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Radiological Risk to Inhalation of Thoron Gas from Medical Materials Samples Derived from Medical Plants in Iraq

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ABSTRACT

Pollution by thoron is one of the factors that is harmful to human health. Medical materials, especially those derived from plants, have natural ingredients which are a major source of natural radioactivity, thoron being one of them. Therefore, the presence of harmful radioactivity in these materials is a matter of concern. This study determined the concentrations of thoron (^{220}Rn or radon-220) from 70 samples of medical materials derived from medical plants using a CR-39 detector. Samples are drugs (solid), skin creams, herbs, toothpaste, drugs (liquid), and cosmetic products found in Iraqi pharmacies. Also, radiological risks such as Annual Effective Dose (AED), Excessive Lifetime Cancer Risk (ELCR), and Lung Cancer Case (LCC) due to inhalation of thoron from medical materials samples in pharmacies were calculated. The results show that the results of the thoron concentrations in the samples of medical materials ranged from 1.02 Bq/m^3 to 74.53 Bq/m^3, with an average value of 18.21 ± 2.00 Bq/m^3. The range values of AED, ELCR (×10^{-3}) and LCC (×10^{-6}) were 0.01-0.588 mSv/y, 0.04-2.36, and 0.18-10.58, respectively. It was also found that the thoron concentrations in samples of the present study vary from a minimum of 12.82 Bq/m^3 in cosmetic products samples to a maximum of 30.29 Bq/m^3 in herbs samples. Nonetheless, all thoron and radiological risk values were lower than the acceptable world limit (thoron = 200-300 Bq/m^3 by ICRP and AED = 1.1-4.4 mSv/y by UNSCEAR).

INTRODUCTION

Radiation is present throughout our lives. It may have existed on Earth since its formation. As a result, life evolved in an environment that contain small amounts of ionizing radiation. There are three sources of radiation: the universe (outer space), the Earth itself (terrestrial), and of from within human bodies [1]. Humans are exposed to radionuclides and hazardous substances through the digestive or respiratory systems [1]. Ionizing radiation comes in a variety of forms. Many radioactivity decay types exist, such as alpha particle, beta particle, and gamma-ray [2]. Alpha particles are one of the types of ionizing radiation, which is the least penetrating of the radiation emitted by unstable heavy metals [3].

The most toxic radioactive elements, such as uranium, radium, and polonium, release alpha particles. Although alpha particles are extremely energetic, their weight prevents them from travelling far from the atom as they expend energy over short distances. The health effect from exposure to alpha particles is contingent largely on how a person is exposed. Alpha particles lack the energy to pierce the outer layer of the skin, so exposure outside the body is not a main concern. Consequently, it may be extremely hazardous if alpha emitters are inhaled, ingested, or introduced into the body through cuts. These heavy particles are more hazardous than other forms of radiation because they harm fragile biological tissue. They produce numerous, closely spaced ionizations that can release their energy in a few cells. This results in more serious damage to cells and DNA [4,5].

Radon gas is an inert, colorless, tasteless, and odorless gas. It is also known as the "invisible or

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silent killer." Radon have three isotopes, ^{222}Rn, ^{220}Rn, and ^{219}Rn [3]. ^{220}Rn (thoron) is an alpha emitter with a half-life of 55.6 seconds and it is a product from the ^{232}Th series. Meanwhile, ^{219}Rn is alpha and gamma emitter with a 3.92-second half-life and it is a product of the ^{235}U series [1]. A measurable amount of background radioactivity can originate from the ambient air carries, either in trace amounts of radioactive gases or dust particles.

Thoron is a short-lived radioactive gas that originates as a daughter product in the decay chains of thorium present either in the soil or plants [3]. The radioactive thorium series' gaseous decay products, radon and thoron, along with uranium, are responsible for a significant portion of the radioactivity found in human bodies. These gases are easily spread in the atmosphere through the rocks and soil. Humans breathe them in when they disperse through the air due to the decay process. Naturally, radioactivity may also be detected in the food supply due to plant and animal uptake of the aforementioned gaseous decay products. Thoron gas is some of the naturally occurring radioactive elements present in our air, water, soil, and plant. Therefore, the exposure can be originated from many sources, like drinking water, food, air, soil. This makes exposure to these radionuclides at higher than average levels a possible health risk [4].

Several plants are used to synthesize pharmaceuticals [5], either directly or indirectly. Using radioactive concentrations in medication as a proxy, one may determine the total radioactive dose administered into human. Radiation-induced pollution of medicinal plants is a major source of the increase in the bioavailable internal dosage [6]. People from all cultures have traditionally relied on natural resources, mainly of plant origin, as folk medicines to treat diseases and disorders. Herbs have also been the source of many "modern" single-component drugs. Today, medicinal plants are being accepted and used increasingly by general populations in both Eastern and Western countries as medicines or dietary supplements, either alone or in combination with more modern chemotherapeutic agents [6,7]. Natural radioactivity may be absorbed by medical plants from many natural sources such as the atmosphere, soil, and water, in which it occurs through different ways to contaminate the environment [5]. When natural radioactivity substances are deposited into medical plants, they might enter the drugs or any materials used in manufacturing the plant-based medicine. Therefore, plant surface could become contaminated and tissue contamination could occur after inhalation or ingesting radiologically contaminated medicine. The continuous monitoring of radiation levels thoron in the environment is one of the measures that can prevent and limit the spread of these harmful substances. A solid-state nuclear track detector (SSNTD) is preferred for continuously monitoring pollutant concentration. SSNTD detectors are widely used to measure thoron concentration in different plant-containing materials [8-10]. In past investigations, thoron has been neglected due to its short half-life and small diffusion length. It was expected that the concentration of thoron decreases very sharply as one moves away from its source and hence it is not of great concern from a health point of view. But today, it is an accepted fact that it needs special attention in high background radiation areas. The knowledge of natural radioactivity like thoron in medical materials samples derived from medical plants is significant for assessing the effect of radiation on human health. The importance of studying radioactivity in medical materials derived from medicinal plants used by humans has increased to obtain complete data on human exposure to thoron gas and harmful substances. Therefore, this study aims to measure the thoron concentrations in 70 samples of medical materials derived from medicinal plants and collected from local pharmacies in Iraq using SSNTD technique.

METHODOLOGY

Six groups of samples (70 samples in total) of medical materials from local Iraqi pharmacies were collected, as shown in Table 1.

Table 1. The data of medical materials samples under study.

Type of medical materials	Sample code	No. of Samples
drugs (solid)	S1 to S15	15
skin creams	S16 to S28	13
Herbs	S29 to S37	9
toothpaste	S38 to S47	10
drugs (liquid)	S48 to S60	13
cosmetic products	S61 to S70	10

The experimental process of preparation of solid samples for the measurement of Thoron concentrations using several steps as outlined in references [11,12]. The preparation of the solid samples to conduct the required analysis was by drying and keeping them moisture-free by placing them for one hour in an oven at 70 ^{o}C. The samples were mechanically grounded using electric mill to reach an appropriate homogeneity. Then, the samples were sieved through 0.8 mm pore diameter size. The oral solution, liquid, and ointment samples were measured directly without any preparation. The respective net weights were measured and recorded with a highly sensitive digital weighing balance with a percent of ± 0.01 %. After preparing the samples, they were packed in plastic cups (length 7 cm and radius 2.5 cm), see Fig. 1. Next, it was sealed tightly and stored for a month to obtain secular equilibrium between ^{226}Ra and ^{222}Rn [13]. CR-39 with a thickness of 1 mm and dimension of 2.5×2.5 cm^2 produced from Track Analysis Systems Ltd., UK, was used in this work. Measurements were performed to 70 different medical materials samples derived from plants. A weighted number of samples was placed in plastic containers. A CR-39 detector was put on the sample directly to measure thoron concentrations. At the same time, a second piece of CR-39 detector was held at the top of the container to measure radon concentration. The cups were left at room temperature for three months of exposure time. During this time, alpha particles from the decay of radon, thoron and their daughters bombard the CR-39 nuclear track detectors in the cup.

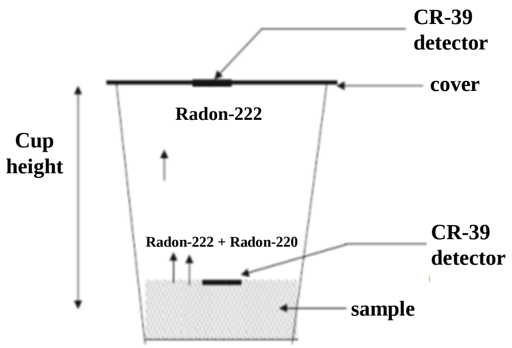

Fig. 1. Schematic of the sealed-cup technique in the present study samples.

After exposure, the detectors were chemically etched in a 6.25 N NaOH at 98 °C for 1 h [14,15] to reveal the tracks, which were microscopically treated with TASLIMAGE technology to measure track density [16]. This experimental setup ensured that the detector in the bulk sample recorded alpha particles from radon, thoron, and their daughter products present in the samples of the present study. The upper detector, however, only recorded the ^{222}Rn component. Consequently, the difference in the track densities between the two detectors represents the content of thoron and daughters in the sample. The density of tracks counted was assumed proportional to the $^{220,222}Rn$ exposure.

THEORETICAL EQUATIONS

In this study, the tracks registered by two detectors, one at 2 cm from the sample and the other is at 5 cm away from the samples. The detector at 5 cm (upper) was recording the radon gas only, and at 2 cm (lower) detector was recording radon and thoron altogether. Then, the signals will be separated by using the expression $\rho_{thoron} = \rho_{lower} - \rho_{upper}$ [17]. Thoron concentration **(C_{thoron})** was calculated from the Eq. (1) [18]:

$$C_{thoron}\left(\frac{Bq}{m^3}\right) = \frac{\rho_{thoron}}{K_{thoron}\ t} \tag{1}$$

where ρ_{thoron} is the track density on the sensitive detector (Tr/cm^2), t is the exposure time of the sample (90 d), and K is the diffusion constant (calibration factor or sensitivity factor). The methodology for the calibration factor for thoron in the present study is the same as the reference papers [19-21] which is in agreement with the ranges from 0.0049-0.0198 Tr mm^2 per K Bq/h m^3 [22].

The radiological risk due to inhalation of thoron concentration, such as Annual Effective Dose (AED), Excessive Lifetime Cancer Risk (ELCR), and Lung Cancer Case (LCC), were calculated using the Eqs. (2-4) [23-26].

$$AED\left(\frac{mSv}{y}\right) = C_{thoron} \times F \times t \times K \tag{2}$$

$$\text{ELCR} = \text{AED} \times \text{DL} \times \text{RF} \tag{3}$$

$$\text{LCC} = \text{AED} \times 18 \times 10^{-6} \tag{4}$$

where C is the average thoron concentration in samples under study (Bq/m^3), F is the equilibrium factor for thoron and its progenies (equal to 0.09 for the indoor period and 0.03 for the outdoor period), t is annual time spent in pharmacies (t = 6 h × 365 day); K = dose conversion factors (40 nSv) [23], DL is the average lifespan of the population (70 years), RF is the risk of fatal cancer in sieverts. According to the ICRP 2007 report [25], the RF factor equal to $5.5 \times 10^{-2}\ Sv^{-1}$ and 18×10^{-6} indicate the probability of developing cancer [26].

RESULTS AND DISCUSSION

Table 2 presents the results of thoron concentrations and its radiological risk (AED, ELCR, and LLC) in six types of medical materials. The range with an average value of thoron concentrations (in unit Bq/m^3) for drugs (solid), skin creams, herbs, toothpastes, drugs (liquid), cosmetic products, and all samples were 1.25-74.53 with an average value of 18.08, 1.25-39.14 with an average value of 15.31, 7.15- 64.24 with an average value of 30.29, 2.26-42.41 with an average value of 19.12, 1.25-54.2 with an average value of 16.33, and 4.66-33.59 with an average value of

12.82, respectively. Meanwhile, the range with an average value of AED (in unit mSv/y) for drugs (solid), skin creams, herbs, toothpastes, drugs (liquid), cosmetic products, and all samples were 0.01-0.588 with an average value of 0.142, 0.01-0.309 with an average value of 0.121, 0.056-0.506 with an average value of 0.239, 0.018-0.334 with an average value of 0.151, 0.01-0.427 with an average value of 0.129, and 0.037-0.265 with an average value of 0.101, respectively. Also, from Table 2, the average values of ELCR ($\times 10^{-3}$) in drugs (solid), skin creams, berbs, toothpastes, drugs (liquid), cosmetic products, and all samples were 0.549, 0.465, 0.921, 0.580, 0.497, and 0.389, respectively. At the same time, the average values of LLC ($\times 10^{-9}$) in drugs (solid), skin creams, herbs, toothpastes, drugs (liquid), cosmetic products, and all samples were 2.56, 2.17, 4.30, 2.71, 2.32, and 1.82, respectively. The results of thoron concentrations (in Bq/m^3), AED (mSv/y), ELCR ($\times 10^{-3}$), LLC ($\times 10^{-9}$) in all samples in the present study were 1.25-74.53 with an average value of 18.21 ± 2.00, 0.01-0.588 with an average value of 0.140 ± 0.016, 0.04-2.26 with an average value of 0.550 ± 0.060, and 0.18-10.58 with an average value of 2.58 ± 0.28. Figs. 2 and 3 show the compaction of the average values for thoron concentrations and AED in six groups of medical materials in the present study, respectively. From Figs. 2 and 3, the descending order of thoron concentrations and AED were herbs > toothpastes > drugs (solid) > drugs (liquid) > skin creams >> cosmetic products, respectively. The high concentrations of thoron content in different herb samples are due to the naturally occurring thorium isotopes in soil. The wide variation observed in the thoron concentrations in different medical materials samples may be attributed to the variation in the concentration of primordial ^{232}Th radionuclide in the soil where the medicinal plants grow of the study samples. However, the concentrations of thoron concentrations for all medical materials in the present study were within an acceptable limit according to ICRP 2010 (200 Bq/m^3) [27-29]. The maximum value of the annual effective dose from inhalation of thoron in six groups of medical materials was 0.588 mSv/y, which is lower than the range 1.1–4.4 mSv/y for dose contribution from thoron according to UNSEAR [30]. Also, the results of ELCR and LLC were very small, so it may be concluded that the radiological risk to inhalation of thoron gas from medical materials samples drugs (solid), skin creams, herbs, toothpastes, drugs (liquid), and cosmetic products derived from medicinal plants in Iraq is negligible.

Table 2. Results of radon-220 and radiological Risk in the samples of the present study.

Sample code	Radon-220 Bq/m^3	AED mSv/y	ELCR×10^{-3}	LCC×10^{-9}
S1	15.31	0.121	0.46	2.17
S2	1.25	0.010	0.04	0.18
S3	74.53	0.588	2.26	10.58
S4	2.26	0.018	0.07	0.32
S5	41.15	0.324	1.25	5.84
S6	12.80	0.101	0.39	1.82
S7	6.78	0.053	0.21	0.96
S8	10.04	0.079	0.30	1.42
S9	62.48	0.493	1.90	8.87
S10	4.52	0.036	0.14	0.64
S11	5.39	0.042	0.16	0.76
S12	11.79	0.093	0.36	1.67
S13	7.03	0.055	0.21	1.00
S14	6.27	0.049	0.19	0.89
S15	9.54	0.075	0.29	1.35
S16	18.82	0.148	0.57	2.67
S17	12.04	0.095	0.37	1.71
S18	6.90	0.054	0.21	0.98
S19	1.25	0.010	0.04	0.18
S20	34.88	0.275	1.06	4.95
S21	4.94	0.039	0.15	0.70
S22	4.62	0.036	0.14	0.66
S23	29.61	0.233	0.90	4.20
S24	5.57	0.044	0.17	0.79
S25	19.57	0.154	0.59	2.78
S26	39.14	0.309	1.19	5.55
S27	17.44	0.137	0.53	2.47
S28	4.27	0.034	0.13	0.61
S29	46.17	0.364	1.40	6.55
S30	9.03	0.071	0.27	1.28
S31	64.24	0.506	1.95	9.12
S32	22.58	0.178	0.69	3.20
S33	56.21	0.443	1.71	7.98
S34	24.59	0.194	0.75	3.49
S35	18.07	0.142	0.55	2.56
S36	24.59	0.194	0.75	3.49
S37	7.15	0.056	0.22	1.01
S38	31.62	0.249	0.96	4.49
S39	2.26	0.018	0.07	0.32
S40	11.54	0.091	0.35	1.64
S41	30.11	0.237	0.91	4.27
S42	7.28	0.057	0.22	1.03
S43	8.03	0.063	0.24	1.14
S44	6.78	0.053	0.21	0.96
S45	40.90	0.322	1.24	5.80
S46	42.41	0.334	1.29	6.02
S47	10.29	0.081	0.31	1.46
S48	15.31	0.121	0.46	2.17
S49	11.04	0.087	0.34	1.57
S50	6.52	0.051	0.20	0.93
S51	10.04	0.079	0.30	1.42
S52	5.77	0.045	0.18	0.82
S53	21.58	0.170	0.66	3.06
S54	1.25	0.010	0.04	0.18
S55	18.82	0.148	0.57	2.67
S56	38.64	0.305	1.17	5.48
S57	12.80	0.101	0.39	1.82
S58	7.78	0.061	0.24	1.10
S59	54.20	0.427	1.65	7.69
S60	8.53	0.067	0.26	1.21
S61	4.66	0.037	0.14	0.66
S62	9.45	0.075	0.29	1.34
S63	7.30	0.058	0.22	1.04
S64	14.61	0.115	0.44	2.07
S65	5.66	0.045	0.17	0.80
S66	19.61	0.155	0.60	2.78
S67	13.10	0.103	0.40	1.86
S68	33.59	0.265	1.02	4.77
S69	13.10	0.103	0.40	1.86
S70	7.08	0.056	0.21	1.00
Count, N	70	70	70	70
Sum, Σx	1274.48	10.042	38.72	180.83
Minimum	1.25	0.01	0.04	0.18
Maximum	74.53	0.588	2.26	10.58
Average	18.21	0.14	0.55	2.58
S. E	02.00	0.016	0.060	0.28

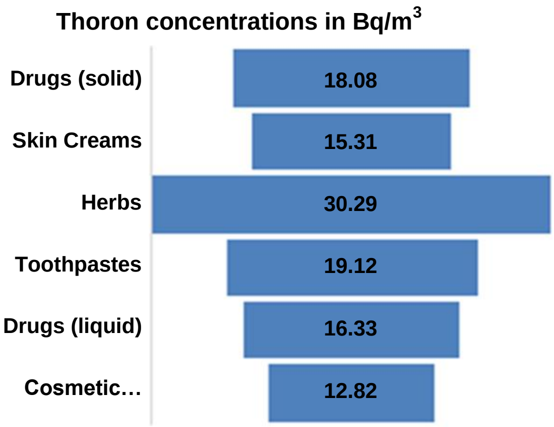

Fig. 2. Comparison of the average values of thoron in all types of samples.

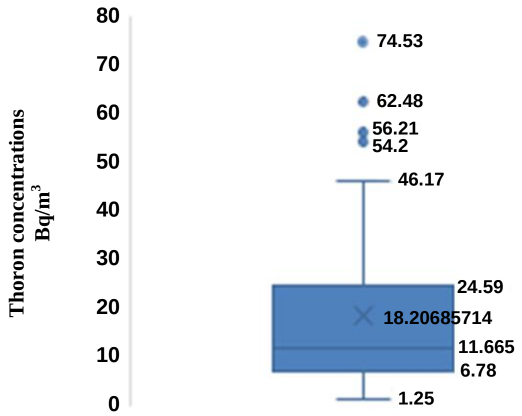

Fig. 4. Box plot of the thoron concentrations results for studied samples.

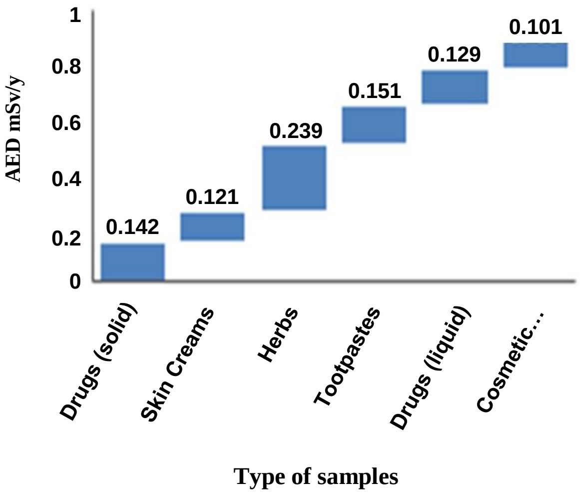

Fig. 3. Comparison of the average values of AED in all types of samples.

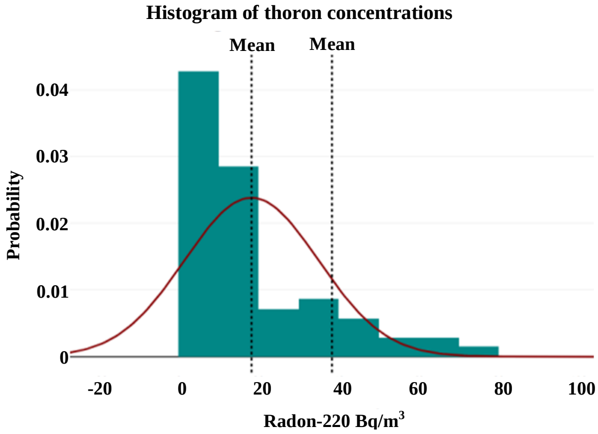

Fig. 5. The histogram of the thoron concentrations results for studied samples.

Figures 4 and 5 show the box plots and the histogram of thoron concentration in samples of medical materials, respectively. Box plots give a visual representation of location, variability, and outliers. The median for the two types of samples is closer to the bottom of the box. Then, the data are likely to be left-skewed. At the same time, the histogram estimates the probability distribution of a continuous variable. It exhibits some degree of multimodality because of the complexity of medical materials.

The results of our work concerning medical materials samples derived from medical plants in Iraq are comparable with another study that determined the thoron concentrations in materials relevant to our sample of the present study. These include medical drugs [21], tea [27], and plants used in traditional medicine toothpaste [31] which found that the average radon concentrations are lower than worldwide average levels.

CONCLUSION

The results of radiological risk to inhalation of thoron gas such as AED as well as thoron concentrations in six groups of medical materials; drugs (solid), skin creams, herbal, kinds of toothpaste, drugs (liquid), and cosmetic products, were within the average world limit according to the UNSCEAR 2006 and ICRP 2009 reports. Also, the results showed a very low radiological risk of inhalation of thoron gas, such as ELCR and LCC, in all samples. Therefore, it may be concluded that the radiological risk of inhalation of thoron gas from medical materials in Iraq is within the acceptable limit. Hence, the radiological risk from medical materials samples derived from medical plants in Iraq appears to be safe from exposure to inhalation of thoron gas.

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AUTHOR CONTRIBUTION

A. A. Abojassim carried out the experiment. D. J. Lawi wrote the manuscript and A. B. Hassan helped supervise the project.

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