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Original Research

Risk Assessment of Outdoor Background Gamma Radiation at Duhok City, in Kurdistan Region, Iraq

Furman Ahmed[1]*, Idrees Kareem[2], Suaad Meerkhan[3], Waseem Shlaimoon[4]

[1]Department of Physiotherapy, College of Health Science, Erbil Medical University, Erbil, Iraq
[2] Department of Civil and Environment, College of Engineering, Zakho University, Zakho, Iraq
[3]MAXIV Laboratory, Lund University, Lund, Sweden
[4]Duhok Environment Office, Government Council of Ministers Environment of Protecting Improvement Board Duhok, Iraq

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Abstract

In this study, a model „ADM606M Portable Multifunction Ratemeter /Scalar" (Gamma GP110 Detector) was used to estimate the effective dose rate in (*μSv.h*$^{-1}$). The data were analyzed for three specified hours per day (9:00 a.m., 11:00 a.m., and 1:00 p.m.) from January 2009 to June 2016. In July 2019, the gamma scout radiation meter (dosimeter) was used to measure the outdoor gamma effective dose rate (*μ*Sv.*h*$^{-1}$) for the same building every minute for three hours, from 10 a.m. to 1 p.m., at 1m above the second floor of the building. The average effective dose rate and average Annual Effective Dose Rate were 0.158±0.013 *μSv.h*$^{-1}$ and 0.2614145 m*Sv.y*$^{-1}$, respectively, within acceptable limits. The excess lifetime cancer risk (ELCR) value was also assessed to be (0.91495×10^{-3}), which was found to be greater than the UNSCEAR, 2000 stated world average (0.29×10^{-3}). The risks of cancer morbidity and mortality for specific organs and tissues from external sources of low linear energy transfer (LET) radiation were also assessed. They showed biological effects associated with the potential long-term exposure of Dohuk city residents to natural background radiation.

Keywords: Duhok city, gamma radiation, ADM606M , effective dose rate, risk assessment

Introduction

Background radiation is created from both naturally existing radionuclides (such as the radiation sent out from radioactive terrestrial components and cosmic rays) and the man-made radionuclides that produce radiations from activities such as the medical procedures that use radiopharmaceuticals for imaging or therapeutic purposes and radioactive uranium that use as fuel for electricity generation [1]. The basic level of natural background radiation varies with the variation of the geological and geographical features of the area [2]. The terrestrial component varies with geography, and the cosmic source component depends on the altitude [3]. It is believed that exposure to high radiation levels will cause cancer [4]. At the same

*e-mail: furman.ahmed@hmu.edu.krd

time, the biological effects of radiation from low radiation doses such as natural background radiation are difficult to determine due to the different factors that can alter the effects of radiation [5]. For example, lifestyle choices, geographic locations, and individual sensitivities are all complicated elements to account [6]. A United Nations committee concluded that exposure to different natural background radiation levels does not significantly affect cancer induction. This point was debated by the committee of the National Academy of Sciences. It arose with a new suggestion, were assumed that the low radiation doses from background radiation might induce cancer even though the risk of induction is very low [7]. Even at low levels, ionizing radiation can induce cancer and heritable disorders, referred to as stochastic effects, since they are probabilistic and presume that any exposure can cause an impact [8]. Because ionizing radiation from the environment is the most common source of exposure, the level of background gamma radiation in any given place is essential in health physics. The measurement can also be used as a reference value for estimating the effects of man-made radiation on health [9]. The Committee on Biological Effects of Ionizing Radiation (BEIR) [10], the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [11], and the International Committee on Radiation Protection (ICRP) was used two relatively simple models to describe and calculate radiation-induced cancer risks [12]. The first is the time-constant absolute risk projection model that assumes that the risk of developing cancer is constant after a latent period. The second is a time-constant relative risk projection model that supposes that the cancer rate increases proportionally to the cancer risk after the period. The linear no-threshold model (LNT) is a cumulative risk model [13], used in radiation protection to estimate stochastic health effects such as radiation-induced cancer, genetic mutations, and teratogenic effects on the human body due to exposure to ionizing radiation [14]. The city of Duhok is one of the study's focus areas since it has long been impacted by the conflicts that have raged nearby. In this area, a number of epidemiological and environmental factors have contributed to a rise in cancer risk [15]. Duhok is a small town surrounded on all sides by mountains (10715 square kilometers). Two mountain chains surround it: Zaiwa to the southeast and Bekhair to the north and northeast. Fig. 1 describes the position Duhok city is 430-450 meters above sea level and is located in the Kurdistan region of Iraq, about 89 and 470 kilometers north of Mosul and Baghdad, respectively. It is situated at 36°52′01″N, 42°59′18″E, at the height of 567 meters (1860 feet) above sea level [16]. The activities and percentages of radioactive chemicals such as ^{214}Pb, ^{214}Bi, ^{212}Pb, ^{228}Ac, ^{40}K, and ^{137}Cs released in Duhok city air were investigated using gamma spectroscopy. With the exception of the anthropogenic radioisotope ^{137}Cs, all radioactive activities rise throughout the summer/autumn season [17]. There were no published statistics for daily monitoring of the gamma radiation level in the air in the Duhok area for the control of background radiation. The data presented in this study summarize the data of the gamma effective dose rate for a period spanning January 2009 to June 30, 2016, and calculated the natural background gamma radiation over Duhok city, the annual effective dose, and the excess lifetime cancer risk (ELCR) using the measured gamma exposure levels.

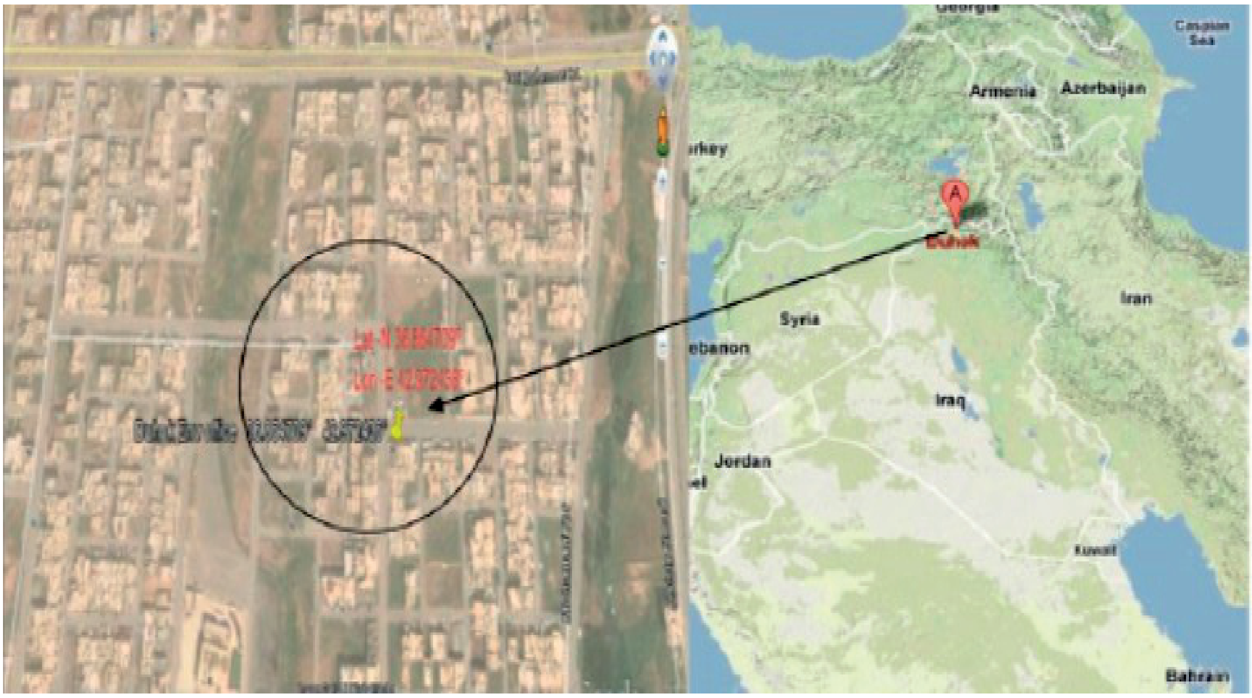

Fig. 1. Map of Duhok and Duhok Environmental Protection office.

Material and Methods

Model ADM606M radiation monitor (CANBERRA Industries, Inc) was used in this study to estimate the outdoor effective dose rate of gamma radiation in μSv.h^{-1}. The ADM606M ratemeter is portable or wall-mountable, calculates dose and dose rate alarms (visual and audible), and supports three smart probe detectors monitoring all types of radiation (including alpha, beta, gamma, x-ray, and neutron). Using "SMART" detectors allows the ADM606M to automatically interrogate the probe and determine probe type and the relative operation and calibration constants. In addition, the readout display units are automatically adjusted to correspond to the probe type. The ADM606M can utilize simultaneous inputs from up to three separate "SMART" detectors. The Gamma GP110 detector is used as the early warning system for continuously measuring the background gamma radiation levels [18]. This study was conducted from 2009 to 2016. The data was taken at the three specific hours of the day (9:00, 11:00, and 1:00) when the largest number of Dohuk residents are outside buildings on their way to work or to complete their daily work. This study's ADM606M setup consists of the monitor Fig. 2a) and detector Fig. 2b). The detector was placed on the roof of the Environmental Protection Office building in Dohuk at the height of 8 meters above ground level and 2 meters above the second floor. The effective gamma dose rate was re-measured and monitored in July 2019 but using another dosimeter (Gamma Scout) for three continuous hours (10 a.m. to 1 p.m.), taking into account times similar to the years mentioned earlier when the largest population of Dohuk was outside their homes. The detector was placed in the same building and on the same floor (second floor) at the height of one meter above the ground and away from the walls to avoid the effect of the construction on the external measurements. The data was processed by the Gamma Toolbox software installed on a personal computer. [19]. This study used a variety of radiation health risk indicators to arrive at a more accurate assessment of the health risks that a person would face if exposed to background radiation. Estimated Equivalent dose rate, absorbed dose rate, annual effective dose rate (AEDE), Collective dose quantities SE, the excess lifetime cancer risk (ELCR), and the risks of cancer morbidity and mortality for specific organs and tissues of the body from the exposure levels to gamma rays had been measured.

Results and Discussion

For a long period, there was conflict in this area, with a wide range of weapons being utilized. Therefore, we conducted this research to determine the impact of these wars on the level of environmental radiation in Duhok city for a period ranging between January 2009 and June 2016. In this study, the radiation level in the air for Duhok city was measured for four seasons of the year and three different hours of the day. Then, in 2019 we measured the background radiation once more.

The Average Effective Dose Rate (μSv.h^{-1})

The value of the average effective dose rate (*μSv.h*$^{-1}$) measurement was done monthly for three specific hours per day (9:00 a.m., 11:00 a.m., and 1:00 p.m.) for the entire years (2009, 2010, 2011, 2012, 2013, 2014, 2015, and until the end of June 2016). The maximum and minimum effective dose rates were 0.171 *μSv.h*$^{-1}$ and 0.145 μSv.h^{-1}, respectively. The results demonstrated that the extraordinary radiation levels in the environment

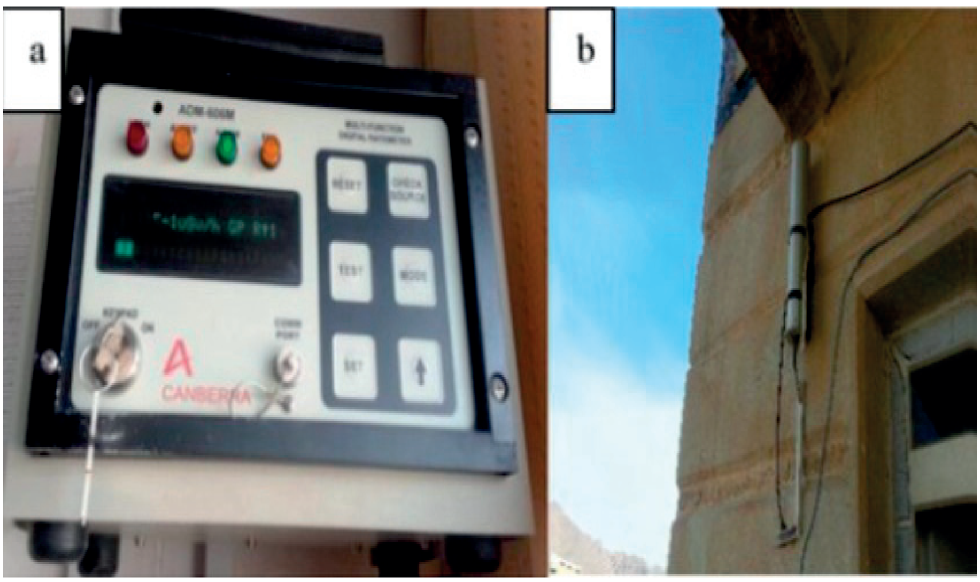

Fig. 2. a) Model ADM606M Portable Multifunction Ratemeter/Sc, b) systems Gamma GP110 Detector.

Table 1. The average effective dose rate that calculated and for time interval 2009 to till the end of June 2016.

Date		Average Dose rate μSv.h^{-1}						
	2009	2010	2011	2012	2013	2014	2015	2016
Jan.	0.149463	0.153833	0.150833	0.150606	0.151350	0.146000	0.148704	0.146222
Feb.	0.149368	0.149200	0.153526	0.150433	0.146650	0.153825	0.149117	0.147591
Mar.	0.156389	0.147889	0.150262	0.146619	0.146778	0.145778	0.148611	0.148611
Apr.	0.150968	0.149583	0.150556	0.147600	0.149968	0.151389	0.149500	0.149500
May.	0.149159	0.149810	0.147591	0.147121	0.147429	0.145567	0.147413	0.147000
Jun.	0.150429	0.170530	0.149864	0.148783	0.145381	0.145303	0.149894	0.147254
Jul.	0.150079	0.147067	0.149067	0.150043	0.149136	0.145500	0.146588	
Aug.	0.152258	0.149899	0.148895	0.148647	0.148573	0.147254	0.150333	
Sep.	0.150722	0.149118	0.147833	0.146222	0.146794	0.146818	0.147704	
Oct.	0.150333	0.147683	0.150470	0.149088	0.148944	0.147000	0.147315	
Nov.	0.147450	0.156196	0.148229	0.148093	0.149259	0.150807	0.149550	
Dec.	0.148637	0.149867	0.149561	0.152730	0.147381	0.147652	0.149550	

are not observed. From Table 1, the average effective dose rate (μSv/h) calculated for the time interval from 2009 to 2016 was found to be 0.158±0.013 μSv.h^{-1}, and it is within the acceptable range of the global average gamma dose rate (0.01-0.2 μSv.h^{-1}) according to UNSCEAR (1993, 2000) reported, and lower than the calculated value of the average gamma dose rate for the Bitlis (0.28 μSv.h^{-1}) [20].

Annual Effective Dose (AED)

The annual outdoor effective dose was calculated for Duhok City by the following equation [21].

$$AED = Dout \times OFout \times T \quad (1)$$

Where AED (mSv.y^{-1}) is annual outdoor effective dose, Dout (μSv.h^{-1}) are mean outdoor effective dose rates, T (hr) the total hours in a year (8760 hours), of out, the occupancy factor, that is the fraction of time that was spent outdoor is 0.2.

The effective annual dose rate for the years listed above were calculated and found to be 0.263567, 0.265818, 0.262316, 0.260753, 0.2607536, 0.258842, 0.260504 and 0.258763 mSv.y^{-1} respectively. There is no significant variance in effective dose rate readings for different years. In addition, no significant differences in effective dose rate measurements were found compared to the value effective dose rate of 0.26130 mSv.y^{-1} obtained in 2019 as shown in Fig 3. The calculated average AED 0.2614145 mSv.y^{-1} value was less than the recommended public dose limit of 1 mSv.y^{-1} set by the ICRP and UNSCEAR [20], and less than the calculated value for Bushehr city (0.36 mSv.y^{-1}) [22] ,Sao Paulo city (1.3-±0.1 mSv.y^{-1}) [23], and Al-Basrah city (Iraq) (0.472 mSv.y^{-1}) [24].

Collective Dose (SE)

Collective dose quantities have also been measured in this study. The collective equivalent dose, SE (human- Sv.y^{-1}), is the average equivalent dose in an exposed group of individuals multiplied by the number of individuals in each group. These are aggregate quantities of dose, and population size was assessed according to the following expression [25].

$$SE = AED \times N(H)\ i \quad (2)$$

Where AED is the effective dose equivalent, N(H) i is the number of individuals in population subgroup i receiving dose equivalent of AED. N(H)i Population of Duhok city is 1.292,535 [26], and the computed value SE was 337887.3907575 human- Sv.y^{-1}

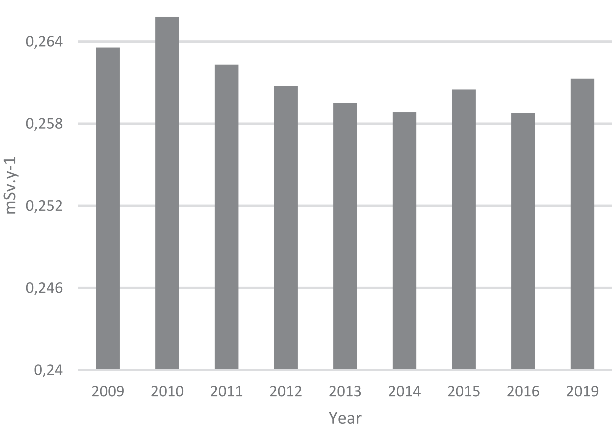

Fig. 3. shows the annual outdoor effective dose for Duhok City (mSv.y^{-1})

Table 2. The calculated effective dose equivalent and the risk of mortality and morbidity (whole-body).

Year	Effective dose equivalent ($mSv.y^{-1}$)	Mortality risk	Lifetime mortality health risk(whole body) (extra fatality case per no. of exposed individuals)	Morbidity risk	Lifetime morbidity health risk (whole body) (extra cancer case per no. of exposed individuals)
2009	0.263567	0.001107	1 per 903	0.001476	1 per 677
2010	0.265818	0.001117	1 per 895	0.001489	1 per 671
2011	0.262316	0.001102	1 per 907	0.001469	1 per 680
2012	0.260753	0.001095	1 per 913	0.001460	1 per 684
2013	0.2607536	0.001095	1 per 913	0.001460	1 per 684
2014	0.258842	0.001087	1 per 919	0.001449	1 per 689
2015	0.260504	0.001094	1 per 913	0.001459	1 per 685
2016	0.258763	0.001087	1 per 920	0.001449	1 per 690
2019	0.26130	0.001097	1 per 911	0.001463	1 per 683
Ave.	0.261402				

The Excess Lifetime Cancer Risk (ELCR)

In this study, a linear non-threshold (LNT) model (dose-response model) was evaluated, which assumes that radiation doses lower than zero will increase the risk of excess cancer and genetic disease in the low dose range in a simple proportional manner. Although the relationship is based on cancers induced in the Japanese A-bomb survivors [27]. Due to outdoor gamma radiations, the excess lifetime cancer risk (ELCR) was measured for people in Duhok to predict an individual‘s lifetime risk of promoting cancer due to exposure to a low dose of radiation, which was calculated using the following equation based on calculated values of the annual effective dose [28].

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

Where (AED) is the annual effective dose, and DL is the average duration of life (70 years). For low dose

Table 3. Risk factors to various body organs and tissues, possible cancer mortality, and morbidity risks to various body organs and tissues as a result of external exposure for Lifetime (70 years).

Cancer	Radiation mortality (risk per Sv)	Mortality Risk	Lifetime mortality health risk (whole body) (extra fatality case per no. of exposed individuals)	Radiation incidence (risk per Sv)	Incidence Risk	Lifetime Incidence health risk (whole body) (extra fatality case per no. of exposed individuals)
Bladder	0.003	0.000059	1 per 18216	0.006	0.000109	1 per 9108
Bone surface	0.0005	0.000009	1 per 109300	0. 001	0.000018	1 per 54650
Breast	0.002	0.000036	1 per 27325	0. 004	0.000073	1 per 13662
Colon	0.0085	0.000155	1 per 6429	0. 015	0.000274	1 per 3643
Leukemia (bone marrow)	0.005	0.000091	1 per10930	0. 005	0.000091	1 per10930
Liver	0.0015	0.000027	1 per36433	0. 002	0.000037	1 per 27325
Lung and Bronchus	0.0085	0.000155	1 per 6429	0. 009	0.000165	1 per 6072
Esophagus	0.003	0.000054	1 per 18216	0. 003	0.000055	1 per 18216
Ovary	0.001	0.000018	1 per 54650	0. 001	0.000018	1 per 54650
Skin	0.0002	0.0000036	1 per 273251	0. 100	0.001829	1 per 546
Stomach	0.011	0.000201	1 per 4968	0.012	0.000219	1 per 4554
Thyroid	0.0008	0.000015	1 per 68312	0.008	0.000146	1 per 6831
Remainder	0.005	0.000091	1 per10930			

background radiations considered to produce stochastic effects, uses values of RF the fatal risk factor per Sievert, which is 0.05 for the public exposure that relies on survivors from atomic bomb [29]. The ELCR calculated value was 0.91495×10^{-3} this value is higher than the world average (0.29×10^{-3}) [30].

Risk Assessment

For external sources of linear low-emissions radiation (LET) that provide nearly uniform body radiation, the risk of cancer (morbidity) and mortality as a function of the external dose was estimated using the 8×10^{-2} conversion factors. per Sv and 6×10^{-2} risk per Sv [31] the risk of cancer incidence (morbidity, as shown in Table 2. The risks of cancer morbidity and mortality for specific organs and tissues from external sources of low linear energy transfer (LET) radiation were also evaluated using the risks factors listed in Table 3 [32].

Conclusions

The average annual effective dose AED outdoor from the background gamma radiation in Duhok city was lower than the global level (worldwide average 0.48 $mSv.y^{-1}$ as presented by UNSCEAR and maximum dose 1.0 $mSv.y^{-1}$ as presented by ICRP2007). Evaluation of the present study results revealed that the war around the city had no significant effects on the background gamma radiation level in Duhok city during seven years. While the estimated excess lifetime cancer risk due to gamma dose rate over the average life span (estimated as 70 years) is higher than reported works in the literature, it indicates that the probability of developing cancer over a lifetime is considerable. Different body organs and tissues vary in their sensitivity to ionizing radiation emitted by background radiation. There are biological effects associated with the potential long-term exposure of Dohuk city residents to natural background radiation, including an increased incidence of genetic abnormalities in humans. The study's outcomes might be employed as baseline data about the background radiation level for Duhok city that might use in routine and emergencies situations, as well as for developing recommendations for public radiation protection and the environmental purposes as well as assessing possible radiological risks human health. They may also serve as a guide for future measurements and assessments of potential radioactive risks to human health in this area.

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Conflict of Interest

The authors declare no conflict of interest.

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