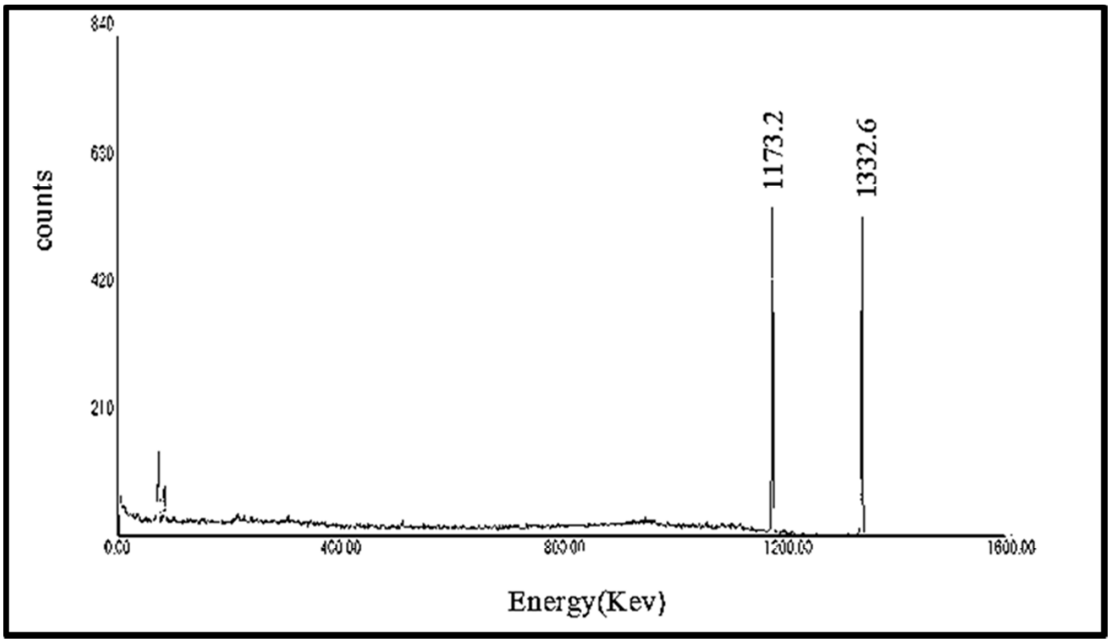

Figure (3): Gamma-ray spectrum for (^{60}Co) source

The efficiency calibration aims to derive a relationship between the absolute full energy peak efficiency of the gamma-ray spectroscopysystem and the energy[11].

The absolute efficiency calibration of the detector was determined using a standard source of one litter capacity Marinelli beaker (mixture of elements). This mixed radionuclides consists of the ten radioelements:^{241}Am, ^{109}Cd,^{139}Ce,^{57}Co,^{60}Co, ^{137}Cs,^{113}Sn,^{88}Y,^{203}Hg and ^{85}Sr which have the same shape and size, were used to complete

the efficiencies over a wide energy range. To determine the efficiency of the calibration, the spectra of standard radioactive sources with known energies and activities are accumulated for long enough time by the detector to produce well-defined photo peaks such as 86,400 seconds (24 hours) .The detector efficiency $\varepsilon(E_\gamma)$ at energy (E) can be found from the relation [12].

$$\varepsilon(E_\gamma) = \frac{Net}{A \times I_\gamma(E_\gamma) \times T} \times 100\% \quad \text{..... (1)}$$

where:

$\varepsilon(E_\gamma)$: The detector efficiency at energy (E_γ) .

N: Is the net peak area under the specific peak corrected for the background at energy (E_γ).

A: The activity in (KBq) of the standard source.

$I_\gamma(E_\gamma)$: The abundance at energy (E_γ).

T: The time of measurement which is equal to (86,400 s.)

The specific activityis defined as the activity per unit mass of the sample. It is measured in Becquerel (or Curies) per unit mass or volume.The specific activity for each detected radionuclides (radioactive element) in soil and oil samples had been calculated using the following equation [13]:

$$A_i(E_\gamma) = \frac{N}{t_c \times I_\gamma(E_\gamma) \times \varepsilon(E_\gamma) \times M} \quad \text{.....(2)}$$

Where :

$A_i(E_\gamma)$: the specific activity of radionuclide measured in (Bq/kg) or (Bq/l).

N:the net peak area under the peak Which is equal(Total counts – background counts).

t_c: is the counting life time, which is equal to (7200 sec).

$I_\gamma(E_\gamma)$:the abundance at energyE_γ.

$\varepsilon(E_\gamma)$: is the detection efficiency at energy E_γ .

M : the mass of the soil and oil sample (kg) or (liter).

The detector efficiency calibration curves as a function of energy are shown in Fig.4.

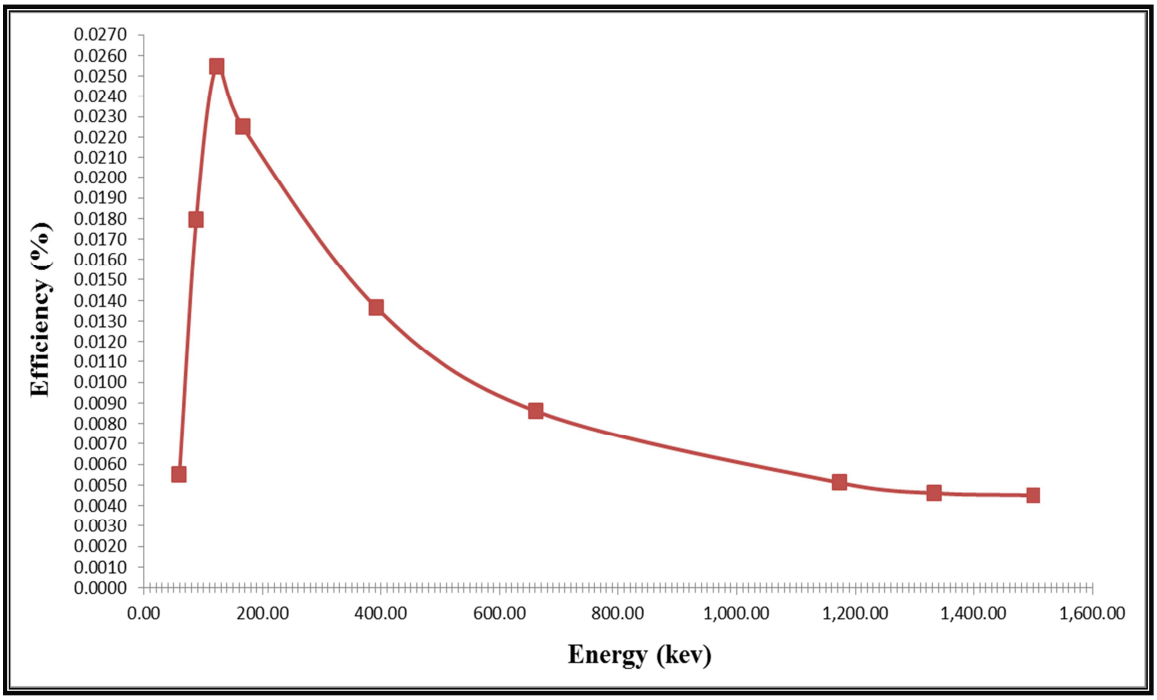

Figure (4): The Efficiency calibration curve of (HPGe) detector using standard mixed sources

Measurement of Parameters :

1. Radium Equivalent Activity (Ra_{eq})

To represent the activity concentrations of ^{238}U, ^{232}Th and ^{40}K by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced. The index is called radium equivalent activity (Ra_{eq}) which is used to ensure the uniformity in the distribution of natural radionuclides ^{238}U,^{232}Th and ^{40}K and is given by the expression [14]:

$$Ra_{eq}(Bq/kg,Bq/l)= A_U + 1.43A_{Th} + 0.077A_K \quad \ldots\ldots\ldots\ldots (3)$$

Where A_U, A_{Th} and A_K are the specific activity concentrations of ^{238}U,^{232}Th and ^{40}K in (Bq/kg)o(Bq/l) , respectively .

2. Absorbed Gamma Dose Rate (D_γ)

The absorbed dose rates in outdoor (D_γ) due to gamma radiations in air at (1m) above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{238}U,^{232}Th and ^{40}K) were calculated based on guidelines provided by[6].The conversion factors used to compute absorbed gamma-dose rate (D_γ) in air per unit activity concentration in Bq/kg (dry-weight) correspondsto 0.462 nG/hfor ^{238}U,0.621 nG/h for ^{232}Th and 0.0417 nG/h for ^{40}K[15].

$$D_\gamma (nGy/h) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \quad \ldots\ldots\ldots\ldots\ldots (4)$$

3. Representative Gamma Index ($I_{\gamma r}$)

Another radiation hazard index used for the estimation of gamma radiation associated with the natural radionuclides called the representative level gamma index($I_{\gamma r}$)is defined according the following equation [16]:

$$I_{\gamma_r} = \frac{A_U}{150} + \frac{A_{Th}}{100} + \frac{A_K}{1500} \leq 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The safety value for this index is ≤ 1

4. Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor by a member is calculated from the absorbed dose rate by applying dose conversion factor of (0.7Sv/Gy) and the occupancy factor for outdoor and indoor was 0.2(5/24) and 0.8(19/24), respectively**.** AEDE is determined using the following equations[17].

$$(AEDE)_{in} (mSv/y)=D_\gamma (nGy/h)\times 10^{-6}\times 8760\ h/y \times 0.80\times 0.7\ Sv/Gy \quad \ldots\ldots\ldots (6)$$

$$(AEDE)_{out} (mSv/y)=D_\gamma (nGy/h)\times 10^{-6} \times 8760\ h/y\times 0.20\times 0.7\ Sv/Gy \quad \ldots\ldots\ldots (7)$$

5. The External Hazard Index (H_{ex})

Beretka and Mathew [18] defined two other indices that represent internal and external radiation hazards. The external hazard index is obtained from (Ra_{eq}) expression through the supposition that its allowed maximum value (equal to unity) corresponds to the upper limit of Ra_{eq} (370 Bq/kg). The external hazard index (H_{ex}) can then be defined as:

$$H_{ext} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots\ldots\ldots\ldots (8)$$

Where (H_{ex}) are an external hazard index. A_U,A_{Th} and $A_K$are the activity concentrations, expressed in (Bq/kg,Bq/l) for ^{238}U,^{232}Th and ^{40}K respectively.

6.The Internal Hazard Index (H_{in})

Internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}) as given below [18] [19]**:**

$$H_{\text{int}} = \frac{A_U}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad \ldots\ldots\ldots\ldots (9)$$

The value of this index(H_{in}, H_{ex}) must be less than unity for the radiation hazard to be negligible.

RESULTS AND DISCUSSION

Table (2) presents the specific activity for the radionuclides for five solid samples of soil and scale in Al-Dora refinery(obtained by using the relation(2)), from Table (1) it can be noticed that:

Table(2): specific activity for the radionuclides for solid samples

Sample code	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	^{137}Cs (Bq/kg)
D4	32.62±5.71	16.42±4.05	175.41±13.24	B.D.L
D5	18.41±4.29	23.02±4.80	245.27±15.66	B.D.L
D6	20.48±4.53	26.56±5.15	277.59±16.66	3.05±1.75
D7	13.04±3.61	18.20±4.27	230.41±15.18	1.60±1.26
D13	11.22±3.35	6.28±2.51	51.22±7.16	B.D.L
Min.	**11.22±3.35**	**6.28±2.51**	**51.22±7.16**	**B.D.L**
Max.	**32.62±5.71**	**26.56±5.15**	**277.59±16.66**	**3.05±1.75**
Ave.	**19.15±4.38**	**18.10±4.25**	**195.98±14.00**	**2.33±1.52**

B.D.L =Below Detection Limit

Table(3): specific activity for the radionuclides for liquid samples

Sample code	^{238}U (Bq/l)	^{232}Th (Bq/l)	^{40}K (Bq/l)	Cs-137 (Bq/l)
D1	15.23±3.90	5.82±2.41	14.90±3.86	1.32±1.51
D2	17.24±4.15	19.00±4.36	105.97±10.29	4.03±2.01
D3	33.16±5.76	6.62±2.57	92.30±9.61	1.17±1.08
D8	35.04±5.92	15.22±3.90	149.01±12.21	1.82±1.35
D9	5.15±2.27	13.45±3.67	50.10±7.08	6.16±2.48
D10	4.12±2.03	B.D.L	14.16±3.76	11.16±3.34
D11	1.59±1.26	35.47±5.96	24.34±4.93	3.47±1.86
D12	6.63±2.57	15.06±3.88	49.53±7.04	1.30±1.14
D14	4.28±2.07	3.27±1.81	208.50±14.44	1.67±1.29
D15	17.11±4.14	15.23±3.90	422.28±20.55	10.64±3.26
Min.	**1.59±1.26**	**3.27±1.81**	**14.16±3.76**	**1.17±1.08**
Max.	**35.04±5.92**	**35.47±5.96**	**422.28±20.55**	**11.16±3.34**
Ave.	**13.96±3.74**	**14.35±3.79**	**113.11±10.64**	**4.27±2.07**

Table (4): Radiation Hazard indices for all Samples in AL-Dora refinery

Sample code	Ra_{eq} (Bq/kg,Bq/l)	D_γ (nGy/h)	Annual effective dose Equivalent (mSv/y)		$I_{\gamma r}$	Hazard index	
			$(AEDE)_{in}$	$(AEDE)_{out}$		H_{in}	H_{ex}
D1	24.70	11.27	0.055	0.014	0.170	0.108	0.067
D2	52.57	24.18	0.119	0.030	0.376	0.189	0.142
D3	49.73	23.28	0.114	0.029	0.349	0.224	0.134
D4	69.61	32.58	0.160	0.040	0.499	0.276	0.188
D5	70.21	33.03	0.162	0.041	0.516	0.239	0.190
D6	79.84	37.53	0.184	0.046	0.587	0.271	0.216
D7	56.81	26.93	0.132	0.033	0.423	0.189	0.153
D8	68.28	31.85	0.156	0.039	0.485	0.279	0.184
D9	28.24	12.82	0.063	0.016	0.202	0.090	0.076
D10	5.21	2.49	0.012	0.003	0.037	0.025	0.014
D11	53.19	23.31	0.114	0.029	0.375	0.145	0.144
D12	31.98	14.48	0.071	0.018	0.228	0.104	0.086
D13	24.14	11.22	0.055	0.014	0.172	0.096	0.065
D14	25.01	12.70	0.062	0.016	0.200	0.079	0.068
D15	71.40	34.97	0.172	0.043	0.548	0.239	0.193
Min.	**5.21**	**2.49**	**0.012**	**0.003**	**0.037**	**0.025**	**0.014**
Max.	**79.84**	**37.53**	**0.184**	**0.046**	**0.587**	**0.279**	**0.216**
Ave.	**47.39**	**22.18**	**0.109**	**0.027**	**0.344**	**0.170**	**0.128**

The highest value of specific activity of (^{238}U) was found in D4(soil),which was equal to (32.62±5.71Bq/kg),while the lowest value of specific activity of (^{238}U) was found in D13(Scale) which was equal to (11.22±3.35 Bq/kg),with anaverage value of (19.15±4.38Bq/kg).

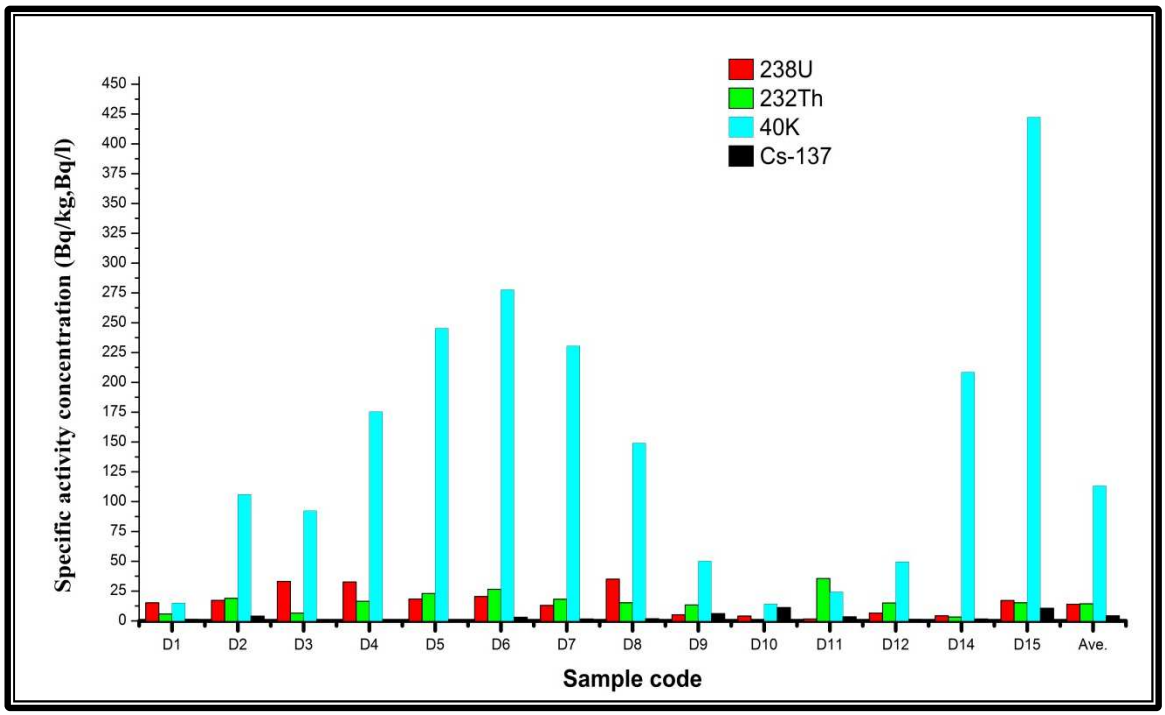

Figure (5): Histogram illustrating the change in specific activity of ^{238}U, ^{232}Th, ^{40}K and ^{137}Cs for all oil products samples sites

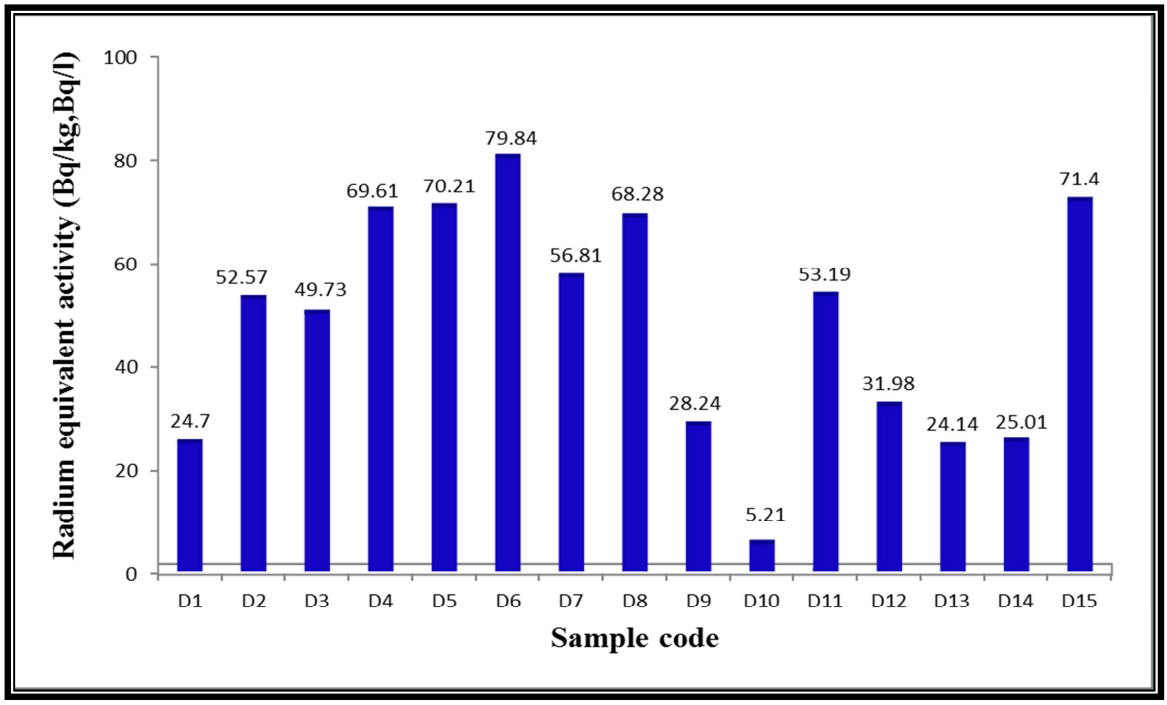

Figure (6): Histogram illustrating the change in radium equivalent activity (Ra_{eq}) for all samples sites

The highest value of specific activity of (^{232}Th) was found in D6(soil)which was equal to (26.56±5.15Bq/kg),while the lowest value of specific activity of (^{232}Th) was found in D13(Scale) which was equal to (6.28±2.51Bq/kg),with anaverage value of (18.10±4.25Bq/kg).

The highest value of specific activity of (^{40}K) was found in D6(soil)which was equal to (277.59±16.66Bq/kg),while the lowest value of specific activity of (^{40}K) was found in D13(Scale) which was equal to (51.22±7.16 Bq/kg),with anaverage value of (195.98±14.00Bq/kg).

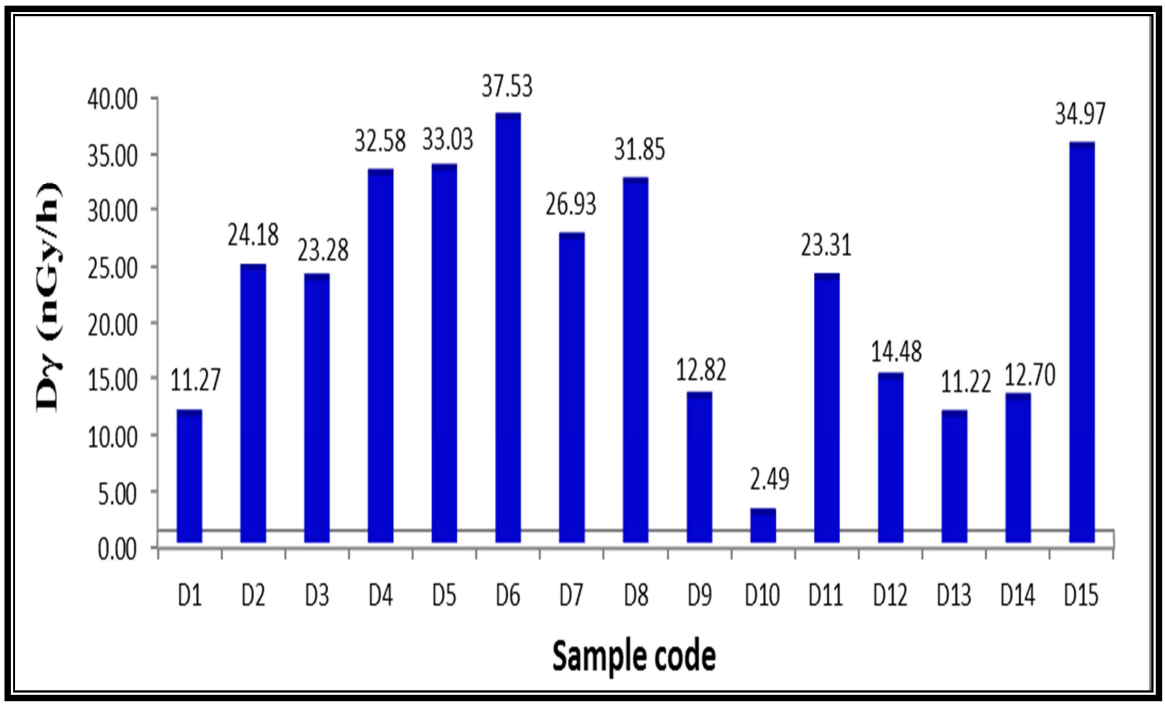

Figure (7) : Histogram illustrating the change in absorbed gamma dose rate (D_Y) for all samples sites

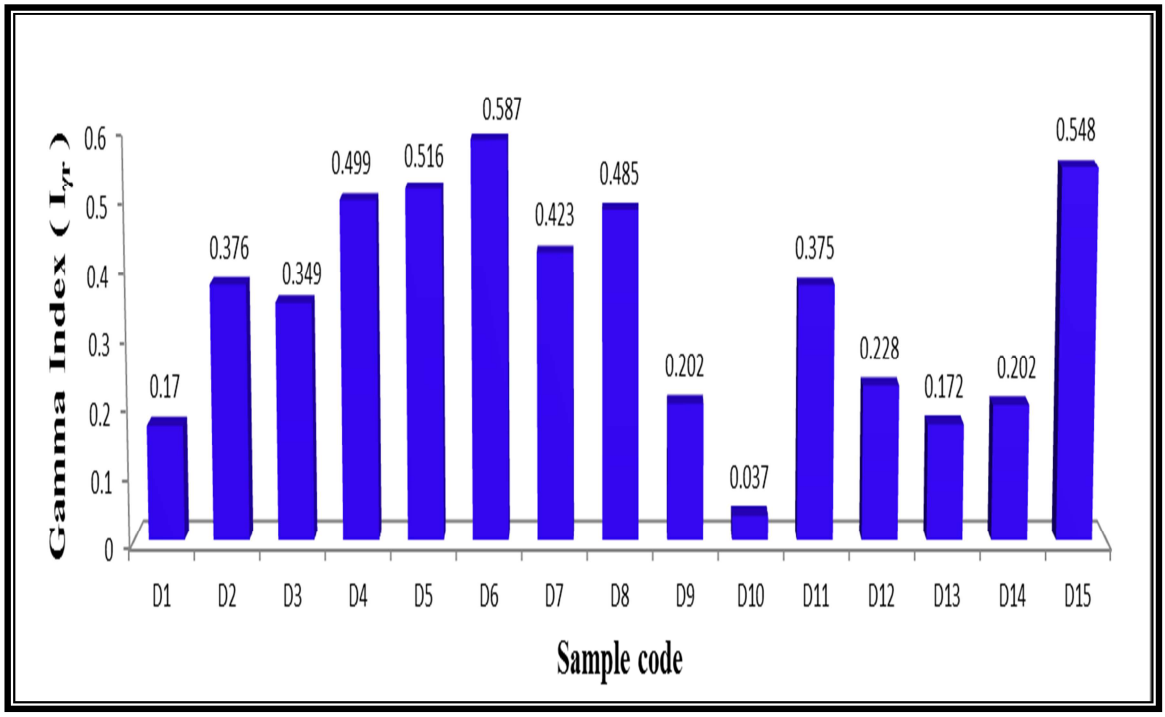

Figure (8) : Histogram illustrating the change in the activity concentration index ($I_{\gamma r}$) for all samples sites

The highest value of specific activity of (^{137}Cs) was found in D6(soil)which was equal to (3.05±1.75Bq/kg),while the lowest value of specific activity of (^{137}Cs) was found in D13(Scale) which was equal to (B.D.L),with anaverage value of (2.33±1.52Bq/kg).

Table (3) presents the specific activity for the radionuclides for ten Liquid samples of Crude oil,sludge,Gasoline,Full oil,Gas oil (petrol),Kerosene and Motor oil in Al-Dora refinery,from Table (2) it can be noticed that:

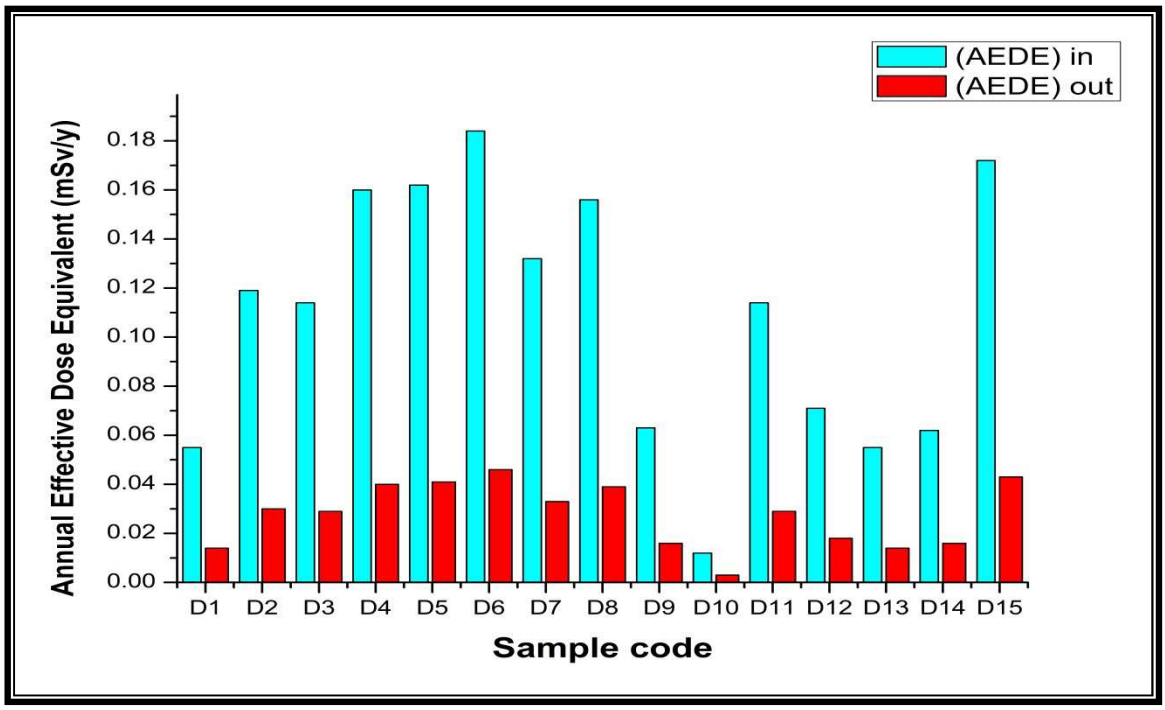

Figure (9) : Histogram illustrating the change in the internal and external hazard index for all samples sites

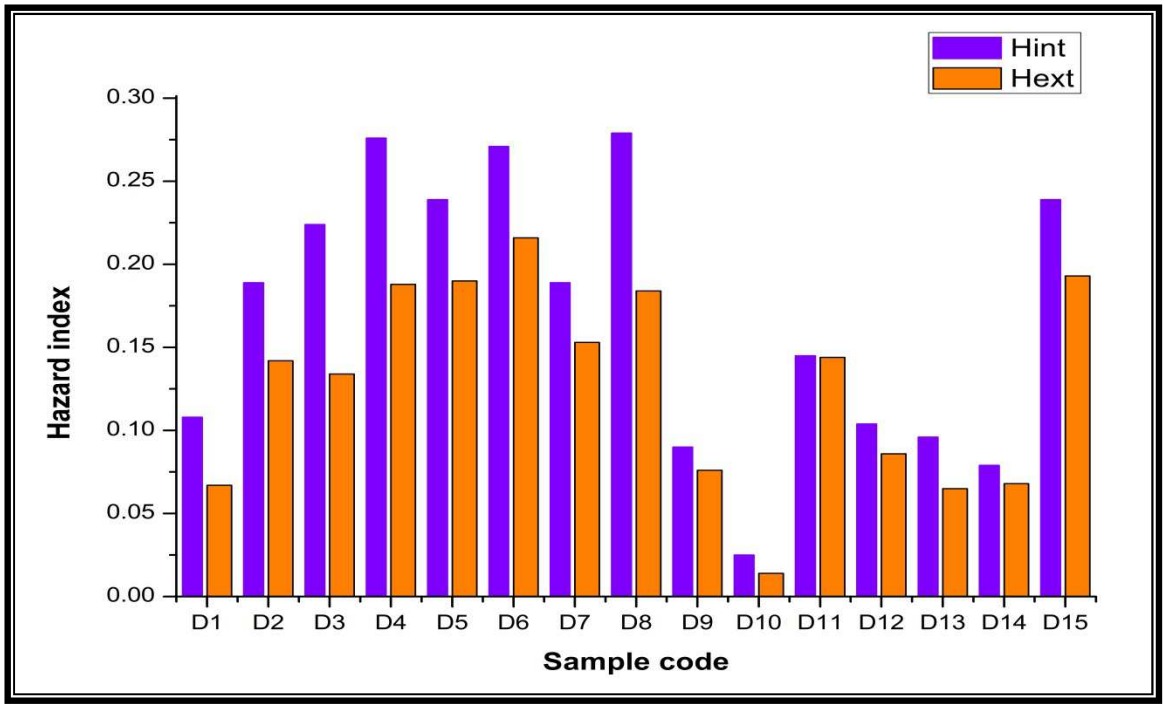

Figure (10) :Histogram illustrating the change in the indoor and outdoor annual effective dose equivalent for all samples sites

The highest value of specific activity of (^{238}U) was found in D8(sludge)which was equal to (35.04±5.92Bq/l),while the lowest value of specific activity of (^{238}U) was found in D11(Gas oil) which was equal to (1.59±1.26 Bq/l)with anaverage value of (13.96±3.74Bq/l).

The highest value of specific activity of (^{232}Th) was found in D11(Gasoil)which was equal to (35.47±5.96Bq/l),while the lowest value of specific activity of (^{232}Th) was found in D14(Motor Oil) which was equal to (3.27±1.81Bq/l),with anaverage value of (14.35±3.79Bq/l).

The highest value of specific activity of (^{40}K) was found in D15(Crude Oil)which was equal to (422.28±20.55Bq/l),while the lowest value of specific activity of (^{40}K) was found in D10(Full Oil) which was equal to (14.16±3.76 Bq/l) ,with anaverage value of (113.11±10.64Bq/l).

The highest value of specific activity of (^{137} Cs) was found in D10(Full Oil)which was equal to (11.16±3.34Bq/l),while the lowest value of specific activity of (^{137} Cs) was found in D3(Crude Oil) which was equal to (1.17±1.08 Bq/l),with anaverage value of (4.27±2.07Bq/l).

The highest value of radium equivalent activity (Ra_{eq})(obtained by using relation(3))was found in D6, which was equal to (79.84Bq/kg), while the lowest value of radium equivalent activitywas found in D10, which was equal to (5.21Bq/l), with anaverage value of (47.39±22.64 Bq/kg,Bq/l).

The highest value of the absorbed gamma dose rate (D_γ)(obtained by using relation(4)) was found in D6, which was equal to (37.53 nGy/h), while the lowestvalue of the absorbed gamma dose rate was found in D10, which was equal to (2.49 nGy/h), with anaverage value of (22.18±10.73 nGy/h).

The highest value of the activity concentration index ($I_{\gamma r}$)(obtained by using relation(5))was found in D6 , which was equal to (0.587), while the lowest value ofthe activity concentration index was found in D10, which was equal to (0.037), with anaverage value of (0.344±0.167).

The highest value of indoor annual effective dose rate $(AEDE)_{in}$ (obtained by using relation(6)) was found in D6, which was equal to (0.184mSv/y), while the lowest value ofindoor annual effective dose rate was found in D10, which was equal to (0.012mSv/y), with anaverage value of (0.109±0.053 mSv/y).

The highest value of outdoor annual effective dose rate $(AEDE)_{out}$(obtained by using relation(7))was found D6, which was equal to (0.046mSv/y), while the lowest value ofindoor annual effective dose rate was found D10, which was equal to (0.003mSv/y), with anaverage value of (0.027±0.013mSv/y).

The highest value of external hazard index (H_{ext})(obtained by using relation(8))was found in D6 ,which was equal to (0.216), while the lowest value ofexternal hazard index was found D10, which was equal to (0.014), with anaverage value of (0.128±0.061).

The highest value of internal hazard index (H_{in}) (obtained by using relation(9)) was found in D8, which was equal to (0.279), while the lowest value ofinternal hazard index was found in D10, which was equal to (0.025), with anaverage value of (0.170±0.083).

The results of the Radiological indices which include (radium equivalent activity, absorbed gamma dose rate, the annual effective dose which include indoor and outdoor effective dose rate in units of mSv/y, activity concentration index,internal hazard index and external hazard index) are listed in table (4).

The present results for Al-Dora Refinery have shown that the specific activity of (^{238}U, ^{232}Th, ^{40}K) in (both solid and liquid) samples to be less than the recommended value given by the worldwide average (UNSCEAR, 1994), which was equal to (50,50 and 500) Bq/kg,Bq/l. Respectively [20],in addition the specific activity of the artificial radionuclide (^{137} Cs)was found to be less than the devised contamination limit (600)Bq/kg/Bq,l[21], see fig. (5)

The present results show that the values of radium equivalent activity in (both solid and liquid) samples were lower than the recommended value of (370) Bq/kg, Bq/l for the radium equivalent activity given by (UNSCEAR, 1994) [20]., see figure (6).

The present results show that the values of of absorbed gamma dose rate were less than the recommended value of (55 nGy/h) for the absorbed gamma dose rate given by worldwide Ave. (UNSCEAR, 1994) [21],see fig. (7).

The present results show that the values of the Representative Gamma Index in (both solid and liquid)were less than the recommended value of (<1) for the Representative Gamma Index given by(UNSCEAR,2000)[6]**,** see fig.(8).

The present results show that the indoor annual effective dose equivalent in (both solid and liquid)samples were less than the recommended value of (20mSv/y) for the indoor annual effective dose equivalent given by worldwide Ave. (UNSCEAR, 1994) [21],Also the outdoor annual effective dose equivalent were less than the recommended value of (1mSv/y) for the outdoor annual effective dose equivalent given by(UNSCEAR, 1994), see fig. (9)

The present results show that the values of internal hazard index and external hazard index in all samples were less than the recommended value of (<1) for the internal hazard index and external hazard index given by(UNSCEAR,2000) [6],see fig. (10).

CONCLUSION

This study showed that the analyzing Petroleum Waste samples by usingthe high-purity germanium (HPGe) detector from different kinds of oil product samples. The specific activity concentrations in (^{238}U, ^{232}Th,^{40}K and^{137}Cs) are below the specific activity concentration of worldwide average, Also the six Radiation Hazard indices account is less than the recommended value of the radiation hazard indices given by worldwide average.Therefore,The study shows that all the Petroleum Waste samples do not pose any significant source of radiation hazard and are safe for use.

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