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A Study of Chemical, Mineral Compositions (of Some Metals) and Natural Radioactivity in Porcelain and Ceramic Dinner Ware

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Abstract

Fifteen Porcelain and Ceramic Dinner Wares samples (collected from local commercial suppliers—Jeddah Saudi Arabia) were studied applying X-Ray Diffraction and Atomic Absorption techniques were used to study the Chemical, Mineral, Compositions Concentrations (of Some Metals). In addition, the Natural Radioactivity measurements of ^{226}Ra, ^{232}Th and ^{40}K, was used by a high-purity germanium (HPGe) detector. X-ray diffraction results showed that the major mineral constituents of 15 samples were quartz (SiO$_2$) (except one), minor and trace elements vary from sample to sample. Atomic absorption spectroscopy results of the concentrations for (Al, Pb, Bi, U, Th and K) in (ppm) showed that Al$_2$O average was 10.3 (ppm) (10%) less than the acceptable value. PbO, its average was 1.65 ppm which was slightly greater than the allowed value 1.35 ppm. Bi concentrations for all samples were lower than (DL < 10). For most samples U, concentrations were lower than (DL < 5) except samples C9 and C11. Th concentrations ranged from LDL (<1 to 52.88) and were much greater than the acceptable value 7.24 ppm except samples P1, P2, P4. The potassium concentration average was greater than the acceptable value. The average concentrations of ^{238}U, ^{232}Th and ^{40}K were (83.83, 91.05 and 751.07) Bq/kg dry. The radium equivalent activity concentration Ra_{eq} (Bq/kg) (302.61) was less than recommended value (370), gamma dose rate D (nGy/h) average (140.15) was much higher than the recommended value (60) (UNSCEER). D_{eff} (mSv/year) and H_{ix} were below the published admissible limit ≤ 1 and the risk is negligible. This study offers needed information for consumers at exposure risk and is useful to be found in terms of radiation protection.

Keywords

X-Ray Diffraction, Atomic Absorption, Gamma-Ray Spectroscopy, Natural

Radioactivity, Dinnerware

1. Introduction

Ceramics are one of the most important types of the industrial materials. Ceramic is made of a mixture of clay, feldspar, silica, talc kaolin minerals together with zirconium silicates ($ZrSiO_4$). The ceramic raw materials contain naturally occurring radionuclide ^{238}U and, ^{232}Th series, and ^{40}K (Abbady, 2004). Ceramic causes a potential radiation risk due to these radiation exposures and their chemical composition, controls should be restricted (Almayahi et al., 2012). Measurements of the radio activities from houseware, due to their composition contain radionuclides of ^{238}U, ^{232}Th and ^{40}K and their radioactive series are important. Such activities would provide the useful data of doses and hazard indices to make them safe in houseware product (Ahmad et al., 2015; Papadopoulos et al., 2013). There are many numbers of work worldwide measured the natural radioactivity of ceramic and porcelain by gamma rays spectroscopy and used their values to determine the doses and the hazard indices, these data are important to human health and compare the results with the recommended limits (Aksoy et al., 2010; Tufail et al., 2010; Janković et al., 2013). The objectives of this study are: 1) Use X-Ray Diffraction and Atomic Absorption techniques to study the Chemical, Mineral, Compositions and Concentrations (of Some Metals) in fifteen local and imported Ceramic and Porcelain dinner wares samples. 2) Measure the Natural Radioactivity of ^{226}Ra, ^{232}Th and ^{40}K by gamma-ray spectroscopy having a high-purity germanium (HPGe) detector in these samples, and to determine their specific radioactivity concentrations. 3) Calculate the radium equivalent activity concentrations Ra_{eq} (Bq/kg), gamma dose rate D (nGy/h), annual effective dose D_{eff} (mSv/year) and external hazard H_{ix} values, and compare the results with worldwide values to control the causes of potential radiation risk.

2. Materials and Methods

2.1. Sample Collection and Preparation

Fifteen different types and different origins of food wares were collected from commercial suppliers as shown in Table 1. These samples were crushed, grounded, sieved by 1 mm × 1 mm, and dried to 105˚C for 24 hr. not to lose the volatile ^{137}Cs or the natural polonium and to remove moisture. Twenty gm of the dried samples were kept for analyzed by XRD and Atomic Absorption spectroscopy. For radiometric analysis, each dried sample was weighed and transferred to 640 cc poly-ethylene Marinelli beakers then sealed and stored for 2 - 4 months to stop the escape of Radon gas and to get the radioactive secular equilibrium between ^{238}U, ^{232}Th and their progenies.

Table 1. Origin, type, and description of the 15 samples.

Sample Code	origin	type	Description
P1	China	Porcelain cup	White glazed
P2	France	Porcelain cup	White glazed
P3	Turkey	Porcelain cup	White glazed
P4	England	Porcelain plate	White glazed
P5	China	Porcelain plate	White glazed
P6	Vietnam	Porcelain plate	White glazed
P7	Portugal	Porcelain plate	White glazed
C8	Pakistan	ceramic cup	Color glazed
C9	S. Yemen Hadramout	ceramic pot	Color glazed
C10	Saudi Arabia Makkah	ceramic cup	Color glazed edge
C11	Morocco	ceramic pot	Color glazed
C12	IRAN	ceramic pot	Color glazed-edge
C13	Yemen Saada	ceramic plate	Color glazed
C14	Saudi Arabia Rasiefa	ceramic plate	Color glazed
C15	Saudi Arabia Jiad	ceramic plate	Color glazed

2.2. Experimental Techniques

Ten gm of the dried samples were analyzed by XRD spectrometer model Burker XR-D D8 Advance for the chemical and mineral compositions. Ten gm of the samples were used for the analysis by Atomic Absorption spectrometer model OPTIMA 4000 DV Series Perkin Elmer for the Al, Bi, Pb, U, Th, and K concentrations. The samples were analyzed non-destructively, using gamma-ray spectrometry with Canberra high purity germanium (HPGe) coaxial detector with relative efficiency of 25% and FWHM 2.0 keV at 1332 keV, of ^{60}Co. Genie 2000 basic spectroscopic software was installed in the computer for data acquisition and analysis. The system was calibrated for energy using standard gamma-ray sources and absolute efficiency. The lowest detection limits (DL) of HPGe detector system were 0.33, 0.27, and 2.31 for ^{226}Ra, ^{232}Th, and ^{40}K respectively for a counting time of 82,800 seconds. An empty polyethylene Marinelli beaker was placed in the detection system for this time period in order to collect the background count rates. Then, each sample was measured during a same accumulating time.

2.3. Calculation

The concentrations of ^{226}Ra, ^{232}Th-232 and ^{40}K were determined from the average concentrations of gamma ray lines of energies tabulated in Table 2. There is secular equilibrium between the ^{226}Ra and its daughters ^{214}Pb, ^{214}Bi. For ^{232}Th, the secular equilibrium is between the ^{232}Th and its daughters ^{228}Ac, ^{212}Bi and ^{208}Tl. The concentration of ^{40}K is determined.

Table 2. Gamma lines used for spectrometry determinations.

Radionuclide	Daughter Nuclei	E (KeV)	Photon Disintegration %
^{226}Ra	^{214}Pb	295.09	20
		351.87	38
		609.31	49
	^{214}Bi	1120.27	16
		1764.49	16
		338.32	13
^{232}Th	^{228}Ac	911.16	30
		968.97	18
	^{212}Bi	727.25	08
	^{208}Tl	583.10 - 2614.48	33
			36
^{40}K	^{40}Ar	1460.8	11

Determination of activity concentrations in Bq/kg dry weight was calculated using the equation (Younis et al., 2018):

$$A_c \left(\text{Bq/kg} \right) = N_c / m \tag{1}$$

where: N_c is the net count area of the gamma line for the measured sample (counts/second), m is mass of the sample, ϵ is the absolute efficiency of the spectrometer at the photo-peak energy and β is the probability of emission of the gamma ray. Exposure to radiation has been defined in terms of the radium equivalent Ra_{eq} Bq/kg which is calculated from equation (UNSCEAR, 1993).

$$Ra_{eq} = C_{Ra} + \left(C_{Th} \times 1.43 \right) + \left(C_K \times 0.077 \right) \tag{2}$$

where: C_{Ra}, C_{Th} and C_K are the concentrations in Bq/kg dry weight for radium, thorium and potassium respectively. The total air absorbed dose rate (nGy/h) in the outdoor air at 1 m above the ground due to the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) dry weight was calculated using the equation (UNSCEAR, 2000; Veiga et al., 2006).

$$D \left(\text{nGy/h} \right) = 0.427 C_{Ra} + 0.623 C_{Th} + 0.043 C_K \tag{3}$$

where: C_{Ra}, C_{Th}, and C_K are the specific activities (concentrations) of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg dry weight respectively. The annual effective dose equivalent D_{eff} (mSv/y) in air was calculated using the values of the absorbed dose rate by applying the dose conversion factor of 0.7 Sv/Gy and the outdoor occupancy factor of 0.2 (people spend about 20% of their life outdoor) the Annual Effective Dose (in mSv/y) received by population can be calculated using equation (UNSCEAR, 2000):

$$D_{eff} \left(\text{mSv/y} \right) = D \left(\text{nGy/h} \right) \times 8766 \, \text{h} \times 0.7 \left(\text{Sv/Gy} \right) \times 0.2 \times 10^{-6} \tag{4}$$

where: D (nG/h) is the total air absorbed dose rate in the outdoor. 8766 h is the number of hours in 1 year. 10^{-6} is conversion factor of nano and milli. To limit the annual external gamma-ray dose to 1.5 Gy for the samples under investiga-

tion, the external hazard index (H_{ex}) is given by the equation (El Aassy Ibrahim et al., 2011):

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810.\qquad (5)$$

3. Results and Discussion

3.1. XRD Analysis

X-ray diffraction is a non-destructive analytical technique, which provides detailed information about the atomic structure of crystalline substances, chemical composition, and physical properties of materials. It is a powerful tool in the identification of minerals in rocks and soils (Harris & White, 2008). The minerals of 15 samples analyzed by XRD spectrometer are shown in Table 2. The results show that the major mineral constituent of all samples (except P4) is quartz (SiO_2). As expected, most common type of clay (ceramic products are clay-based) consists of kaolinite, mica, quartz (SiO_2), and feldspar (a group of rock-forming tectosilicate minerals). While Porcelain is mostly kaolinite ($Al_2Si_2O_5(OH)_4$) and is defined as glazed or unglazed glassy ceramic. Minor element in porcelain samples is mullite ($Al_6Si_2O_{13}$) except sample 7, its minor element is Albite ($NaAlSi_3O_8$). In ceramic samples minor elements vary from sample to sample as well as trace elements in all samples. Table 3 represents the mineral chemical composition and its description (Don Leet et al., 1982).

Table 3. The mineral constituents analyzed by XRD spec.

Sa. No.	MAJOR	MINOR	TRACE
P1	Quartz	Mullite	Albite, Zircon, Montmorillonite
P2	Quartz	Mullite	Albite, Zircon, Montmorillonite
P3	Quartz	Mullite	Albite, anasseite, Pargasite, Zircon, Zaherite
P4	Fluorite	-	-
P5	Quartz	Mullite	-
P6	Quartz	Mullite	-
P7	Quartz	Albite	Mullite, Artroeite
C8	Quartz	Muscovite	Mullite
C9	Albite Quartz	Diopside, Microcline	Nontronite, Saponite, Montmorillonite
C10	Quartz	Albite	Pargasite, Calcite, Montmorillonite, Nontronite, Clinechlore, Zircon, Kaolinite
C11	Albite Augite Quartz	Magnetite	Biotite, Saponite, Clinechlore, Kaolinite
C12	Quartz	Anatase	Ablite, Diopside, Calcite, Ferroactinolite, Gypsum, Nontronite, Zircon
C13	Albite Quartz	-	Biotite, Magnetite, Clinechlore, Kaolinite, Montmorillonite, Riebeckite
C14	Quartz	Albite, Microcline	Calcite, Kaolinite, Clinochloe Montmorillonite, Pargasite, zircon
C15	Quartz	Albite, Anatase	Augite, Biotite, Magnetite, Pargasite, Montmorillonite,

3.2. Atomic Absorption Spectroscopy

Table 4 lists the results of the concentrations for 15 porcelain and ceramic samples for sex elements (Al. Pb, Bi, U, Th, K) are measured by atomic absorption spectroscopy. Ceramic and porcelain include Aluminum (Al) in the form of aluminum oxide (Al_2O_3), Aluminum is considered to be a non-essential element and is known to be toxic to different species, the toxicity depends on its form in solution. Results show that the concentrations (ppm) of Al ranged from 4.56 (P2) to 15.97 (C10), with mean 10.3 (ppm) (10%) which is less than the acceptable value (11%) (Lehman, 2002). Lead (lead oxide (PbO)) glazes used on many kind of porcelain and ceramic food wares. Lead is high toxicity element when absorbed into the body, depending on the size and shape of the wares. It is harmful to human health at high concentrations, the allowed limit is 0.2 ppm (European Community, EC, 2005). Lead concentration mean value is 1.65 ppm. Bi concentrations for all samples were lower than (DL < 10). For U, concentrations were lower than (DL < 5) except samples C9 and C11 (7.67 and 11.84) respectively, these values are much less than values measured by gamma spectroscopy (C9: 93.8, C11: 144.8). Thorium is found almost everywhere, and it can be absorbed through food, drinking water, and in air. Thorium has no known biological function. Th concentrations ranged from LDL (<1) (P2) to

Table 4. Concentrations of Al, Bi, Pb, U, Th and K measured by Atomic Absorption spectrometer.

Elements	Al	Pb	Bi	U		Th		K	
DL.	1.00	1.00	10.00	5.00	61.75	1.00	4.07	1.00	0.031
Units	ppm	ppm	ppm	ppm	Bq/Kg	ppm	Bq/Kg	ppm	Bq/Kg
P1	12.26	1.07	<10	<5	<61.75	6.71	27.31	2079.09	64.45
P2	4.56	1.64	<10	<5	<61.75	<1	<4.07	28,868.00	894.91
P3	13.31	2.23	<10	<5	<61.75	52.88	219.01	55,139.70	1709.33
P4	5.97	1.78	<10	<5	<61.75	4.68	19.37	46,402.02	1438.46
P5	10.96	2.44	<10	<5	<61.75	33	136.67	48,205.50	1494.37
P6	10.96	1.92	<10	<5	<61.75	40.04	165.81	38,304.50	1187.44
P7	10.78	1.11	<10	<5	<61.75	25.04	103.70	21,165.00	656.12
C8	9.83	2.38	<10	<5	<61.75	45.72	189.34	32,220.00	998.82
C9	9.14	1.76	<10	7.76	93.8	17.56	72.73	27,929.90	865.83
C10	15.97	1.68	<10	<5	<61.75	47.96	198.62	15,771.00	488.90
C11	9.18	1.80	<10	11.84	144.80	15.84	65.61	4203.00	1303.33
C12	15.32	1.29	<10	<5	<61.75	24.84	102.89	4774.00	147.99
C13	9.12	1.83	<10	<5	<61.75	16.48	68.25	39,440.00	1222.64
C14	14.51	1.75	<10	<5	<61.75	41.36	171.27	18,936.00	587.02
C15	14.32	1.75	<10	<5	<61.75	35.28	146.11	16,155.00	500.81
mean	10.39	1.65		9.8	119.31	27.16	114.54	24,974.54	847.52

52.88 ppm (P3), Th concentrations for all samples (accept P1, P2, P4) were much greater than the acceptable value 7.24 ppm (Rudnick et al., 2004). Potassium is the eighth most abundant element in the Earth's crust (2.1%) (Emsley, 2001), it is found in almost all solids on Earth It is not found in pure form in nature, but in from of compounds. Potassium is an essential element for all organisms. Potassium toxicity, a condition called hyperkalemia, is very rare the potassium concentrations in ppm range from 2079.09 (P1) to 48205.50 (P5), where the mean is 24974.54 ppm (2.5%), which is greater than the acceptable value (1.92%) (Heiserman, 1992).

Figure 1 shows a comparison between samples activity concentration values for ^{232}Th, and ^{40}K were measured by Gamma-Ray Spectrometry and samples concentration values for Th, and K measured by Atomic Absorption Spectrometer. Both analysis results are in a good agreement and this means that the geochemical analysis (Atomic Absorption Spectrometer) can determine the concentrations of elements in the minerals with reasonable values.

3.3. Gamma Spectroscopy

Porcelain and ceramic samples were measured using the gamma spectrometer. The results in Table 6 show that: There is secular equilibrium between the ^{226}Ra and its daughters ^{214}Pb, their activities were used to calculate the concentrations of ^{226}Ra in Bq/kg dry weight. Their ranged were from 11.51 (P2) to 192.67 (P7). Samples show high radium in samples P3 (184.68) and P7 (192.67). The decay of short half-life daughters ^{228}Ac, ^{212}Bi, and ^{208}Tl were used to determine the activity concentrations of ^{232}Th, since there is secular radioactivity equilibrium in ^{232}Th series. The activity concentrations in Bq/.kg dry weight of ^{232}Th were varied form 13.01 (P4) to 184.04 (C10). Activity concentration values in Bq/.kg dry weight for ^{40}K were from low value 67.10 (P1) to high value 1736.30 (P3). The ^{226}Ra, ^{232}Th and ^{40}K activity concentrations were varied, this is due to the mineral constituents (Table 3), of the studied samples. The high value of ^{226}Ra was in porcelain sample (P7), ^{232}Th highest concentration was in ceramic sample (C10), for ^{40}K, the highest concentration was in porcelain sample (P3), this is due to the chemical composition of these sample (Table 5).
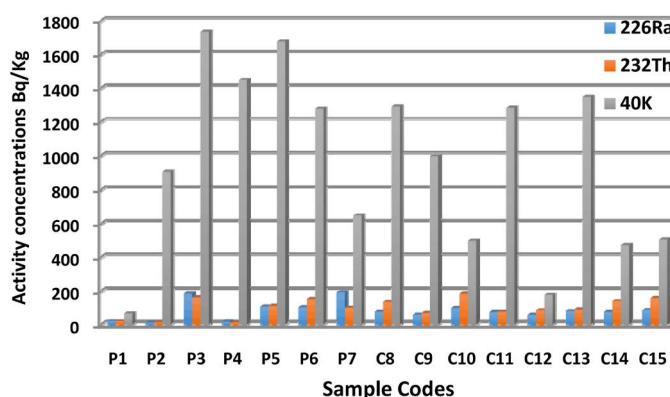

Figure 1. Activity concentrations (Bq/Kg) of ^{226}Ra, ^{232}Th and ^{40}K.

Table 5. The mineral chemical composition and its description (Don Leet et al., 1982; Mineral Data, 2012).

Mineral chemical composition	Description	Mineral/chemical composition	Description
Albite $NaAlSi_3O_8$	Sodium Plagioclase feldspar. Magmatic and pegmatitic rocks.	Manasseite $Mg_6Al_2(CO_3)(OH)_{16} \cdot 4(H_2O)$	In iron ore skarns.
Anatase TiO_2	Derived from other Ti-bearing minerals. Common as a detrital mineral	Microcline $KAlSi_3O_8$	Granitic gmatites hydrothermal and, metamorphic rocks.
Artroeite $PbAlF_3(OH)_2$	In a quartz-lined vug	Montmorillonite $NaCaAl_2Si_4O_{10}(OH)_2(H_2O)_{10}$	Absorbing water and expanding.
Augite-a pyroxene $(Ca, Na)(Mg, Fe, Al, Ti)(Si, Al)_2O_6$	Ferromagnesian silicate. Basic igneous and metamorphic rocks.	Mullite $Al_6Si_2O_{13}$	Remelted Tertiary-aged clays.
Biotite-Black mica $K(MgFe^{2+})_3AlSi_3O_{10}(OH, F)_2$	Granitic rocks. Forms a series with phlogopite.	Muscovite $KAl_2(Si_3Al)O_{10}(OH, F)_2$	Granites and pegmatites.
Calcite $CaCo_3$	Found in all kind of rocks	Nontronite $Na(Fe^{3+})_2Si_3AlO_{10}(OH)_2 \cdot 4(H_2O)$	It is the iron(III) rich member of the smectite group of clay meminerals.
Clinochlore $(MgFe^{2+})_5Si_3Al_2O_{10}(OH)_8$	Alteration mineral. Metamorphic rock.	Pargasite $NaCa_2Mg_3(Fe^{2+})Si_6Al_3O_{22}(OH)_2$	A complex inosilicate mineral of the amphibole group.
Diopside $CaMg(Si_2O_6)$	Basic and ultrabasic igneous and metamorphic rocks.	Quartz (SiO_2)	It is a component of almost every rock type.
Ferroactinolite $Ca_2(Fe^{2+})_5(Si_8O_{22})(OH)_2$	Prismatic crystals of ferro-actinolite showing terminal crystal faces	Riebeckite $Na_2(Fe^{2+})_3(Fe^{3+})_2(Si_8O_{22})(OH)_2$	A sodium-rich member of the amphibole group of silicate mine.
Fluorite CaF_2	Low temperature vein deposits.	Saponite $CaNa(MgFe^{2+})_3Si_3AlO_{10}(OH)_2 \cdot 4H_2O$	Amygdaloidal cavities in basalts.
Gypsum $Ca(SO_4) \cdot 2(H_2O)$	Sedimentary evaporite deposits	Zaherite $Al_{12}(SO_4)_5(OH)_{26} \cdot 20(H_2O)$	In a massive kaolinite-boehmite rock.
Kaolinite $Al_2Si_2O_5(OH)_4$	Secondary mineral derived from the weathering of alumino-silicate minerals.	Zircon $ZrSiO_4$	Zircon is a mineral (group of nesosilicates).
Magnetite $(Fe^{3+})_2(Fe^{2+})O_4$	Common mineral in igneous, metamorphic rocks, known as lodestone		

The mean concentrations of ^{226}Ra, ^{232}Th and ^{40}K are greater than the mean values reported by UNSCEAR (Table 6). So, there is necessary need for more specific rules for buy and sale these local and imported housewares. Figure 1 shows the Activity concentrations (Bq/kg) of ^{226}Ra, ^{232}Th and ^{40}K.

A comparison between the results of activity concentrations for ^{232}Th, and ^{40} measured by γ-Ray spectrometer and concentrations values for Th, and K measured by A. A. Spectrometer. Both analysis results are in a good agreement and this means that the geochemical analysis (Atomic Absorption Spectrometer) can determine the concentrations of elements in the minerals with reasonable values, shown in Figure 2.
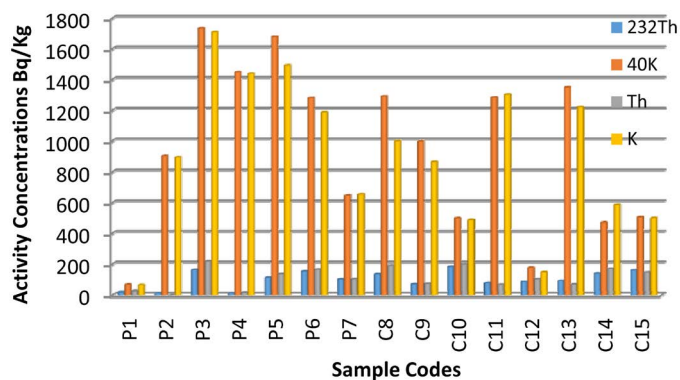
Figure 2. A comparison between activity concentrations for [232]Th, and 40 measured by γ-Ray Spectrometer and concentrations values for Th, and K measured by A. A. Spectrometer.

Table 6. The specific activity concentrations in Bq/kg for 15 samples.

Sa. no.	Specific activities (Bq/kg)		
	[226]Ra	[232]Th	[40]K
P1	22.26 ± 0.01	21.96 ± 0.01	67.10 ± 0.01
P2	11.51 ± 0.04	14.15 ± 0.03	904.37 ± 0.02
P3	184.68 ± 0.04	162.85 ± 0.01	1736.30 ± 0.02
P4	17.58 ± 0.03	13.01 ± 0.02	1449.60 ± 0.02
P5	108.35 ± 0.03	111.96 ± 0.02	1678.60 ± 0.01
P6	104.85 ± 0.03	153.16 ± 0.01	1280.08 ± 0.02
P7	192.67 ± 0.05	102.20 ± 0.01	648.53 ± 0.01
C8	76.80 ± 0.05	135.81 ± 0.02	1292.16 ± 0.03
C9	59.72 ± 0.04	68.86 ± 0.01	997.40 ± 0.01
C10	100.24 ± 0.03	184.04 ± 0.02	997.40 ± 0.01
C11	74.80 ± 0.05	76.98 ± 0.01	1284.55 ± 0.02
C12	59.03 ± 0.06	85.98 ± 0.01	177.55 ± 0.02
C13	81.22 ± 0.05	91.93 ± 0.01	1348.96 ± 0.02
C14	75.88 ± 0.05	140.26 ± 0.01	470.96 ± 0.01
C15	87.28 ± 0.04	160.10 ± 0.02	506.30 ± 0.02
Range	11.51 - 192.67	13.01 - 184.04	67.10 - 1736.30
Mean	83.83	91.05	751.07
Worldwide*	35	30	400

*UNSCEAR (2000).

3.4. Radiation Hazard Indices

The distribution of natural radionuclides in the samples is not the same. Therefore, radiological index has been used to estimate the actual activity values of [226]Ra, [232]Th and [40]K in the samples and the radiation hazards accompanied with

these radionuclides (the radium equivalent activity Ra_{eq}, absorbed dose rate D, the annual effective dose rate D_{eff}, and external hazard index H_{ex}. The results were presented in (Table 7).

The values of the radium equivalent activities range in Porcelain from (58.83 to 551.25 Bq/kg). For Ceramic, the values of the radium equivalent activity range from (195.66 to 401.87 Bq/kg), its mean value for all samples is (302.61 Bq/kg), which is lower than the worldwide value (370 Bq/kg). The radium equivalent activities for samples (P: 3, 5, 6, 7 and C: 8, 10) are higher than the maximum admissible limit of 370 Bq/kg. The analysis of the data in Table 7 shows the variation of area for the same type of material. This is due to the place of origin, varied origin sources, different additives. More indices are useful to be found: gamma dose rate D (nGy/h), annual effective dose D_{eff} (mSv/year), and external hazard H_{ix} for analyzed samples. The mean value of D (nGy/h) is 140.15 is higher than the maximum admissible limit of 60 (nGy/h), D (nGy/h) exceeding should be taken into account in terms of radiation protection. It is therefore recommended that controls should be based on a dose range. D_{eff} (mSv/year) and H_{ix} are below the published admissible limit ≤ 1 and the risk is negligible (UNSCEAR, 2000).

Table 7. Ra_{eq} (Bq/kg), D (nGy/h), D_{eff} (mSv/year), H_{ix}.

Sa. no.	Ra_{eq} (Bq/kg)	D (nGy/h)	D_{eff} (mSv/year)	H_{ix}
P1	58.83	26.07	0.03	0.16
P2	101.38	52.62	0.07	0.27
P3	551.25	254.98	0.31	49
P4	147.80	77.94	0.10	0.40
P5	397.68	188.19	0.23	1.07
P6	422.43	195.23	0.24	1.14
P7	388.76	173.83	0.21	1.05
C8	370.21	172.84	0.21	1.00
C9	234.99	111.29	0.14	0.63
C10	401.87	178.94	0.22	1.09
C11	283.79	135.13	0.17	0.77
C12	195.66	86.41	0.11	0.53
C13	316.56	149.95	0.18	0.86
C14	312.72	140.04	0.17	0.85
C15	355.21	158.78	0.19	0.96
Mean	302.61	140.15	0.17	0.82
Worldwide*	370	60	≤ 1	<1

*UNSCEAR (2000).

4. Conclusion

Fifteen samples of ceramic and porcelain items commonly were found in everyday living in Jeddah Saudi Arabia were examined by three techniques. *X-ray diffraction provides detailed information about the atomic structure of crystalline substances, chemical composition and physical properties of materials. The major mineral constituent of all samples in ceramic (except P4) is quartz (SiO_2). Ceramic samples minor and trace elements vary from sample to sample. Porcelain is mostly kaolinite ($Al_2Si_2O_5(OH)_4$), and minor element is mullite ($Al_6Si_2O_{13}$) (except P7), its minor element is Albite ($NaAlSi_3O_8$). This is due to the geological origin for the samples. Atomic absorption spectroscopy is used to measure the concentration values in ppm for sex elements (Al, Pb, Bi, U, Th, K). In this study, ceramic and porcelain include Aluminum (Al) which is known to be toxic to different species, the mean concentration (ppm) of Al is 10.3 ppm which is less than the acceptable value. Toxicity lead oxide (PbO) glazes are used on many kinds of porcelain and ceramic food wares. The allowed limit is 0.2 ppm (EC, 2005), the mean concentration value is 1.65 ppm. Bi concentrations for all samples were lower than (DL < 10). For U, concentrations were lower than (DL < 5) except two samples, Thorium is chemotoxic, radiotoxic and a carcinogen element. The mean concentration value is 27.16 ppm, which is much greater than the acceptable value 7.24 ppm. Potassium is the eighth most abundant element in the Earth's crust (2.1%), Potassium mean concentration is 24974.54 ppm (2.5%), which is greater than the acceptable value (1.92%). *Porcelain and ceramic samples were measured using the gamma spectrometer. The results show that: their activities were used to calculate the concentrations of ^{226}Ra, Th and ^{40}K. The mean concentrations of ^{226}Ra, ^{232}Th and ^{40}K are greater than the mean values reported by UNSCEAR. So, there is necessary need for more specific rules for buy and sale these local and imported housewares. The mean value of the radium equivalent activities for all samples is (302.61 Bq/kg), which is lower than the worldwide value (370 Bq/kg). This is due to the place of origin, varied origin sources, different additives. Indices mean values of D (nGy/h), D_{eff} (mSv/year) and H_{ix} are useful to be found in terms of radiation protection. The mean value of D (nGy/h) is higher than the maximum admissible limit. It is therefore recommended that controls should be based on a dose range. D_{eff} (mSv/year) and H_{ix} are below the published admissible limit ≤ 1 and the risk is negligible.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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