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Spatial analysis of radon gas concentration inside homes in Al-Huwaish neighborhood using geographic information systems (GIS), Najaf, Iraq

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Abstract

The indoor radon level was assessed by field measurements and GIS based spatial analysis in Al-Huwaish neighborhood. Results Radon levels were in the interval of 22-100 Bq/m³ (median level 69.23 Bq/m³ which is less than WHO recommended limit: WHO recommends that indoor air radon < 100 Bq/m³). This results in the area usually being within norms for radiation safety. The AED was determined to be in the range of 0.55-2.52 mSv/year with an average mean of 1.74 mSv/yr, and the lung cancer risk (CPPP) was from 10.0 to 45.4 cases per million with an average of 31.3 million cases per million. These values are also significantly smaller than the upper limits established by the International Commission on Radiological Protection (ICRP), so it is clearly seen that this example of low-energy gamma-ray emissions does not represent a public health problem as a whole.

Keywords: Indoor radon, radon concentration, annual effective dose (AED)

1. Introduction

Aside from high levels of indoor ionizing radiation emitted from human-made sources, natural radioactive gases are a worldwide environmental and public health problem because they correlate directly with the risk of lung cancer in humans, particularly indoors (in dwellings) ^[1]. Radon is a colorless, odorless and tasteless noble gas produced by the natural radioactive decay of uranium in soil, rocks and some construction materials. Radon is a gas that moves readily through porous media and becomes trapped in homes or other buildings when it enters through cracks in the floors, walls, foundations and gaps between pipes or cables. Radon can accumulate in confined spaces, and especially with low air flow indoor settings (i.e. homes), to concentrations that are expected to pose a significant chronic health risk for inhabitants of the space ^[2]. Radon exposure is well-documented as an environmental health risk, with a large body of epidemiological literature on radon exposure identifying it as the second-highest definitive cause of lung cancer after smoking. Together with additional environmental and behavioural hazards - for example tobacco consumption and protracted indoor publicity to biomass fuel this risk is worsened. As it is impossible for humans to introduce radon without measurements, this radio element often appears unnoticed as an invisible and high-risk environmental pollutant that must be systematically monitored and evaluated ^[1]. Owing to the human exposure to indoor radon during the last decades, scientists worldwide switched their research towards quantifying not only its concentrations and spatial distribution but also investigating displacement mechanisms and their controlling parameters. Because of the geological formations, soil permeability, uranium content and environmental variables radon values may differ a few meters apart. Similarly other factors such as building design, construction materials, age of buildings and ventilation rates are also important elements which found to be transformed ^[2-3]. Advanced analytical and spatial techniques can thus be utilized to evaluate radon distribution trend and identify risk areas. With GIS being a powerful and integrated platform for many environmental applications, it has documented the spatial variability (and consequent risk) of a wide variety of exposures. GIS: Type of geo-spatial data research which integrate two dimensions of estate (e.g., location and attribute information (point measuring effective radon levels)). In general, GIS has been used in visualizing radon distribution and show by spatial interpolation (ie, surface or hot

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spot mapping thematic maps 4. GIS is also useful in providing inputs based on data, and it is precise to the point that mitigation-related decisions can be made within a certain time period and for environmental planning. Abstract. On one hand, Al-Huwaish district of Najaf city is a rural site that can be developed for such an important source in terms of its radon indoor radiogenic way This area has a very dense residency facts and figures so maybe the differences in geology and soil properties might interfere with indoor radon as well. The risk of inhalation due to radon is universal but national studies in Iraq are mostly vague and do not apply the latest methods such as spatial analysis using GIS. Lack of these data implies that understanding of radon behaviour in dwellings must be carried out so to understand those data which will serve as control data for other studies [4-5-6]. Science reaches into applied sciences in many areas such as spatial and environmental health. It can also determine areas where enforcement might be needed for building specifications or warnings to the public, on indoor-air quality. These efforts will be crucial to the ultimate goal of long-term persistence with disease burden reduction, notably in making urban areas safer (especially sub-Saharan Africa). Given this, the principal scientific objective of this research is examining in-house spatial calculation radon concentration for Al-Huwaish area using GIS. These experiments consist of systematic field measurements of radon, statistical inferences to estimate concentrations and geocartography to produce the continuous surface maps. These maps assist in

identifying the risk zones, geographical area and its response with respect to various determining parameters like building type, soil characteristics and environmental behavior etc. as well defined Areal distribution of understood radar levels will be explained [7].

2. Study area

The study area is Al-Huwaish neighborhood in Najaf city, Iraq: one of the most ancient and densely populated urban districts surrounding the Imam Ali Holy Shrine. The map is outlined in red tassel line clearly depicting the network of an extensive study area which consists of a small densely built residential area with irregular urban frameworks and compact housing units. Located near important landmarks such as Wadi Al-Salam Cemetery to the north, and major streets like Al-Toosi Street and Al-Sadiq Street, give shape not only to accessibility but to urban structure as well. Al-Huwaish is characterized by high population density, type of buildings and materials used in its construction, which may have led to variations in radon accumulation indoors. The neighborhood is mainly formed by residential apartments and it has limited open spaces and narrow streets that can influence the ventilation scenario resulting in pollutant accumulation inside buildings reducing indoor air quality. The locations of sampling points in yellow colors indicated a good coverage of the entire spatial pattern within this neighborhood well and high reliability for estimation on radon concentration in the study area.

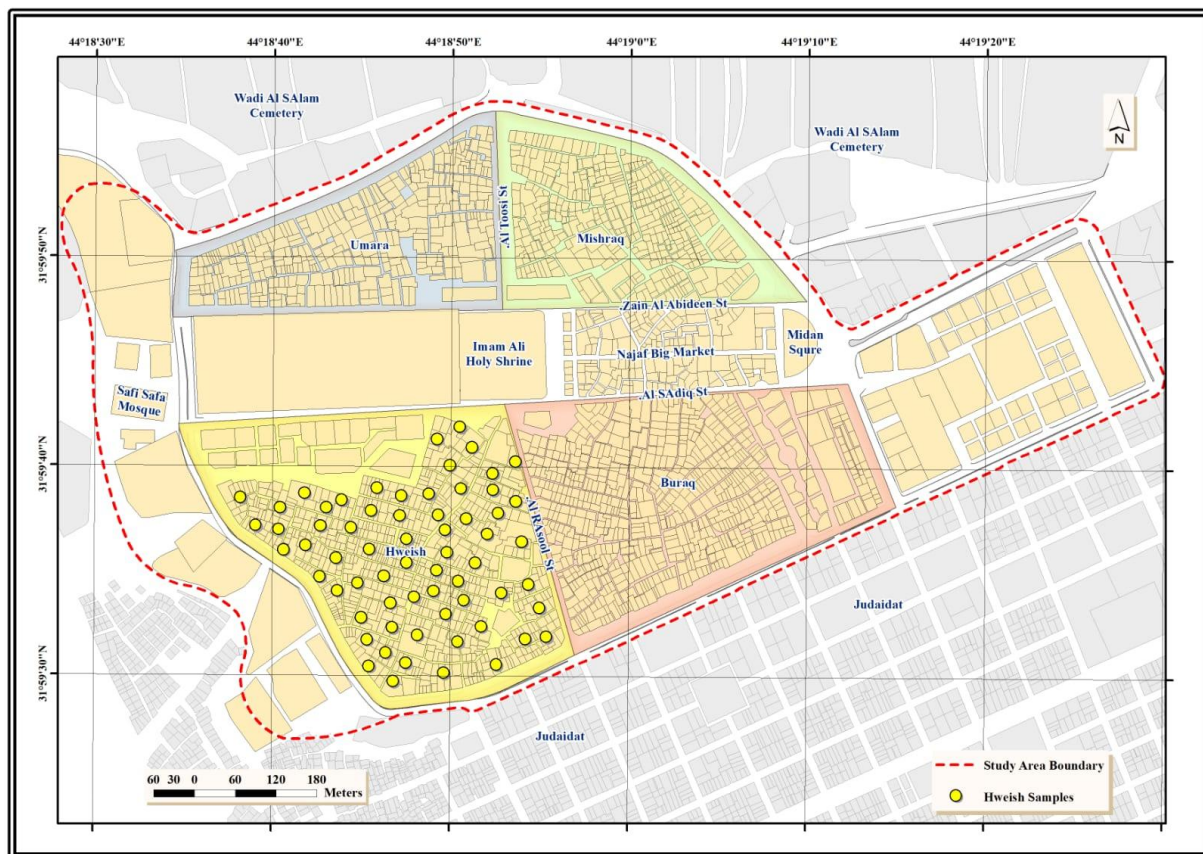


Fig 1: Map of the study area

3. The practical aspect

The actual part of this study was implemented by conducting a field measurements for radon concentrations indoor in 65 residential houses inside Al-Huwaish

neighborhood, Najaf city. A systematic sampling process was followed to ensure spatial distribution of selected houses in the area of study (see Study map). This helps to increase the reliability of the spatial analysis and it makes

sure that the neighborhood is well covered. Radon was measured using a digital radon detector device presented by Airthings, which is well-known and reliable for detecting indoor radon. The device generates near-continuous short and long-term averages in picocuries per liter (pCi/L) and records the data over extended periods of time. The device was placed approximately 1-2 m off the ground with adequate indoor placement (mostly in living rooms or bedroom) of individual household during installation. The device was placed at distance from windows, doors and vents which may interfere with the measurements of their performance exposed to direct sunlight. However, the militarised placement were done in high density populating regions to imitate blood exposure. They had made it through most of the testing period to be trusted. Values for radon were obtained from short-term tests (7 days) conducted in both partial and full/total duration, enabling immediate evaluation of respective radon concentrations that are more representative in actual importance than longer term averages which underwent analyses only for the quantification of sufficiently constant measures closest to actual environmental risk. House location in relationship to GPS (A totalization of a GPS is done when the device collects the radon expressed in picocuries per liter (pCi/L) and this quantity we have converted into becquerels per cubic meter (Bq/m³), which constitutes one internationally recognized SI unit). Consequently, all averaged readings were times by the factor 37 to put them into a Bq/m³ equivalent. This transformation conforms to international recommendations (WHO, IAEA) so that results can be compared with defined safety limits. [8-11].



F2: the Airthings Corentium Digital Radon Detector

3.1. Radon Parameters calculations

3.1.1. The annual effective dose (AED) in the (mSv/yr) unit can be performed as Equation (1) [12]

$$AED = C \times EF \times H \times T \times D \quad (1)$$

where C represents the radon concentration, EF indicates the worldwide average of the EF for radon-222 and its progeny,

which has a value of 0.4. H represents the occupancy factor, valued at 0.8, and T, which equals 8,760, denotes the number of hours per year, while D represents the dose conversion factor for adult age groups and is equal to 9×10^{-6} mSv/(Bq. hr/m³) [13].

3.1.2. The lung cancer cases per year per million person (CPPP) have been determined by applying the formula

$$CPPP = AED \times (18 \times 10^{-6}) \quad (5)$$

4. Results and discussion

The indoor radon concentrations that were obtained from Al-Huwaish neighborhood (Table (1) & Figure (3)) have clearly showed that there was an excellent variation in the suspended concentration of ²²²Rn. Values measured from 22 to 100 Bq/m³ with a mean of 69 Bq/m³. This mean is less than the reference level of 100 Bq/m³ as recommended by World Health Organization (WHO) and proves that radiological safety limits would generally be safe for this area. It was observed that some houses like H59 (100 Bq/m³), H40 (99 Bq/m³) and H33(97 Bq/m³) were close to action level, suggesting localized areas of radon accumulation. Radon measurements in homes seem to be explained by the high content of uranium in the ground, a relatively high permeability of soil types near buildings (end or walls of buildings) and various building related characteristics such as insufficient air ventilation and openings that result from construction (floors / joints). Table (2) and Figure (4) present the AED and lung cancer risk (CPPP) due to radon exposure. AED values has been reported to ranges from 0.55 to 2.52 mSv/year with average AED equals 1.74 mSv/year which is lower than ICRP recommended range of the intervention level on human being which is in the 3-10 cGy/day This means the residents are at levels below drinking water standards. Likewise, CPPP frequencies (cases per million persons per year) exhibited a range of 10.0-45.4 cases/million (mean: 31.3 cases/million) and some worldwide reference values reported in PPB were 130 -230 and >370-400 PPB respectively. This is another direct correlation relationship picture of the radon concentration and AED to CPPP which can easily explained by this post. The lung cancer risk also increases linearly with higher radon levels, over and beyond the annual effective dose. This relationship discovered is consistent with behaviour of the mathematical formulae in this study (compare Tables (1) and (2), and, trends in Figs. 3 and 4. As well as tracks the concentration radon shown in Figure (3) The distribution of radon is inconsistent in the studied area. This difference is explained by the location and type of soil, which contains radium as well as building materials used for construction or age and other living conditions during their life. In contrast to properly ventilated homes, higher concentrations is seen in poorly ventilated residences. Overall, this indicates a safe level of radon exposure in Al-Huwaish neighbourhood. Those at most other localities, while fairly high should continue to advocate for ongoing home based monitoring and mitigation actions (e.g. enhancing indoor ventilation capacity). The consequence is crucial as the description of numerical enforceable shown in table (1)(2) with pictorial interpretation seen in Figure (3)(4) creates a complete radon distribution and support [20-14].

Table 1: Radon concentration results for houses in Al-Huwaish neighborhood in the old city of Najaf

No.	House Code	Radon (Bq/m ³)
1	H1	32
2	H2	45
3	H3	58
4	H4	27
5	H5	65
6	H6	72
7	H7	60
8	H8	50
9	H9	85
10	H10	22
11	H11	95
12	H12	55
13	H13	70
14	H14	30
15	H15	88
16	H16	48
17	H17	52
18	H18	68
19	H19	61
20	H20	90
21	H21	47
22	H22	29
23	H23	73
24	H24	62
25	H25	80
26	H26	92
27	H27	85
28	H28	57
29	H29	40
30	H30	46
31	H31	75
32	H32	89
33	H33	97
34	H34	54
35	H35	44
36	H36	67
37	H37	82
38	H38	88
39	H39	95
40	H40	99
41	H41	53
42	H42	61
43	H43	70
44	H44	76
45	H45	84
46	H46	91
47	H47	87
48	H48	63
49	H49	56
50	H50	38
51	H51	47
52	H52	59
53	H53	73
54	H54	84
55	H55	90
56	H56	94
57	H57	96
58	H58	98
59	H59	100
60	H60	92
61	H61	88
62	H62	85
63	H63	80
64	H64	75
65	H65	70
Average	69.0 Bq/m	
WHO	100	

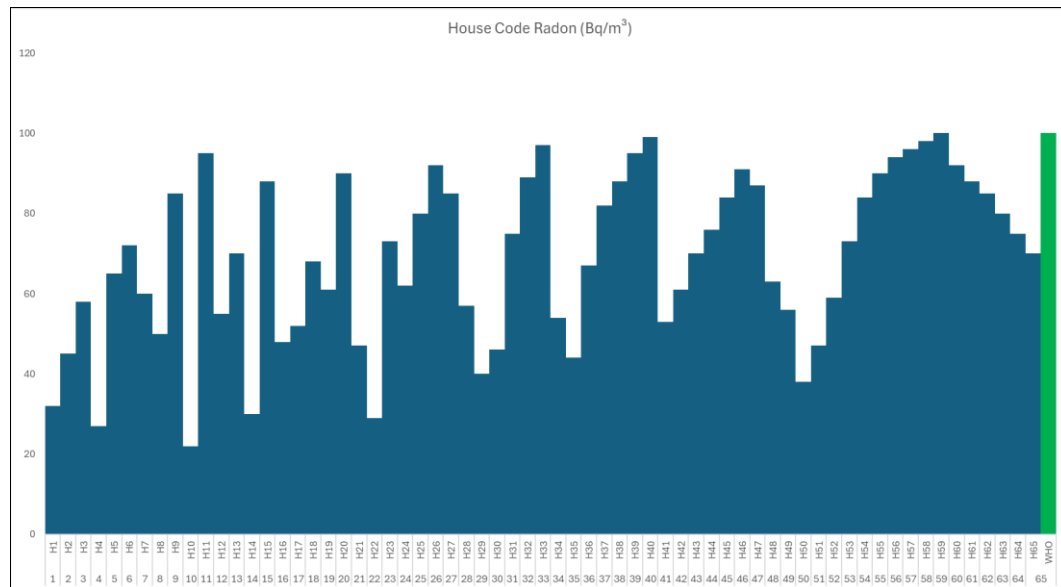


Fig 3: Comparison Radon concentration results for houses in Al-Huwaish neighborhood in the old city of Najaf BY W

Table 2: Radon concentration results for houses in Al-Huwaish neighborhood in the old city of Najaf

No.	House Code	AED (mSv/y)	CPPP (cases/million)
1	H1	0.81	14.6
2	H2	1.14	20.5
3	H3	1.46	26.3
4	H4	0.68	12.2
5	H5	1.64	29.5
6	H6	1.82	32.8
7	H7	1.51	27.2
8	H8	1.26	22.7
9	H9	2.15	38.7
10	H10	0.55	10.0
11	H11	2.40	43.2
12	H12	1.39	25.0
13	H13	1.77	31.8
14	H14	0.76	13.7
15	H15	2.22	40.0
16	H16	1.21	21.8
17	H17	1.31	23.6
18	H18	1.72	31.0
19	H19	1.54	27.7
20	H20	2.27	40.9
21	H21	1.19	21.4
22	H22	0.73	13.1
23	H23	1.84	33.1
24	H24	1.56	28.1
25	H25	2.02	36.4
26	H26	2.32	41.8
27	H27	2.15	38.7
28	H28	1.44	25.9
29	H29	1.01	18.2
30	H30	1.16	20.9
31	H31	1.89	34.0
32	H32	2.25	40.5
33	H33	2.45	44.1
34	H34	1.36	24.5
35	H35	1.11	20.0
36	H36	1.69	30.4
37	H37	2.07	37.3
38	H38	2.22	40.0
39	H39	2.40	43.2
40	H40	2.50	45.0
41	H41	1.34	24.1
42	H42	1.54	27.7
43	H43	1.77	31.8

44	H44	1.92	34.6
45	H45	2.12	38.2
46	H46	2.30	41.4
47	H47	2.19	39.4
48	H48	1.59	28.6
49	H49	1.41	25.4
50	H50	0.96	17.3
51	H51	1.19	21.4
52	H52	1.49	26.8
53	H53	1.84	33.1
54	H54	2.12	38.2
55	H55	2.27	40.9
56	H56	2.37	42.7
57	H57	2.42	43.6
58	H58	2.47	44.5
59	H59	2.52	45.4
60	H60	2.32	41.8
61	H61	2.22	40.0
62	H62	2.15	38.7
63	H63	2.02	36.4
64	H64	1.89	34.0
65	H65	1.77	31.8
Average		1.74mSv/year	31.3cases per million
ICRP 1993 limit		(3-10) mSv/year	(170-230) per year per million person

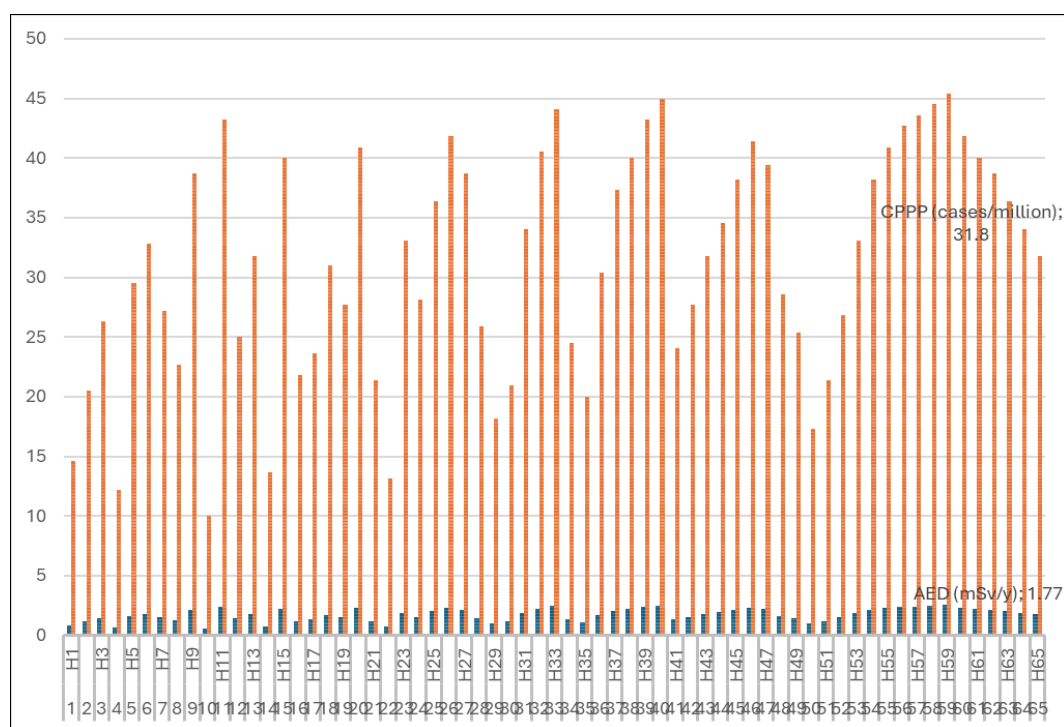


Fig 4: Comparison AED (mSv/y), CPPP (cases/million) results for houses in Al-Huwaish neighborhood in the old city of Najaf BY ICRP

5. Conclusion

All computed indicators (radon concentration, AED and CPPP) are below the international safe thresholds verifying that indoor radon levels in Al-Huwaish neighborhood does not constitute an immediate radiological risk; nevertheless GIS-based analysis is also necessary for appropriate detection and identification of radon-prone areas consequently serves as a great tool for environmental risk assessment and local public health policy solution.

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