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Assessment of radon concentrations and effective radium content in Samawa desert truffles-Iraq

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ABSTRACT

The radon concentrations and radium effective contents in truffle samples collected randomly from Samawa desert in southern Iraq, have been measured using both techniques, active (RAD-7) and passive (LR-115 type II nuclear track detectors). The (Rn^{222}) concentrations measured by both techniques are found to vary from (5.54 Bq/m^3) to (28.5 Bq/m^3) with a mean value of (14.447 Bq/m^3) and from (18.5 Bq/m^3) to (80.7 Bq/m^3) with a mean value of (39.175 Bq/m^3) respectively. The effective radium content are found to vary from (0.755 Bq/kgm) to (3.293 Bq/kgm) with a mean value of (1.599 Bq/kgm). The values of radon concentrations and radium contents are found to be quite lower than the permissible value of (400 Bq/m^3) and (32 Bq/kgm) recommended by (ICRP) and (UNSCEAR). From radiation protection point of view, it was found that the Samawa truffles do not pose any significant health hazard for the presence of Rn^{222} concentration and Ra^{226} contents, and it is considered radiologically safe for human consumption.

Keywords: radon, radium, RAD-7, LR-115, radiation hazard, truffles, Samawa, Iraq.

INTRODUCTION

Exposure of human populations can cause harmful effects. The extent of these effects is dependent on the intake dose. The possible exposure pathways to populations include direct radiation from an air born radioactive plume, inhalation of radioactive gases and aerosols, external radiation from the contaminated ground, and internal dose from ingestion of contaminated food [1, 2]. Food intakes is one of the important pathways for long term health considerations. There may be a variety of radionuclides of artificial as well as natural origins which normally get entry into human body through food chain and other pathways and deposited in the critical organs (for example U^{238} accumulated in human kidney and lungs), causing internal irradiation and hence produce radiation damage, biochemical and morphological changes which weakening of immune system, and development various forms of diseases or cancers which contributing to increase in mortality rate [3, 4].

However, artificial radioactivity comes mainly from nuclear and radiological weapons, nuclear power accidents, radioactive wastes and depleted uranium projectiles. Among the naturally occurring radionuclides, K^{40} and the products of the Th^{232} and U^{238} decay series. These convert via a chain of radioactive products to stable lead as the final products. These products include over sixteen isotopes of radon but in terms of their radiological significance the most important isotopes are: (Rn^{222}) (Radon, half–life 3.81 days) (Figure 1), which is generated as a decay product of radium–226, produced from the radioactive decay of U^{238}, (Rn^{220}) (Thoron half–life 54sec) (Figure 2) which is in the decay chain of Th^{232}, and ($Rn^{219)}$ (Actinon, half–life 3.96 sec) (Figure 3) , which is products in the decay chain of U^{235} [5].

Radioactive elements are found in fruits, vegetables, potato's, meet, rice, flour, milk, spieces, …etc, and the annual effective dose due to the ingestion of these foods and their derived products have been calculated [6,7,8,9].

In Iraq, it is a habitat exist in the west region near the Saudi Arabia border (Figure 4), to collect the truffles fruit which spans 2-3 month after adequate rain fall in the autumn season [10] . Because our country has been exposed to intensive military operations since 1991 especially in the south where different types of radiological weapon (Depleted Uranium projectiles) were used in addition to the natural radiation doses, the radionuclides present in contaminated soil are absorbed by the truffle and become a part of the food chain, and when truffle are grown in the contaminated soil the activity is shifted from the soil to the truffle. Ultimately the activity is transferred to the human diet [10,11].

A through literature search reveals that no studies on the radon concentration measurements in truffles consumed in Iraq. Such lake was the main motive to conduct the current study in addition to meet internal radioactivity exposure to the general public from truffle consumption .

Due to possible transfer of these radionuclides and their progeny from truffle to human body. It is necessary to measure the radon activity and radium content of truffles to assess potential radiation doses and, if necessary, to take action to avoid the exposure of consumers to radiation. Thus, the purpose of the present work is to measure the radon concentrations in Samawa desert truffles which commonly eats by inhabitants of Iraq, using the active (RAD–7) as well as passive (SSNTD) techniques which were not reported previously, and hence knowing about the intake exposure of the general public to alpha particles from radon and its decay product with a view to establishing their radiological risk. In addition the effective radium contents in truffle samples has been estimated.

MATERIALS AND METHODS

2.1 Sampling and sample preparation

A total of twenty samples (one kilogram each) were collected randomly from different locations of the Samawa desert to represent the overall truffles body (Figure 4). All truffle samples were pre–treated by washed many times in water to clean it and to remove all desert sands. Afterwards, they were cut into small pieces and prepared for measurements by first drying in an electric oven (memmert type UNB200, Germany) at 110℃ for 24 hours to ensure complete removal of moisture and coold to room temperature in a desiccator. After that the samples were grounded into a fine powder, and sieved by using 100 micron mesh to obtain uniform particle size (uniform emanation of radon). The samples were sealed in standard Marinelli plastic beaker for 30 days to bring Rn^{222} and its short lived daughter products in equilibrium with Ra^{226} [12].

2.2 Experimental Techniques

Radon concentration measurements were performed using active and passive methods. In active method, RAD7 radon gas detector manufactured by Durridge Company Inc. have been used. The (30 gm) of truffle sample was loaded into 1Liter cylindrical chamber used as emanation container. The RAD7 detector was operated in Grab mode for 1day protocol, with cycle 1 hour, recycle 48 and thoron off. In this system , the accumulated chamber is connected to the RAD7 detector by two gas–tight tubes in the removable lid, and by vinyl tubing with a gas drying unit filled with a desiccant ($CaSO_4$ with 3% $CoCl_2$ as an indicator) between them, to maintain the relative humidity at less than 10% within the measurement system. The system is a closed loop in which the gas circulates continuously. the experiment was performed at a relative humidity of 8%, 18–25℃ and normal room atmospheric pressure [Figure 5A]. After the truffle sample is placed in the accumulation chamber, air containing radon gas is drawn into the inner chamber of the RAD7 detector generate detectable α- particle emitting progenies, particularly polonium isotopes, which are collected onto the solid–state detector by high voltage (2500V) .

In passive method , the solid state nuclear track detection technique (SSNTD) (sealed can technique) was used during the present study (Figure 5B). The LR–115 types II nuclear track detector sheet of 12μm thick obtained from Kodak Pathe, France, were cut into small pieces each of (1.5x1.5 cm^2) area. Equal amount of the dried samples (30 gm) placed in the PVC plastic cylinder of radius (4cm) and height (21cm) to ensure radon detection only [13]. A semi-permeable soft sponge of 1mm thickness was fitted in between the sample and detector film to prevent thoron gas from reaching the SSNT detector [14]. A piece of the cut LR–115 type II detector were placed in the bottom of each cylinder cover, with samples at the bottom of cylinder and then sealed for exposure of 30 days. The collected LR–115 type II detectors were chemically etched using a 2.5 N solution of NaOH, at temperature of 60℃ , for a period of 60 min in the etching bath. An optical microscope with magnification of 400X were used to count the number of tracks per cm^2 in each detector and subsequently the average radon (Rn^{222}) concentration in Bq/m^3 have been calculated .

the activity concentrations of radon in (Bq/m^3) for truffle samples have been obtained using the expression [15] :

$$\mathbf{C_{Rn}} = \frac{\rho}{KT} \qquad \textbf{(1)}$$

Where ρ is the radon track density (track / cm^2), **T** is the exposure time (30days) and K is the calibration factor equal to (0.056 tracks.cm^{-2}.d^{-1}/ Bq.m^{-3}) [16].

The effective radium content in (Bq / kgm) was obtained using the expression [17] :

$$C_{Ra} = \frac{\rho h A}{K T_e M} \quad (2)$$

Where hA is the volume of the chamber (1L = 0.001m^3) (h is the distance between detector films and surface of the specimen sample. A is the area of cross-section of the cylindrical can), **M**: is the mass of the truffle samples (0.03 kgm), and T_e : is the effective exposure time (24.5 days) obtained by [18] :

$$T_e = T - \tau (1 - e^{-\lambda T}) \quad (3)$$

Where : λ is the decay constant of radon (7.55x10^{-3} h^{-1}), and τ mean life of radon (5.519 days) [19].

RESULTS AND DISCUSSION

Table (1) presented the results of radon concentrations of truffle samples obtained by passive and active techniques and shown in (Figure 6). The range of radon concentration varies from (18.5 Bq/m^3) to (80.7 Bq/m^3) with a mean value of (39.175 Bq/m^3), and (5.54 Bq/m^3) to (28.5 Bq/m^3) with a mean value of (14.447 Bq/m^3) respectively. It is clear that the measurement made by the RAD-7 indicates low emission of radon from truffle samples, which is lower than that measured concentration by passive techniques. These results may be due to the RAD-7 measurement is based on 24 hours cycle, where as the measurement by the passive technique is based on 30 days, as well as the LR-115 SSNTD was in direct contact with the truffle sample (i.e. with radon gas released from the sample).

Table (1): values of radon (Rn^{222}) activity concentration and effective radium (Ra^{226}) content in the truffle sample

Sample code	Truffle type (national name)	Passive (Rn^{222}) Concentration (Bq/m^3)	Effective radium content (Bq/kgm)	Active (RAD7) (Rn^{222}) concentration (Bq/m^3)
S1	Ahraq (black)	62.2	2.538	21.2
S2	Ahraq(black)	37.8	1.543	5.54
S3	Ahraq (black)	33.3	1.358	13.5
S4	Zbedy(white)	22.4	0.914	19.4
S5	Zbedy(white)	52.6	2.146	15.4
S6	Zbedy(white)	18.5	0.755	12.3
S7	Zbedy(white)	33.5	1.367	16.2
S8	Zbedy(white)	80.7	3.293	28.5
S9	Zbedy(white)	37.2	1.518	15.3
S10	Zbedy(white)	43.3	1.767	16.4
S11	Zbedy(white)	18.8	0.767	9.4
S12	Zbedy(white)	34.2	1.396	9.9
S13	Ahraq(black)	25.3	1.032	16.6
S14	Ahraq(black)	40.5	1.653	9.3
S15	Ahraq(black)	68.2	2.783	12.5
S16	Ahraq(black)	36.4	1.485	18.6
S17	Ahraq(black)	41.8	1.706	8.4
S18	Ahraq(black)	27.6	1.126	10.5
S19	Zbedy(white)	30.8	1.257	14.8
S20	Ahraq (black)	38.4	1.567	15.2
Average	--------	39.175	1.599	14.447

However, data shown in Table (1) indicate that radon concentration was nearly differ in black truffles as compared to white truffles. It can also be seen that radon concentration in these samples varies from sample to sample, which could be due to the difference in the level of radium contents or uranium contamination in the soil where the truffles are grown or due to the difference in the mechanism of radionuclides transmission to truffles.

Table (2): Comparison of the average (Rn^{222}) concentration in Samawa truffle with those published data in different foodstuffs

Food type	(Rn^{222}) concentration (Bq/m^3)	Method of measurement	Reference
Samawa truffle	14.447 39.175	Active (RAD7) Passive (LR-115 SSNTD's)	Present work
Onion Potato Rice Wheat Flour Tomatoes Tea Bean Okra Cucumber Kidney bean Chick bean	148.4 299.8 45.63 81.24 37.71 79.66 39.41 24.17 62.16 139.4 137.9 151.9	Passive CR-39	[3]
coffee	(36-180)	Passive CR-39	[23]
Tea	(27- 42)	Passive CR-39	[24]
Tea	(23-51)	Passive CR-39	[25]
Dates	(136.3-260.8)	Passive CR-39	[26]
Tobacco	(72 – 123)	Passive CR-39	[27]

Table (3): Comparison of effective radium (Ra^{226}) content in the Samawa truffle with those published data in different foodstuffs

Food type	Effective radium content (C_{Ra}) (Bq/kgm)	Method of measurement	Reference
Samawa truffle	1.599	Passive (LR-115 type II)	Present work
Tomatoes Celery Swiss chard Onion Pumpkin Eggplant Potato Cucumber Okra Bean Lentil Chick bean Kidney bean Rice Wheat Flour Tea	1.17 1.01 2.55 2.19 1.68 2.14 4.42 2.05 0.92 0.36 1.04 2.24 2.03 0.67 1.2 0.56 0.88	Passive CR-39	[3]
Vegetables Garden rocket Lettuce Potato Carrot	0.317 (2.11+- 0.01) (1.05 + 0.48) (0.80 + 0.49) 0.32	Passive CR-39 Passive CR-39	[28] [29]
Drumstick Tomatoes	(1.227 + 0.24) (0.064 + 0.03)	Passive CR-39	[30]

With regards to radon concentration in various type of foodstuffs a very little amount of data has been published in the literature especially for truffles. Some of these data reported by different researchers in different countries are presented in Table (2). These values are lower or higher than the truffle results of the present study. Through comparison with these values it is obvious that the obtained concentration from all samples were lower than the natural limits for public (400 Bq/m^3) given by the international commission on radiological protection (ICRP) [20].

The effective content of Ra^{226} in the twenty truffle samples was calculated using equation (2), presented in Table (1), and shown in (Figure 7). Ra^{226} activity concentration was measured in all samples with minimum value of (0.755 Bq/kgm) in (S6-white) and maximum value of (3.293 Bq/kgm) in (S8-white) with a mean value of (1.599 Bq/kgm). As it clear from the graph samples no.8 have higher concentrations of Ra^{226} than others, which could be attributes to the existence of high levels of U^{238} in desert sand.

The average Ra^{226} concentration reported in the present work were compared with those listed in table (3). It is clear that the levels of Ra^{226} radionuclides in the present study are lower than those reported in the literature for different foodstuff samples. The variation among the levels in foodstuffs may be attributed to the wide variations in geological formation of soil and or to the nature of soil and hence to the existence of radionuclides in it [21]. In general, and through comparison with these values it is obvious that the obtained Ra^{226} activity concentration from all samples of the present study were lower than the global world average value of (32 Bq/kgm) given by UNSCEAR [22].

However, the annual intake of truffles nearly about (6kgm/yr) (the average consumption of Samawa desert truffles ranges from 5-7 kgm/yr, because the production is not sufficient and hence it is not available and naturally grow depending on the meteorological conditions). So with the obtained average value of effective Ra^{226} content (1.559 Bq/kgm) and the above annual intake (6kgm/yr), the total radium contents will be about (9.354Bq/kgm) which is also less than from the global average concentration value of (32Bq/kgm) recommended by UNSCEAR [22], and this means that the peoples should not worry about the usage of this food type.

From (Figure 8), a good positive correlation (0.999) has been obtained between the radium content present in the samples and the radon concentrations. As such, it is evident that as the contents of the radium increased, the contents of daughter radon also increased, which enhanced concentration rates as well as effective doses. On the other hand, weak positive correlation has been observed between the results of passive and active techniques. The linear correlation value for both techniques was (0.487) as shown in (Figure 9).The weak correlation may reflect the differences in the mechanism used to measure the radon concentration.

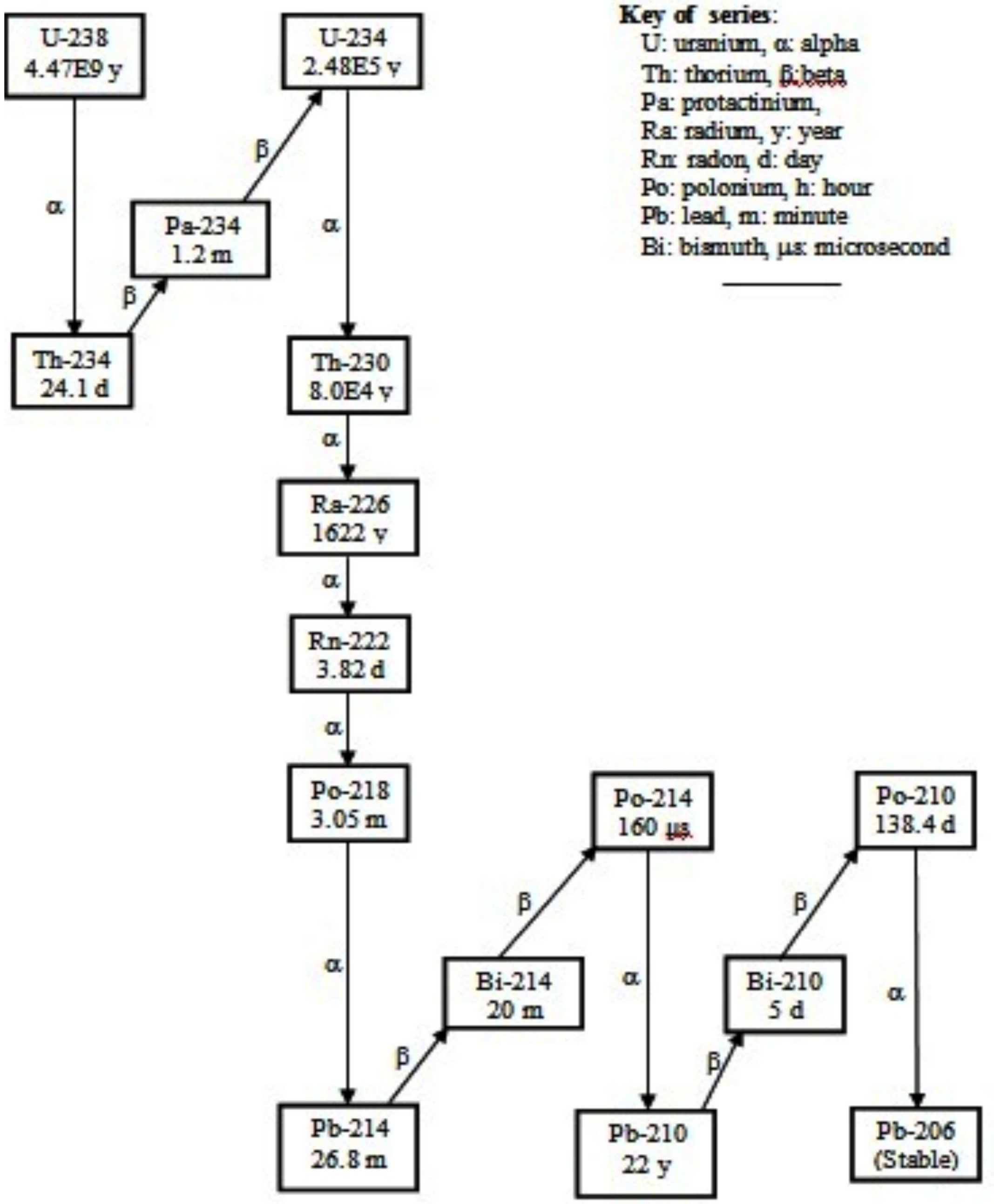


Figure 1 : Decay scheme of U^{238}

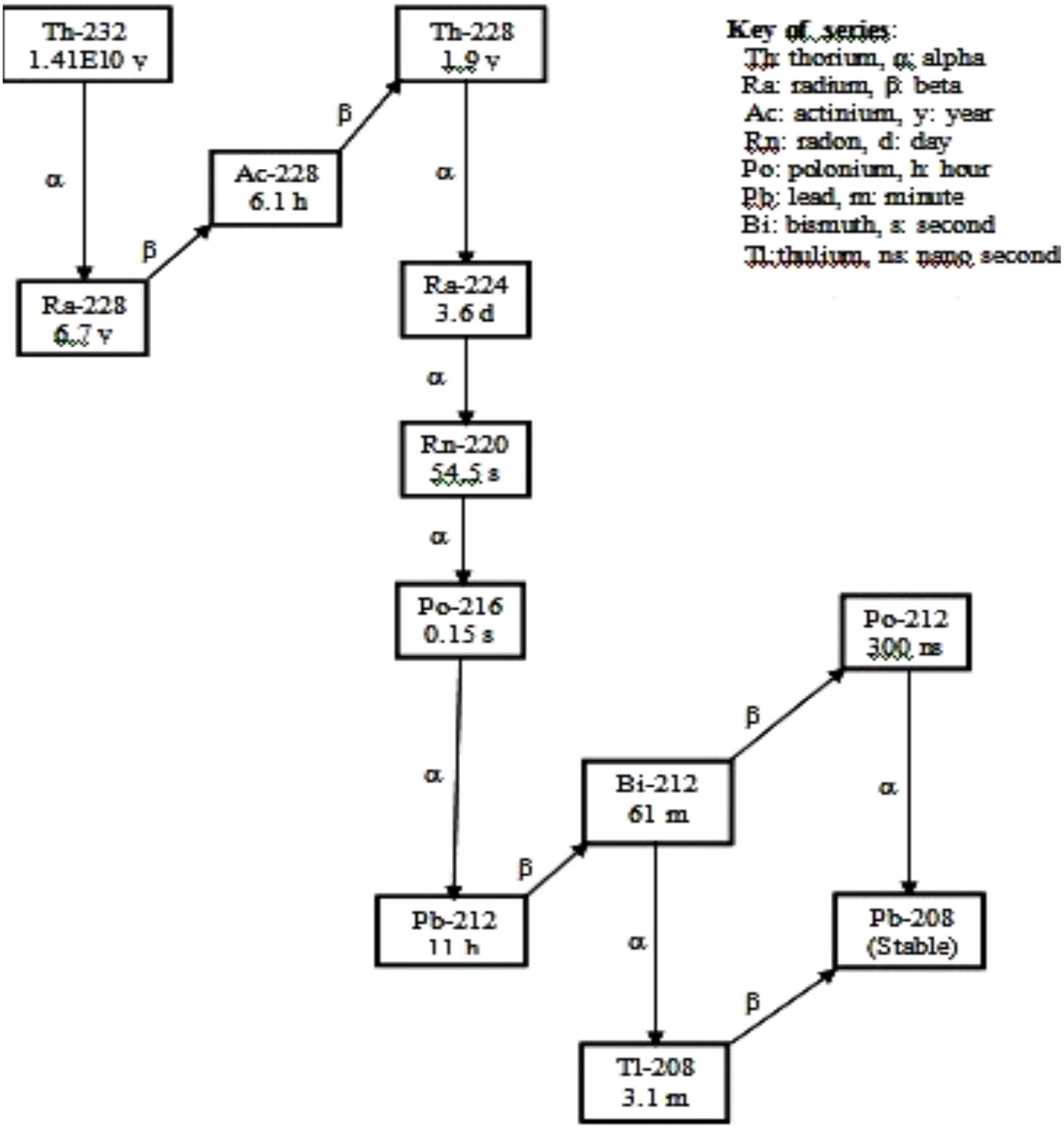


Figure 2 : Decay scheme of Th^{232}

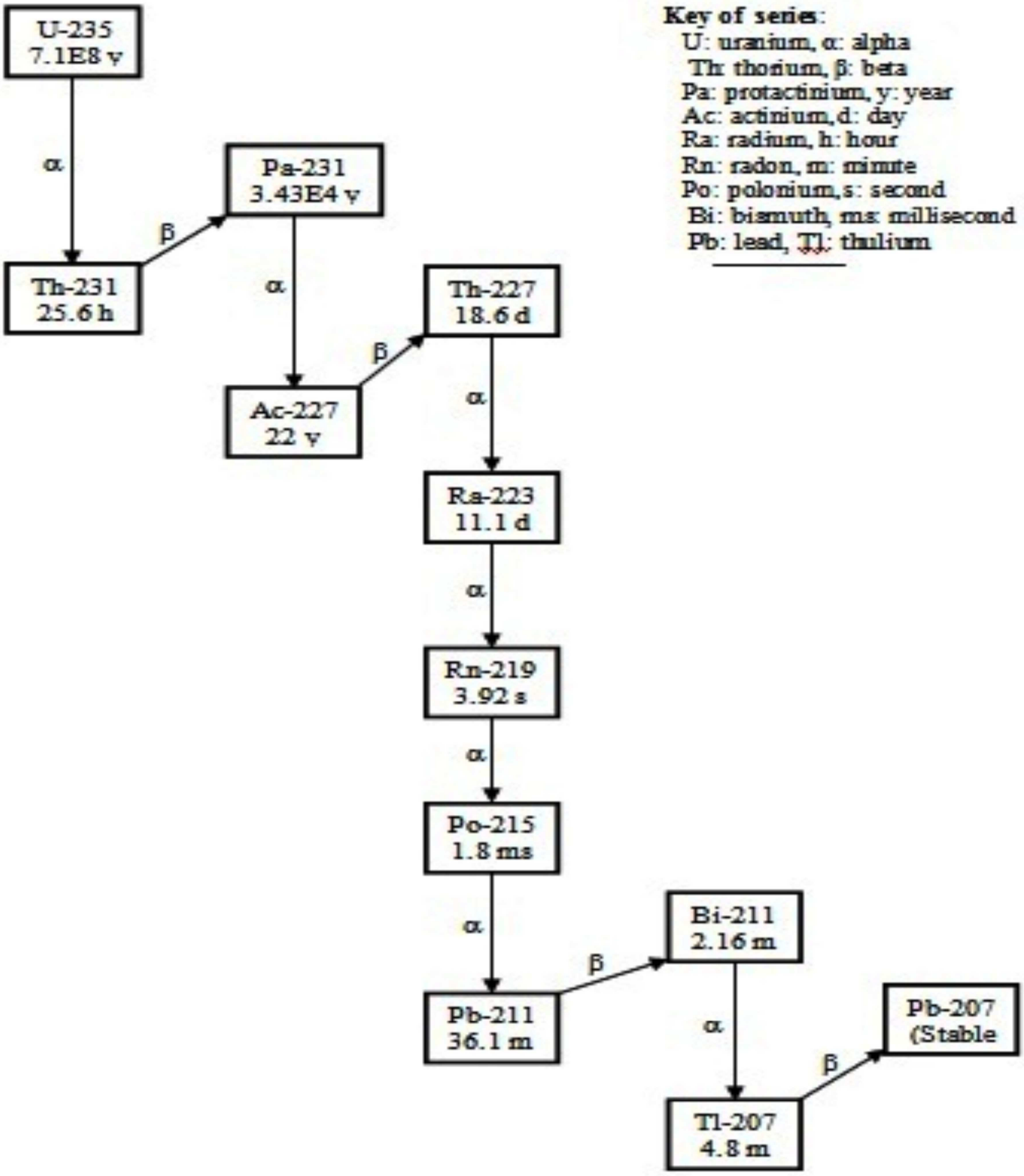


Figure 3 : Decay scheme of U^{235}

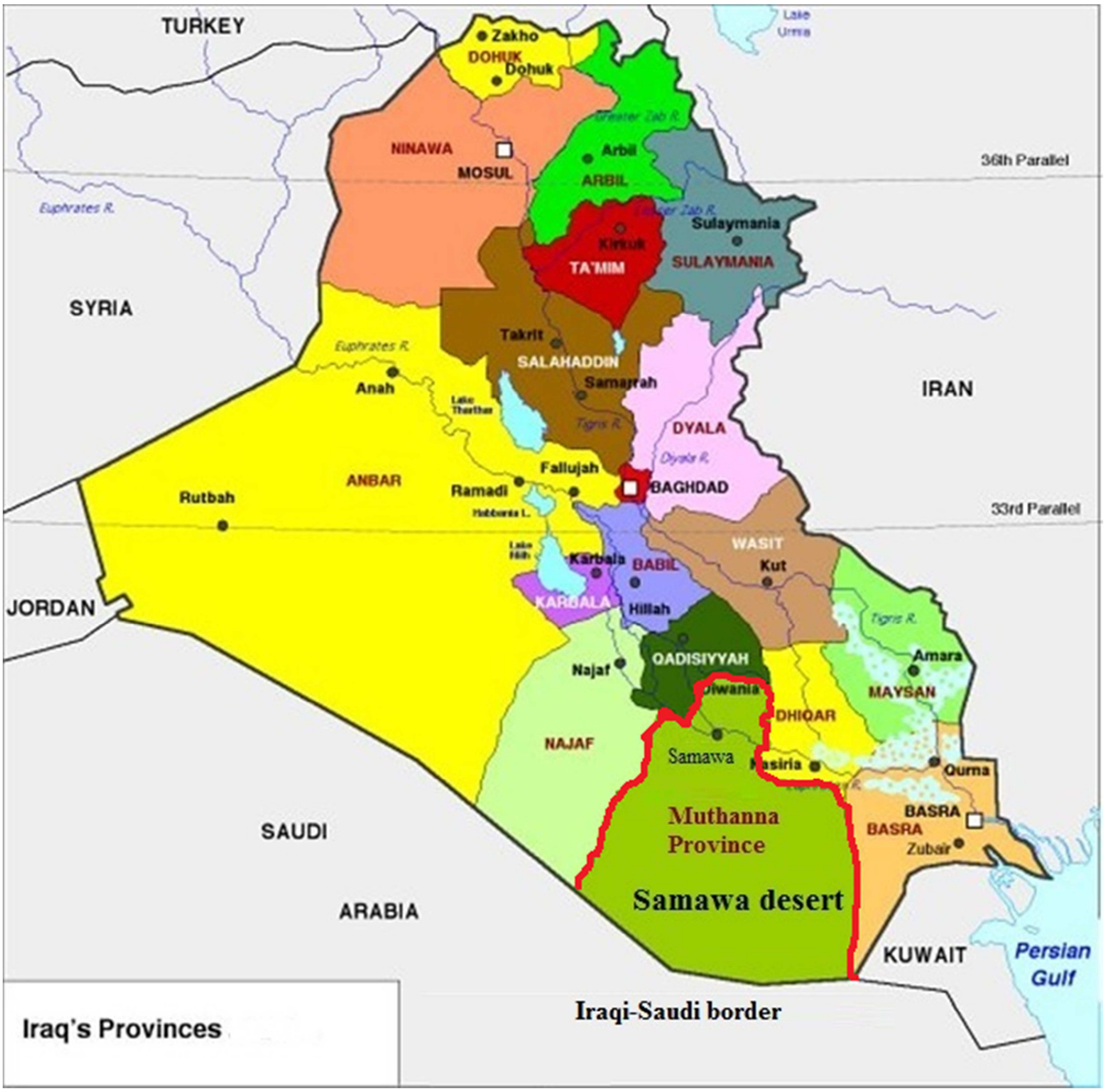
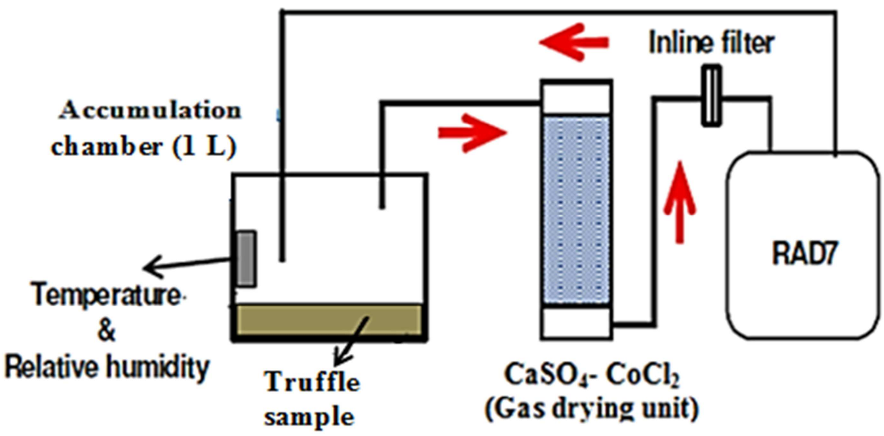
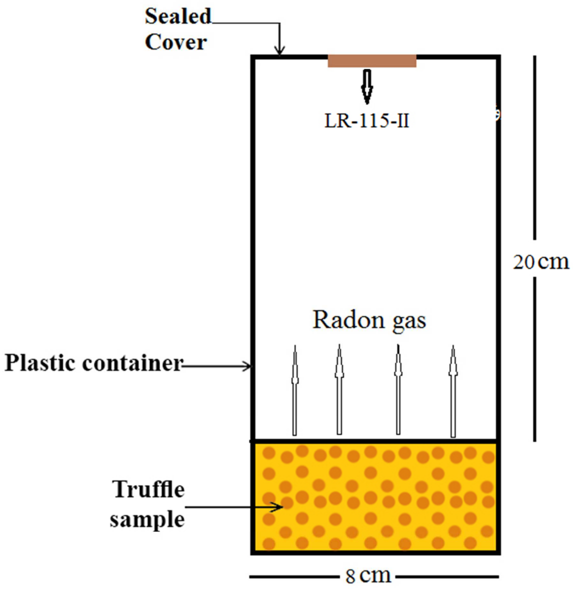


Figure (4) : Map of Iraq showing the location of Samawa desert where the truffle samples collected



(A)



(B)

Figure (5): Schematic diagram of (A) the RAD-7 experimental system, and (B) SSNTD experimental setup (sealed can technique) used in this study

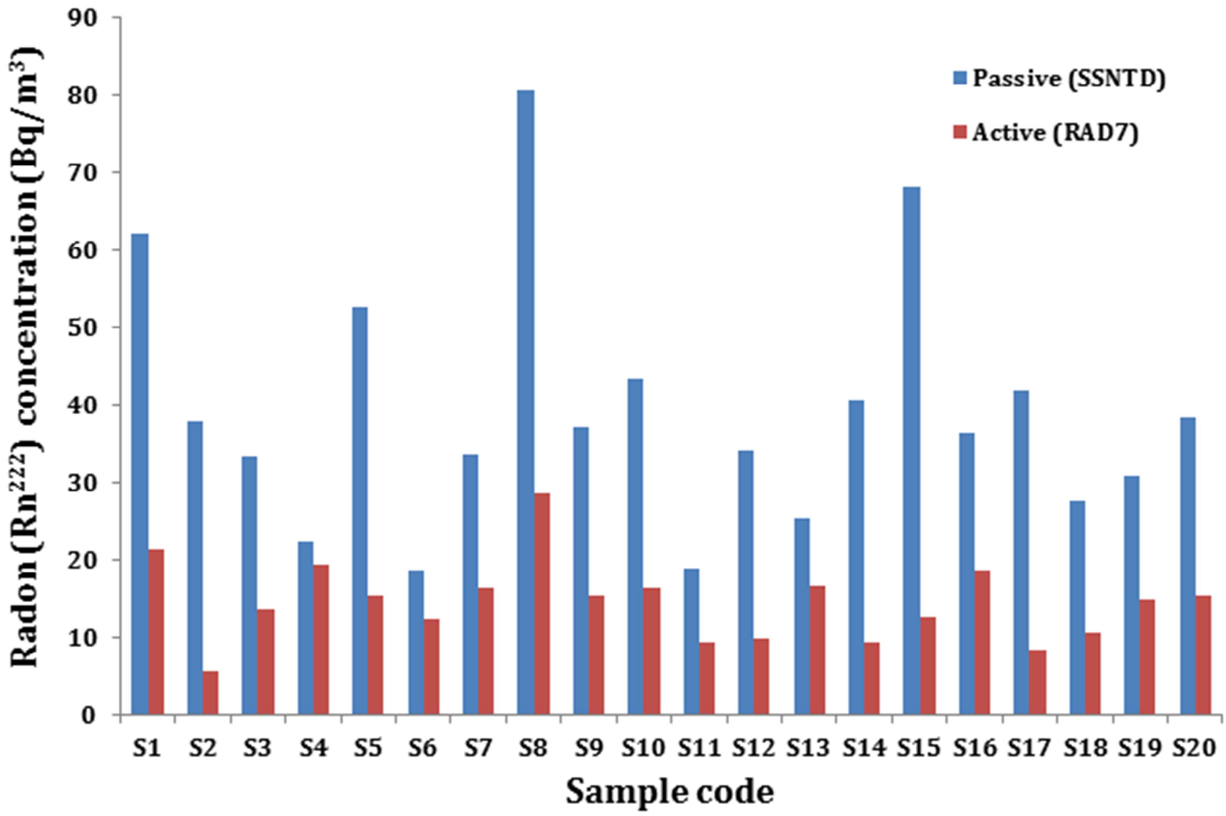


Figure (6): Concentration of radon (Rn^{222}) in (Bq/m^3) for each selected sample

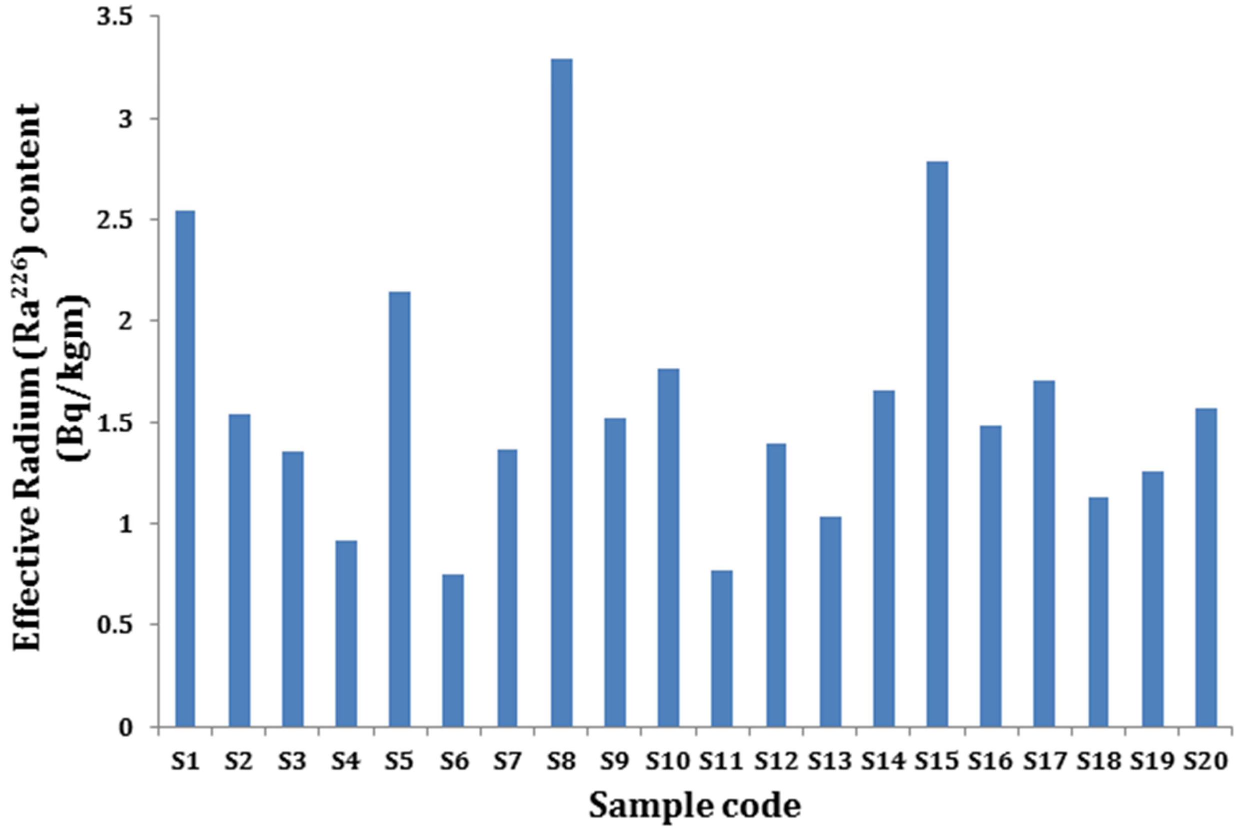


Figure (7): Effective radium (Ra^{226}) contents in (Bq/kgm) for each selected sample

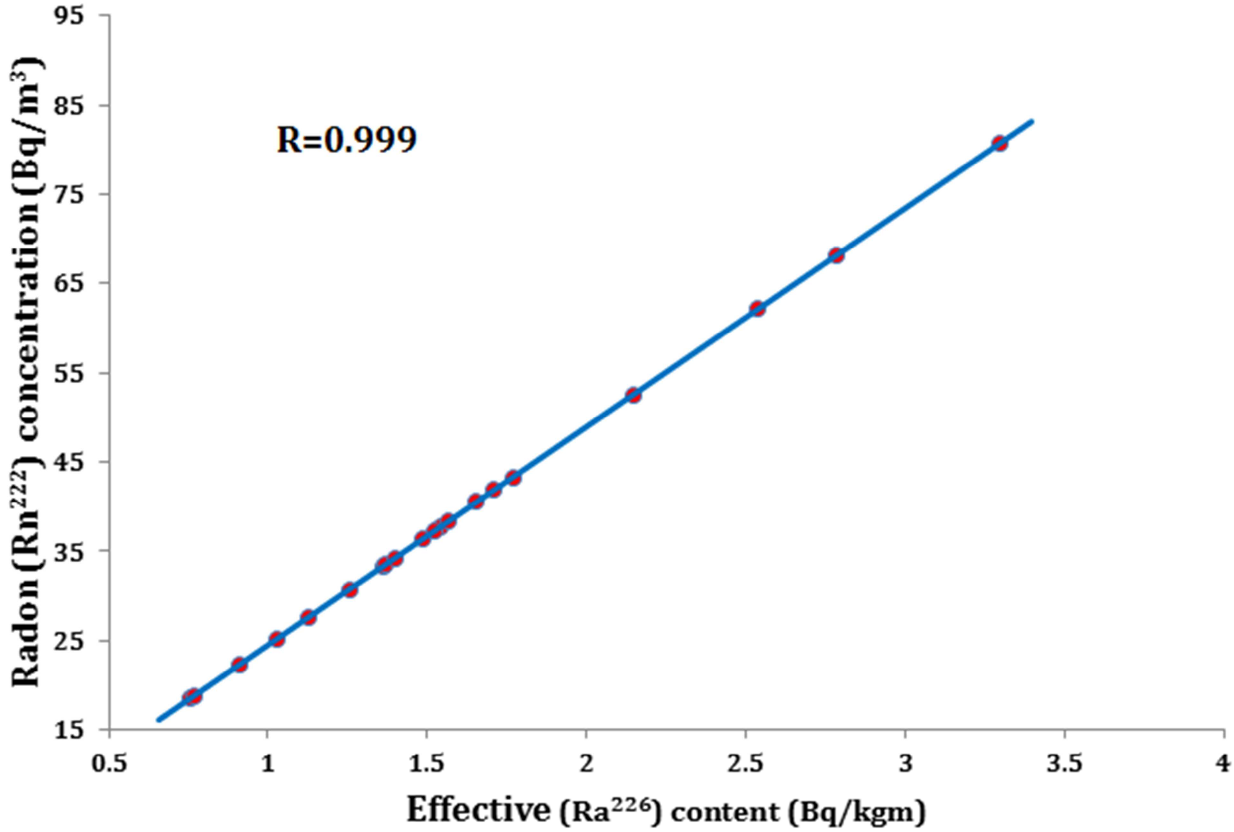


Figure (8): Correlation between (Rn^{222}) and parent (Ra^{226}) in the selected samples

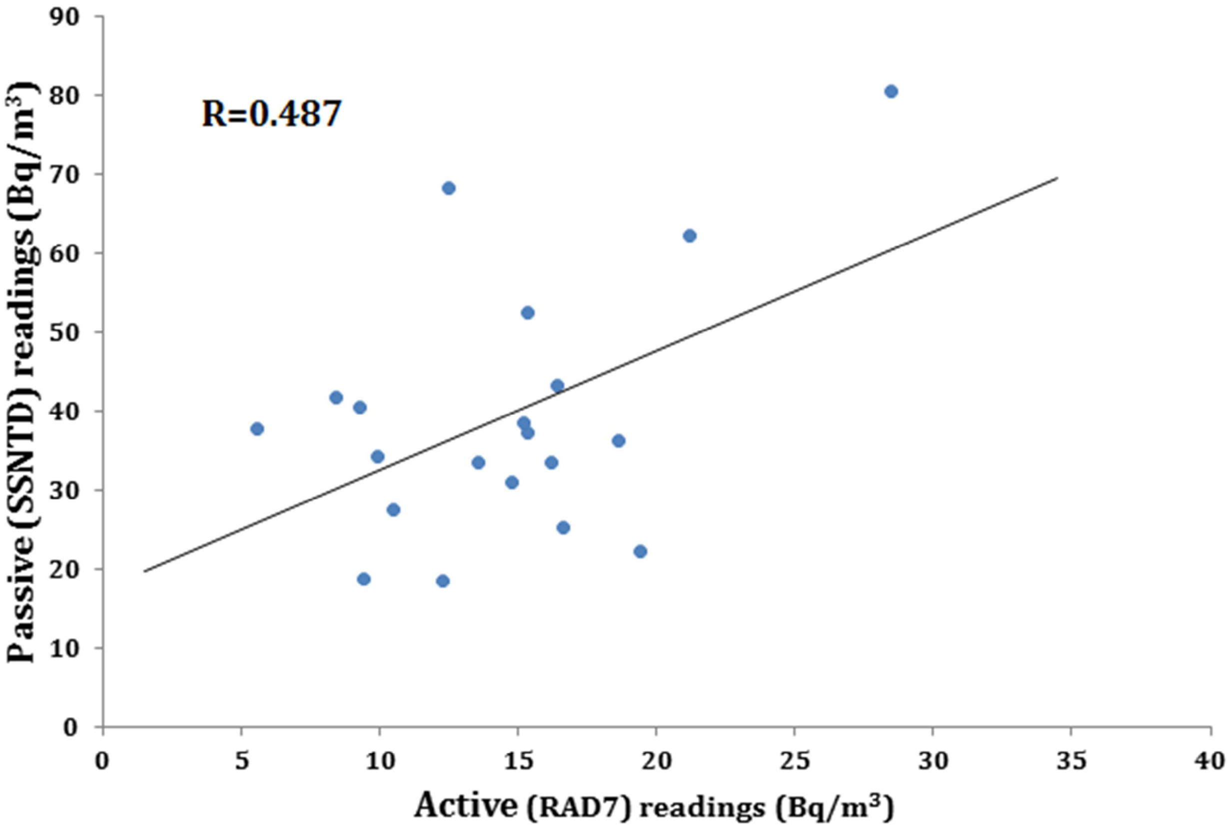


Figure (9): Correlation between Passive (SSNTD) and Active (RAD7) readings recorded for each samples

CONCLUSION

Radon (Rn^{222}) concentrations and the effective radium content of Samawa desert truffles consumed in Iraq have been investigated. The samples, which were collected randomly from different locations of the Samawa desert, are designated from two different national types (Ahraq-black and Zbedy-white).

The present study is the first at the national level (in Iraq) to investigate radon (Rn^{222}) concentrations and radium content in Samawa desert truffles. The obtained values of (Rn^{222}) concentrations and (Ra^{226}) contents were found to be less than the maximum permissible value of (400 Bq/m^3) and (32 Bq/kgm) as per recommendation of (ICRP) and (UNSCEAR). On the basis of our results, we concluded that there are differences in the degree of translocation of radionuclides to truffles depending upon physiological characteristics of the truffles and or the radionuclides itself in addition to the properties of soil, and water transportation.

The result shows that there is a significant correlation between radon and radium of truffle samples. The Radon is a liner function of the radium with a good liner correlation coefficient of 0.999. Weak Positive correlation has been observed between the results of passive and active techniques. The linear correlation value for both techniques was (0.487).

Because of their low activity concentrations, it is found that consumption of Samawa truffle is safe for the presence of the investigated Rn^{222} concentration and Ra^{226} radionuclides, and hence for general public in terms of the radiological hazard, as well as the finding of this work will help in establishing a baseline of radioactivity exposure to the general public from ingestion of this type of foodstuff. However, Samawa truffles is only one dietary component and the focus of the present study was radon (Rn^{222}) concentrations and (Ra^{226}) effective content. To establish a more information, there is a need to investigate more types of foodstuffs grown in the desert, as well as targeting gamma emitters and alpha or beta radionuclides.

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