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# Indoor and outdoor gamma radiation level in mud and concrete houses and the annual effective dose and excess life time cancer risk in Gahkuch Ghizer valley of Hindukush Range

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## Abstract

This study is an attempt to quantify the indoor and outdoor gamma radiation level, the associated effective dose rate and Lifetime Cancer Risk in Gahkuch, the capital city of district Ghizer in the eastern Hindukush. All measurements have been carried out by FAG radiation dose rate meter in representative houses made of different construction materials. These measurements were performed at standard height of 1 meter above the ground level. The mean absorbed dose rate was 229.5 nGy/h for indoor and 220.6 nGy/h for outdoor environments, which is greater than global level. Annual Effective Dose for indoor were determined as 1.0 mSv/y while for outdoor its value was 0.4 mSv/y, which differs to the average worldwide value of 0.48 mSv/y. Average Excess Lifetime Cancer Risk was found to be 3.4×10-3 for indoor while it was 1.4×10-3 for outdoor. Both of these values are higher than the World average value 0.29×10-3. The current study shows that Gahkuch, Ghizer is placed in those regions where a remarkably high dose rate exists.

*Keywords:* Absorbed dose, Effective dose, Excess life time cancer risk, Gahkuch Ghizer, indoor, Outdoor and background gamma radiation.

## 1. Introduction

With the growing awareness about the health effects of background gamma radiation (cosmic as well as terrestrial), the estimation of the indoor and outdoor radiation dose has gained considerable attention of the researchers around the world.

Assessment of gamma radiation is important because of its capability of ionizing the absorbing material (Keith et al., 1999). Living things are continuously exposed to radiation by various sources. Radiations come from both artificial (man-made radioactive materials) and natural sources. The important sources of natural radiations are cosmic rays; coming from outer space activities (Cember, 2008). The cosmic rays are of two types; primary and secondary cosmic rays. The Primary cosmic radiations are mainly originating from outer space such as stars explosions, galaxies, back holes, sun etc. These primary cosmic particles interact with atoms in the earth's atmosphere and produce a large variety of secondary cosmic particles that are pions, muons, electrons, gamma rays etc. The exposure to cosmic radiation depends mostly on height above sea level. It also relies upon latitude, and solar activity (UNSCEAR, 2000). Terrestrial radiations are those radiations which are emitted by the earth itself. For example, radioactive materials present in the soil, rocks, water, soil, air, coal etc. The important radioactive elements are Potassium-40, Uranium-series and Thorium series (Karunakara, 2014).

Gamma-emitting radionuclides present in bits in all soils is the main reason for terrestrial outdoor or external radiations. They include 40K and the 238U and 232Th families. The concentration of uranium in the soil varies with its locality. The concentration of these radionuclides rely upon the source of rocks from which the soil originates e.g. high convergence of radiations is detected in igneous rocks such as granite, however, low concentrations in sedimentary rocks are observed (UNSCEAR, 2000). The estimated average amount of annual effective dose each person receives on earth is about 0.48 ms/y (UNSCEAR, 1982). Radium and Radon the daughter yields of Uranium and Thorium are also present in the soil. Radium decay into Radon (222Rn) by emitting alpha particle followed by gamma radiation, (Kobeissi, 2014) which is in gaseous form and diffuse out of the soil. Radon-222 has a half-life of some days; however, it decays into Polonium-210 and lead-214, having the longest half-life (UNSCEAR, 2000).

Generally, Indoor exposure to gamma radiation is larger than outside exposure which is an aftereffect of ground materials like soil, rocks, water etc. utilized as building materials (Almgren, 2008). Normally, individuals spend over 80% of their time indoors, like in houses, workplaces and schools occupants remain indoor for activities, for example, resting, working studying and so on. So, indoor exposure turns out to be considerably more noteworthy (UNSCEAR, 2000; Miah, 2004). The construction materials behave as a source for indoor radiation and furthermore as attenuators for outside radiation. Wooden houses, for instance, have a significant impact on these unsafe external sources of radiation. The walls; depending upon their composition, are capable or incapable shielding concerning the open-air sources. So in wooden houses, the indoor gamma dose rate is lower than the outside environment (UNSCEAR, 1982).

Radon is a decay product of uranium; as a gas, diffused almost everywhere in the environment. As a result, it leaks straight into a building made of ground material through basements, wall cracks and floors. The radiation dose differs from place to place depending on the local geology. The concentration of radiations varies from place to place because of different geological settings, the building materials used and the ventilation of structure.

The contribution of cosmic rays to background radiation depends upon altitude. Air performs its role as a shield from radiations. Going on high altitude decreases the amount of air so, amount of exposure to radiations increases while going up at high altitude. Each 1500 meter rise in altitude doubles the amount of radiation because of the contribution of cosmic radiation (UNSCEAR, 2000; Gahrouei, 2003).

The present study is aimed at quantifying the indoor and outdoor gamma radiation level in the dwellings of the capital city of district Ghizer and the associated effective dose rate and lifetime cancer risk.

## 2. Materials and methods

### *2.1. Study area*

The study area is covering the town of Gahkuch, upper and lower Gahkuch, Aishe and Damas in Ghizer District. The geographic location of the study area lies between 36°09′ N to 36o14′ N and 73°42′ E and 73°49′ E at an average altitude of 7500 feet above sea level.

Figure 1 presents the map of the area with sampling locations. The study area is situated 70 km northwest of Gilgit city (Bakr, 1965). The rocks of Gahkuch, Damas and Aishe, are mostly consist of Chalt Volcanic group, Kohistan Batholith and Greenstone complex. Rocks in these groups are mainly amphibolite, metasedimentary, volcanic basalt, andesite and rhyolites. The people of that area use granite and local soil as constructing material, as it contains naturally occurring radioactive components like uranium, thorium, radium, cesium and their progeny, which are gamma emitters. The soil of Gilgit-Baltistan is such that the natural radionuclides; Radium-226, Thorium-232, Potassium-40 and anthropogenic radionuclide Cs-137 in soil is relatively high as compared to the other areas.

### *2.2. Methods and sampling*

A total of seventeen representative buildings in the study area were selected for gamma dose measurement that include both mud house (MH) and concrete houses (CH) lying on various altitudes. Gamma rays' dose inside the houses was measured by Gamma

Survey Meter (FAG meter FH40F) from one meter above the ground at the center of the houses. Outdoor dose rates were also measured near those residential houses. At each house (indoor and outdoor), about 100 readings were noted down. Then for each location mean value was calculated which represented the dose rate of that particular area.

Gamma survey meter gives data for the indoor and outdoor exposure rate in mili Roentgen per hour. It was changed to an absorbed dose rate in Nano Gray per hour using the following relation (Erdoğan and Manisa, 2016).

$$1\ \mu R/h = 8.7\ nGy/h.$$

Using calculated absorbed doses, annual effective dose equivalent (yearly dose rate) from gamma radiation and excess Lifetime Cancer Risk (ELCR) was estimated as follow:

$$AEDE_O\ (mSv/y) = \text{outdoor absorbed dose rate } (nGy/h) \times 0.30 \times 8760h \times 0.7 Sv/Gy \quad (1)$$

$$AEDE_I\ (mSv/y) = \text{indoor absorbed dose rate } (nGy/h) \times 0.70 \times 8760h \times 0.7 Sv/Gy \quad (2)$$

$$ELCR = AEDE \times \text{Mean duration life (DF)} \times \text{Risk factor (RF)} \quad (3)$$

Where AEDE is the annual effective dose equivalent, DL is a duration of life (70 years), and RF is the risk factor (per sivert). The value of 0.05 for public exposure was used by ICRP. The occupancy factor, which is rate during which a people exposed to radiation has been taken 30% for outside and 70% for indoor of the house. A conversion coefficient of 0.7 for adults has been used as reported by UNSCEAR (1993), to convert absorbed dose in the air to effective dose in human (UNSCEAR, 2000 (b); UNSCEAR, 2000 (a)). By using these average absorbed dose rates, the average annual effective dose equivalent (AEDE) were computed as 1.0 mSv/y for indoor and 0.4 mSv/y for outdoor.

The indoor and outdoor absorbed dose rate of the selected house and their corresponding effective dose, as well as the excess lifetime cancer risk (ELCR), is given in Table 1:

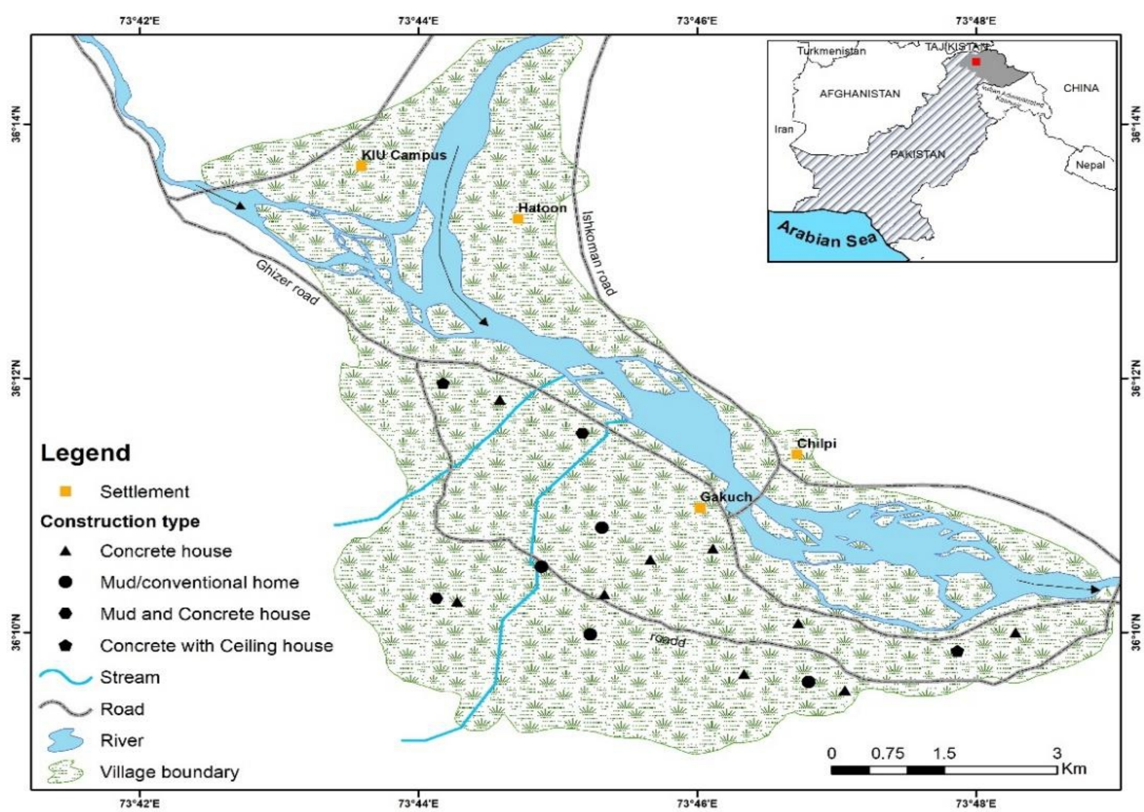


Fig. 1. Map of Study area showing sampling points.

Table 1. Average indoor and outdoor absorbed dose rates and their corresponding Effective dose and ELCR in selected houses of Gahkuch.

| Houses No. | Indoor | | | Outdoor | | | In/out |
|---|---|---|---|---|---|---|---|
| | Absorbed dose rate (nGy/h) | Effective dose rate (mSv/y) | ELCR×1 $0^{-3}$ | Absorbed dose rate (nGy/h) | Effective dose rate (mSv/y) | ELCR×1 $0^{-3}$ | |
| 1 | 212.5 | 0.9 | 3.2 | 269.6 | 0.5 | 1.7 | 0.8 |
| 2 | 301.1 | 1.3 | 4.5 | 194.1 | 0.4 | 1.2 | 1.6 |
| 3 | 198.1 | 0.9 | 3.0 | 194.1 | 0.4 | 1.2 | 1.0 |
| 4 | 231.0 | 1.0 | 3.5 | 255.1 | 0.5 | 1.6 | 0.9 |
| 5 | 255.7 | 1.1 | 3.8 | 255.1 | 0.5 | 1.6 | 1.0 |
| 6 | 261.5 | 1.1 | 3.9 | 255.1 | 0.5 | 1.6 | 1.0 |
| 7 | 292.9 | 1.3 | 4.4 | 210.8 | 0.4 | 1.4 | 1.4 |
| 8 | 270.7 | 1.2 | 4.1 | 193.3 | 0.4 | 1.2 | 1.4 |
| 9 | 172.2 | 0.7 | 2.6 | 203.4 | 0.4 | 1.3 | 0.8 |
| 10 | 240.4 | 1.0 | 3.6 | 192.6 | 0.4 | 1.2 | 1.2 |
| 11 | 187.1 | 0.8 | 2.8 | 243.1 | 0.4 | 1.6 | 0.8 |
| 12 | 190.9 | 0.8 | 2.9 | 251.5 | 0.5 | 1.6 | 0.8 |
| 13 | 247.7 | 1.1 | 3.7 | 189.2 | 0.3 | 1.2 | 1.3 |
| 14 | 212.4 | 0.9 | 3.2 | 195.7 | 0.4 | 1.3 | 1.1 |
| 15 | 165.6 | 0.7 | 2.5 | 207.1 | 0.4 | 1.3 | 0.8 |
| 16 | 204.4 | 0.9 | 3.1 | 194.0 | 0.4 | 1.2 | 1.1 |
| 17 | 195.8 | 0.8 | 2.9 | 176.3 | 0.3 | 1.1 | 1.1 |
| | | | | | | | |
| **Max** | **301.1** | **1.3** | **4.5** | **269.6** | **0.5** | **1.6** | **1.6** |
| **Min** | **165.6** | **0.7** | **2.5** | **189.2** | **0.3** | **1.2** | **0.8** |
| **Average** | **229.3** | **1.0** | **3.4** | **220.6** | **0.4** | **1.4** | **1.1** |

## 3. Results and discussion

Table 1 shows average indoor and outdoor absorbed dose rates and their corresponding Effective Dose and Excess Lifetime Cancer Risk (ELCR) in selected houses of Gahkuch. The average indoor absorbed dose estimated for the study area was 229.3 nGy/h whereas for outdoor its value was 220.6 nGy/h. Both the values are higher than the permissible limits of ICRP, 2003 standard estimation of 113.1 nGy/h. The maximum and minimum absorbed dose rates estimated in the current study were 301.1 nGy/h and 165.6 nGy/h for indoor and for outdoor its maximum and minimum gamma dose rates were 269.6 nGy/h and 189.2 nGy/h respectively. The average annual effective dose equivalent (AEDE) was computed as 1.0 mSv/y for indoor and 0.4 mSv/y for outdoor.

Effective Dose is calculated to find how much damage a particular radiation kind can cause in a biological system. The excess lifetime Cancer risk estimated in this study was 3.4 × 10-3 for indoor and 1.4 × 10-3 for outdoor which is high as compared to the average world value of 0.29× 10-3 (UNSCEAR, 2000; Koray, 2009). The high dose rate in these houses is due to the local material; mud and stone, used for the construction of the houses and the part of the dose received from terrestrial radionuclides that present in the soil. The reason for the high dose rate for open air (outside the houses) is both terrestrial and cosmic contribution. The major terrestrial contribution comes from the naturally occurring radio nuclides 226Ra, 232Th and 40K in the soil. The studies carried out in surrounding geographically similar areas of Gilgit-Baltistan; Hunza and Skardu, have revieled that the concentration of these radio nuclides in the soil is quite high compared to world average. These studies have also shown that absorbed dose rate in Hunza varies between 52.1 and 158.9 nGyh-1 with an average value of 95.4 nGyh-1 whereas for Skardu the rage of absorbed dose is 91.2 to 151.1 nGyh-1 (Ali, 2012; 2010; 2013).

The effective dose rate from cosmic rays has got two components; the dose from directly ionizing and indirectly ionizing (neutron) rays. The cosmic rays' dose depends substantially on the altitude. It meagerly depends upon latitude as well but in the present case the latitudinal variation is not significant, therefore, its impact is negligible.

The annual effective dose from the direct ionizing component is expressed as

$$E1(z)= E1(0)[0.21\exp(-1.649z) +0.79\exp(0.4528z)],$$

where z is altitude in kilo meters, E1(0) is the effective dose rate at Sea level and is taken as 31nGyh-1 (UNSCEAR, 2000; UNSCEAR, 1993). In the current case the average altitude of the study area is 2286 meters asl. So using this model, the dose because of directly ionizing radiations comes out to be 69 nGyh-1.

The effective dose rate from neutrons is expressed as $EN(z) = EN(0) [1.98 \exp(0.698z)]$ Where z is the altitude in Km above sea level and EN(0) is the effective dose rate of neutrons at sea level which is 0.5 nGyh-1 (UNSCEAR, 2000). By inserting the altitude, the calculated contribution to absorbed dose from neutrons is 5nGyh-1. Hence the total cosmic contribution to the absorbed dose becomes 74 nGyh-1. The remaining part of the observed value is 146.6nGyh-1. This value is comparable with the absorbed dose rates recorded at Hunza and Skardu.

Figure 2 shows a comparison of average Indoor Gamma Dose Rate (nGy/h) of some selected countries with the current study. It is evident that the present absorbed dose rate of the study area is 3-4 times higher than those of countries like USA, Greece, Poland, Norway, Spain and Australia but comparable with that of Ardabil, Iran (Hazrati, 2010) represented in figure 2. The reason being the similarity of the geomorphology of Ardabil with that of the study area, the similarity of the construction material and traditional construction design.

As shown in figure 3 houses number 2, 7, 8, 10, 13, 14, 16 and 17 have higher inside radiation dose rate compare to the outside of a house. The difference is due to the materials used for the construction of these houses. It was observed that house number 2, 8, 16 and 17 were made of mud and stone from the surrounding area. House 2 has the highest estimation of the gamma dose rate. The materials used in the construction of this house was local soil and stone, the walls of this house were made up of stone with plaster of soil on it, and its roof was also made up of mud. Whereas house number 7 and 10 were made of concrete. The gamma rays' dose in these houses was also high. The owner revealed that the sand and chippings for the construction were collected from a nearby seasonal creek. This observation is consistent with another study made by the author at Hunza which shows that the alluvial sand and soil deposits in seasonal creeks contain more radioactive material (Parveen, 2018). Gahkuch is a place having higher radiation dose environment.

House number 6, 13 and 14 have similar building material (stone and sand) used, but instead of local soil plaster, cement plaster with sand collected from the river bank was used. So, in these houses, the exposure rate is slightly less than other houses.

On the other hand, house number 1, 3, 4, 5, 6, 7, 9, 11, 12, 13, 14 and 15 are made of concrete. The sand and chippings for these houses were collected from the river bank. Among these houses, house number 15 has the lowest indoor gamma radiation level of 165.6 nGy/h. The walls of this house were covered with wooden panelling.

In terms of effective dose, people in Gahkuch region get an average annual effective dose of 1.0 mSv/y from indoor background radiation and 0.4 mSv/y from open air. Annual effective dose from indoor is greater than 0.48 mSv/y reported by UNSCEAR (2000). The Cancer Risk computed from an effective indoor dose as shown in figure 4 was in the range of 2.5 *10-3-4.5 *10-3 with a mean value of 3.4 *10-3. The acceptable limits of ELCR (excess lifetime cancer risk) set by UNSCEAR (2000) is 0.29 *10 -3, which is very less compared to the current study.

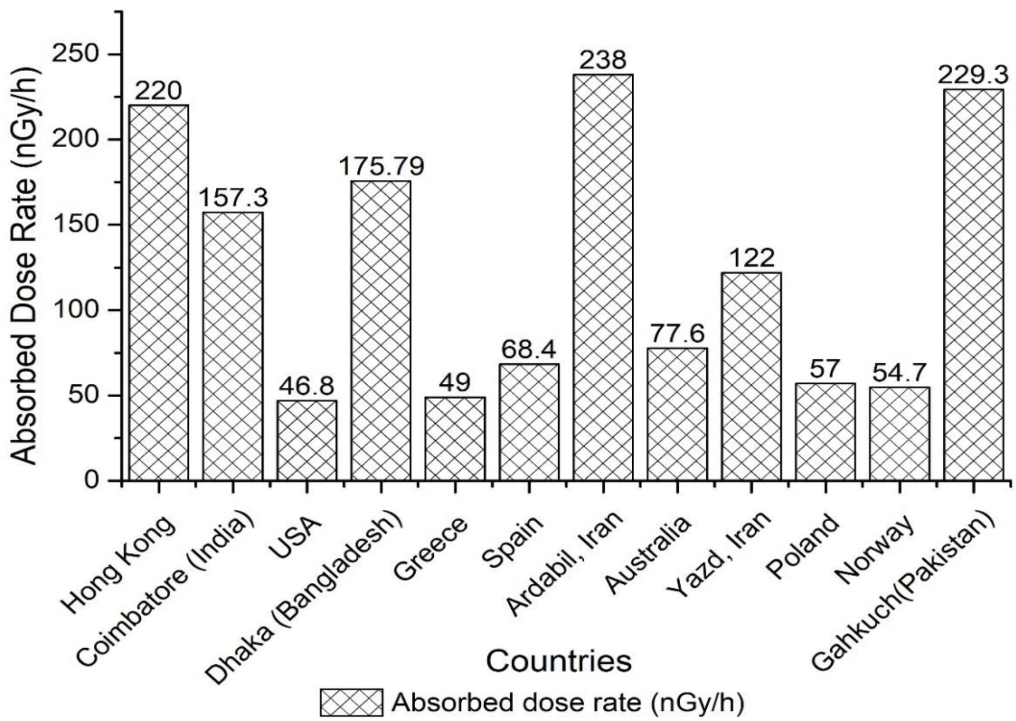


Fig. 2. Comparison of indoor gamma dose rate (nGy/h) between some countries.

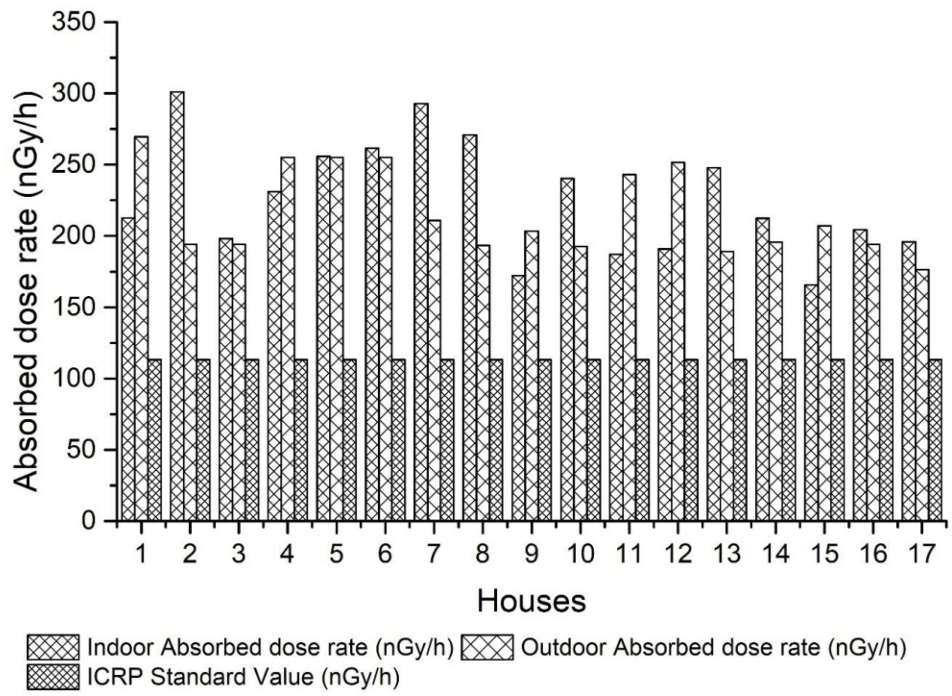


Fig. 3. Comparison of indoor and outdoor gamma absorbed dose rate with a standard value which is recommended by ICRP.

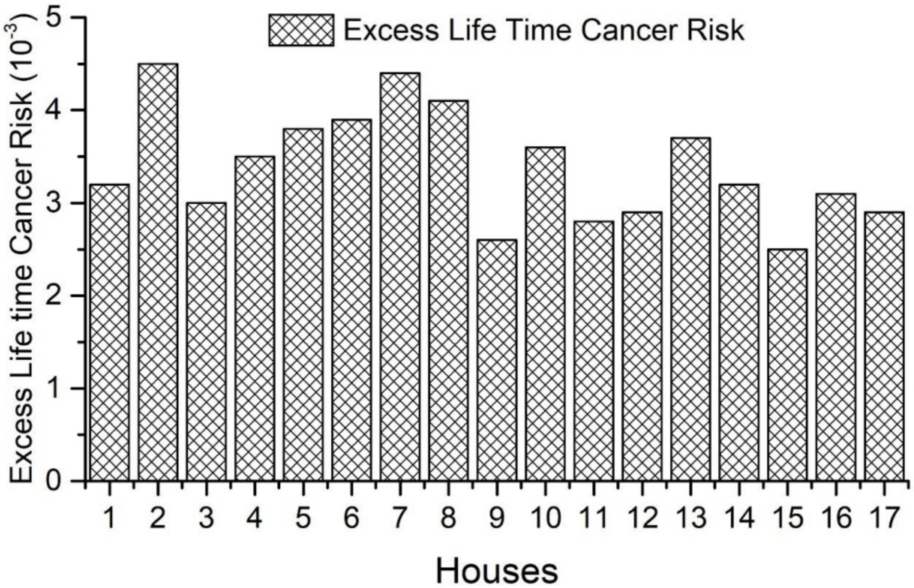


Fig. 4. Excess life time cancer risk in different houses.

## 4. Conclusion

The present study states that the average absorbed dose, average annual effective dose and excess lifetime cancer risk measured in the Gahkuch Ghizer area, exceed the corresponding World average values of 1.0 mSv/y for indoor background radiation and 0.4 mSv/y for open air, 0.48 mSv/y and 0.29 *10 -3 respectively. Local soil, rocks and construction materials from the alluvial deposits contain more radioactive material whereas the sand from the fluvial deposits contains a low concentration of radiation sources.

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***Author's Contribution***

*Manzoor Ali proposed the theme and idea of this project and involved in data collection, data analysis and paper writing. Sher Bono supported the team during data collection. literature review and writin the paper. Muhammad Wasim beign the expert of the field did technical review before submission and proof read the manuscript. Faria Begum was part of the team in field data collection. She was also involved in discussions and organizing the paper. Javed Qureshi and Muhammad Alam were involved in field data collection. They identified the geological settings of study area and contributed the same in the paper. Garee Khan developed the GIS map of the study area which is part of the paper.*

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