Assessment of cancer risk and tissue equivalent dose in rainwater samples in Iraq

Suha Waleed Mustafa[1], *Safaa* Fadhil Shnain[2], *Noor* Sabah Muttaleb[3,*], *Zahraa* H. K. AlJelawy[4], and *Omar* Mohammed Hameed[5]

[1]University of Basrah, College of Education for women, Department of Geography, Basrah, Iraq
[2]College of Applied Science, University of Technology, Baghdad, Iraq
[3]University of Kufa, Faculty of Education for Women Chemistry Department
[4]Department of Anesthesia Techniques, College of Health and Medical Techniques /Kufa, Al Furat Al Awsat Technical University, Iraq.
[5]Department of Pathological Analysis, College of Applied Sciences, University of Samarra, 34010 Samarra, Iraq

Abstract. Objective: In this study, we investigate the radiological safety of rainwater samples at specific sites in Iraq by determining the dose rate, annual effective dose (AED), tissue equivalent dose and excess lifetime cancer risk (ELCR). Natural and anthropogenic sources of environmental radioactivity can be transported by atmospheric precipitation; therefore, rainwater is an important indicator of the radiological status in the environment. Tests were performed using a calibrated FS-600 Geiger–Müeller (GM) detector in a controlled vacuum chamber to reduce background effects.The measured dose rates ranged from 0.026 to 0.132 μSv/h, and none of the values were found to exceed the international standard reference limit of 0.274 μSv/h (UNSCEAR).Estimated annual effective doses calculated ranged from 0.021 to 0.033 mSv/y; these levels are lower than suggested public exposure limit of 0.48 mSv/y.Excess life-cancer risk associated with outdoor radiation absorbed by skin varied between for both genders: 81 $\times 10^{-3}$ -128$\times 10^{-3}$ which is well below global reference value of excess life cancer risk estimate-,029 x10^{-3}.The results show that the radioactivity from rainwater to the public exposure for the studied sites is low and can be considered as not dangerous to health. The results were in agreement with ICRP and UNSCEAR reports, and can be used as established data for environmental radiation monitoring in Iraq. Monitoring needs to be ongoing to ensure the radiological safety and environmental protection.

1 Introduction

Environmental Radioactivity is an established part of the human environment and has originated from cosmic radiation, natural terrestrial isotopes as well as man-made sources. Rain also serves as a conduit for the transit of airborne contaminants to the surface and is potentially indicative of environmental radiochemical status. The radioactivity of rainwater

* Corresponding author: noors.almousawi@uokufa.edu.iq

can be detectable by means of field instruments (a Geiger–Müller counter) in a fast and convenient way for determining the background radiation level and its temporal variation [1]. These measurements are essential for estimating the public radiation dose, and potential late health effects. The concept of tissue equivalent dose is widely used to specify the biological effect of ionizing radiation in the human body. This is because – in contrast to the measured activity concentration – this dose is not a direct measure, but must be calculated taking into account the radiation type and energy [2]. The counts of the Geiger measurements can be converted to absorbed dose and equivalent dose, where it can be compared with recommended international safety levels such as (ICRP and UNSCEAR) [3]. This approach can help scientists determine whether the detected rainwater radioactivity is likely to have any health implications for the general public. Lower doses of man-made radiation received slowly over years may also increase the risk that a person will develop cancer. Risk of cancer was calculated using models which relate annual effective dose to lifetime risk coefficient [4]. In presumably military situation, storm dust in atmosphere and other anthropogenic pressure on environment (the example is Iraq) may be worried about the increasing content of natural and technogenic radionuclides in atmospheric precipitation [5]. However, few organized investigations relate direct Geiger sending organic matter measurements in rainwater to calculated tissue-equivalent dose and derived cancer risk [6]. In the Middle East, several studies determined that amounts of natural radionuclides: U–238, Th–232 and K–40 were measurable in rainwater which contributed to both external and internal pathway exposure. That is why we have to keep checking the rainwater - we need to establish a good radiological baseline and give themselves powers of environmental protection. In this work, the normalized absorbed dose resulting from natural radioactive pollutants and the corresponding background radiation, which was measured to samples of rain water from different places in Iraq, will be investigated through properly calibrated Geiger counter so that we computed their lifetime cancer risk rate with respect to reference.

2 Materials and methods

The experimental apparatus was aimed to measure the background radiation released from rainwater in experiment. The sample was isolated from an external environment by a translucent VEVOR vacuum chamber connected to a pressure gauge, control valves and a vacuum hose. A glass beaker, containing 150 ml of rainwater, was introduced inside the chamber and a FS-600 GM (Geiger–Müller) radiation detector was placed into the same chamber at constant distance from water in order to directly count the radiation emitted by sample. Employment of vacuum chamber intended to diminish effects such as ambient background radiation, airborne radon decay products or humidity which may affect precision of readings. All measurements were conducted at normal room temperature conditions and internal pressure of the chamber decreased gradually before each measurement session until reaching stable counting conditions [7-9].

2.1 Sample collection

Rainwater during rain natural precipitation was collected in clean and chemically inert containers. The collection containers were located about 1.5 meters above the ground to prevent dust and soil particle contamination and taken back to the laboratory, filtered for removing suspended matters which could affect radiation attenuation. Radiological measurement A volume of 150 ml was transferred from each sample into clean glass beaker [10].

2.2 Measurement procedure

The FS-600 monitor was initially verified and calibrated as per the manufacturer's recommendations and previously described calibration procedures [9]. The natural radioactivity in the empty vacuum chamber was counted over ten minutes to establish the unshielded background count rate. Following it, the rainwater sample in the beaker was placed at center of a chamber and constant geometry between each measurement (detector vs. sample) was employed. The chamber was then closed and evacuated to form a semi-vacuum state limiting the concentration of radon progeny [10]. The detector dose rate current in μSv/h was recorded every minute for a total length of 30 minutes. The mean of these readings was taken as the sample representative radiation level.

2.3 Dose and cancer risk calculation

The dose rates with which the rainwater sample emitted radiation were directly read from the FS-600 GM probe in microsieverts per hour (μSv/h). This is the ambient dose equivalent rate at the location of the detector inside the vacuum chamber. To assess the radiological impact on human health, measured dose rate was converted to an annual equivalent dose following standard time conversion values according to international guidelines for radiation protection. The annul equivalent dose was determined by: $D = d \times t$ Where; d= the dose, and t= time

$$H \text{ annual } (\mu\text{Sv per year}) = R\ (\mu\text{Sv per hour}) \times 24 \times 365$$

where R is the measured dose rate average as recorded by the detector, 24 h is the number of hours a day and 365 days in a year. It is assumed that the individual receives an always-on irradiation and represents a conservative estimate of the annual dose to which an individual could be exposed [10]. For the assessment of radiological health impact, excess lifetime cancer risk was calculated. This is an estimate of the lifetime probability of receiving cancer as a result of ionizing radiation. The following formula was used based on the ICRP recommendations:

$$ELCR = H \text{ annual } (\text{Sv per year}) \times DL \times RF$$

where DL is the mean span of life, taken as 70 y, and RF is the risk factor for fatal cancer which =5×10 -4 / Sv for public. Prior to using this equation, the annual equivalent dose was transformed from microsievert to sievert multiplying the result for 1,000,000 in order to keep the unities adequate. This procedure makes it possible to convert the measurements obtained from the Geiger counter into a biological risk which can be compared with international limits. The computed ELCR was assessed against the global average reference level (2.9×10^{-4}) which is deemed as an acceptable risk for the general population.

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Fig. 1. Experimental setup for measuring background radiation emitted from a 150 ml rainwater sample using an FS-600 Geiger counter inside a vacuum chamber.

3 Result and discussion

The measured rainwater ⁄dose rate (μSv/h), the annual effective dose (AED, mSv/y), and excess lifetime cancer risk (ELCR $\times10^{-3}$) are presented in Table 2 for 30 sampling sites (RW1–RW30). These variables were considered to study the radiological quality of the harvested rainwater and its consequent risk to human health. Measured dose rate Rate values vary between 0.026 and 0.132 μSv/h with the majority of samples being relatively low and fairly uniform. The maximum and minimum dose rates were observed in RW30 (0.132 μSv/h), and RW21 (0.026 μSv/h) respectively. Nevertheless, all dose rates are several Å-below the above-mentioned international reference level of 0.274 μSv/h established as guideline value for environmental radiation exposure. For one year, the annual effective dose (AED) was estimated using measured dose rates in order to evaluate radiation exposure of an individual. The AED values are 0.021-0.033 mSv/y, well below the international public exposure limit of 0.48 mSv/y. This shows that the contribution of rainwater to the annual dose is negligible. The ELCR for the 238 U, 232 Th, and 40 K radionuclides ranges from 0.081 $\times10^{-3}$ to 0.128 $\times10^{-3}$ with an average value much lower than the global reference level of 0.29 $\times10^{-3}$. These findings indicate that, over a lifetime, the risk of radiation-induced cancer is very small from exposure to rainwater. the low dose rate values obtained in most of the rainwater samples are indicative for the natural contributions as opposed to harmful anthropogenic radioactive contamination. Dose rates within the same range of values are reported for rainwater in studies carried out in other areas of the world where atmospheric deposition of natural radionuclides like uranium-238, thorium-232, and potassium-40 is the main source of radiation (UNSCEAR, 2000; UNSCEAR, 2008). The slightly high dose rate recorded at site RW30 could be due to atmospheric conditions in the vicinity such as dust loading, amount of rainfall, or proximity to natural terrestrial sources. Nevertheless, the maximum of this highest value still lower than the safety levels which recommended by international organizations and consensus that didn't raise a radiological issue. The estimated AED indicate that radiosignature of rainwater in their contribution to public exposure is insignificance with respect to the worldwide average annual effective dose from natural sources, ~2.4 mSv/y (UNSCEAR, 2008). The AED's obtained are less than 2% of this worldwide average, indicating the trivial radiological consequence if rainwater was ingested or contacted. Additionally, ELCR values obtained in the current study are much lower than ICRP's acceptable risk levels. Guidance of ICRP sets the risk coefficients for fatal cancer at 0.05 per sievert to the public (ICRP, 2007). The low ELCR values observed suggests that having long-term exposure to the measured rainwater radiation levels is unlikely to be associated with any adverse health risk. In conclusion, the general compliance of values with world recomendations and litarature data attests for radio-radiological safety of rainwater at the studied location.

Table 1. Results of Rainwater Dose Rate (μSv/h), AED (mSv/y), and ELCR at the Sampling Sites.

No.	Sample Code	Dose Rate (μSv/h)	AED (mSv/y)	ELCR $\times 10^{-3}$
1	RW1	0.035	0.025	0.096
2	RW2	0.03	0.028	0.108
3	RW3	0.034	0.024	0.092
4	RW4	0.031	0.027	0.104
5	RW5	0.033	0.025	0.095
6	RW6	0.036	0.026	0.101
7	RW7	0.029	0.029	0.112
8	RW8	0.038	0.023	0.088
9	RW9	0.034	0.03	0.116
10	RW10	0.028	0.027	0.105
11	RW11	0.035	0.022	0.085
12	RW12	0.036	0.028	0.107
13	RW13	0.033	0.029	0.109
14	RW14	0.042	0.026	0.102
15	RW15	0.03	0.033	0.128
16	RW16	0.034	0.024	0.093
17	RW17	0.037	0.027	0.105
18	RW18	0.028	0.03	0.115
19	RW19	0.033	0.022	0.085
20	RW20	0.038	0.026	0.101
21	RW21	0.026	0.03	0.116
22	RW22	0.033	0.021	0.081
23	RW23	0.028	0.026	0.102
24	RW24	0.03	0.022	0.085
25	RW25	0.034	0.024	0.093
26	RW26	0.037	0.027	0.104
27	RW27	0.035	0.029	0.112
28	RW28	0.04	0.028	0.108
29	RW29	0.032	0.032	0.123
30	RW30	0.132	0.025	0.097
International limit		0.274	0.48	0.29

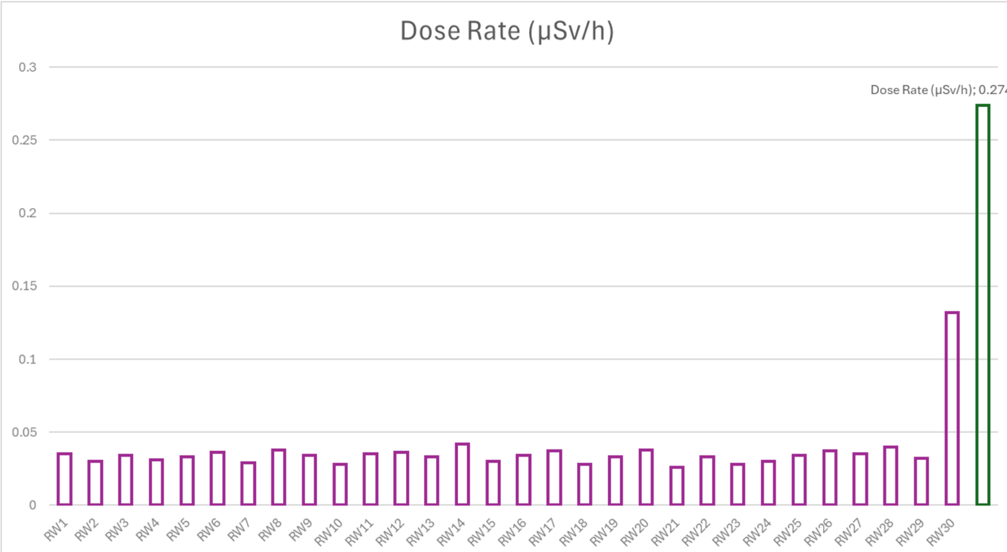

Fig. 2. Distribution of Measured Rainwater Dose Rates (μSv/h) at Sampling Sites with Reference to the International Safety Limit.

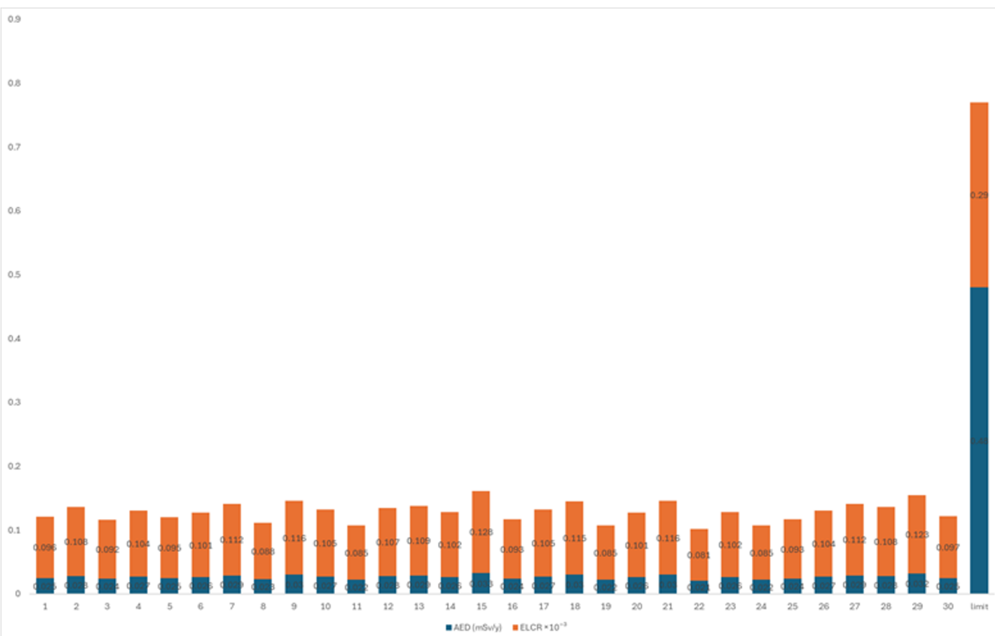

Fig. 3. Distribution of Measured Rainwater AED (mSv/y), ELCR $\times 10^{-3}$ at Sampling Sites with Reference to the International Safety Limit.

4 Conclusion

The present study showed that rainwater samples collected from all the studied locations were found to be radiologically safe according to gamma dose rate, annual effective dose and excess life time cancer risk calculations. All monitored parameters are well below the internationally adopted limits for exposure of the general public. The low AED and ELCR values derived here imply that rainwater is not a substantial source of radiation dose for the public nor does it present a relevant health risk. These results serve as baseline data for monitoring environmental radiation and are helpful for the safe use of rainwater in terms of radiological risk.

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