Applied Physics Research; Vol. 8, No. 6; 2016
ISSN 1916-9639 E-ISSN 1916-9647
Published by Canadian Center of Science and Education

Awareness of Radon-222 and its Health Hazards in Jordan

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Received: September 17, 2016 Accepted: September 26, 2016 Online Published: November 22, 2016

doi:10.5539/apr.v8n6p31 URL: http://dx.doi.org/10.5539/apr.v8n6p31

Abstract

Many studies addressed radon (Rn^{222}) gas concentration levels in a number of locations in Jordan. But, none investigated the level of awareness of Jordanians of radon and its harmful effects on public health. In this study, a sample of 200 participants has been tested for their knowledge of radon and its effects on human health. The authors estimated that 63.1% are unaware of this gas and its respective effects on their health

Keywords: radon, Jordan, health hazard, radioactivity, dosimetry

1. Introduction

Radon is a noble gas that is both colourless and odourless. It is created from the decay of radioactive uranium (U^{238}) found in the soil and rock. Like uranium, radon is radioactive. The resulting radiation is a kind of energy that, when exposed to, can cause lung cancer. Radon is found everywhere, but with different concentration levels, and when this gas is released from the ground into air, it is diluted and thus does not cause any problem. However, in enclosed spaces, the gas could reach high concentration levels and become hazardous, causing lung cancer (Krewski, 2005; Zeeb, 2009).

Jordan is endowed with uranium deposits found in phosphate rock being processed into fertilizer (Ragheb, 2010). In its decay to Lead (Pb^{206}), uranium generates radon which is a moderately short-lived element with a life-span of approximately 3.825 days. Henceforth, phosphate mines located in highly populated areas (e.g. Al-Ruseifa town, a suburb of Zarka city) is the main threat to public health of those living in the mine's proximity. Additionally, there exist other sources of natural and industrial radioactivity scattered throughout Jordan. Recently (July, 2016), the Jordanian Energy and Minerals Regulatory Commission (EMRC)[1] endorsed a map showing radiation levels in Jordan, created from hundreds of soil samples. The map does not however, reflect levels of radioactivity originating from radon gas in particular.

In a third world country, like Jordan, the social and economic impacts of diagnosing and treating lung cancer is high. Therefore, it is important to accumulate a level of awareness of radon and its respective health effects. Education on this issue has proven that once awareness on the subject is established, people are more likely to take precautions in prevention and control activity, which plays a key role in protecting public health against radon hazards.

Although a considerable size of data has been recorded and analysed on radon concentration in Jordan (Appendix A), yet the government took no initiatives to raise public awareness nor did the education system was improved to contain information on radon. Accordingly, we believe that the level of awareness of Jordanians on this subject is quite poor, which is our hypothesis.

In this paper, we measure the level of awareness on radon and its effects for a group of university students in an area of the highest radon concentration in Jordan.

2. Background

The average measured concentration level of radon in dwellings in Jordan is 56.7 $Bq.m^{-3}$ (Abumurad, 1997), which is way below the recommended action level of the International Commission of Radiological Protection (ICRP). However, measurements conducted by a number of Jordanian researchers have revealed significant variations around this average value, exceeding in some places the ICRP action level. We have carried out a survey of all accessible measurement results of natural radon concentration levels performed in Jordan and summarized them in a table in Appendix A. Our criteria in compiling this survey is finding the minimum and maximum values (usually localized) together with mean values calculated by the researchers themselves. The main goal of this survey is to identify regions in Jordan with radon concentrations above the ICRP action level. The table shows locations where detectors have been placed, ranges of measurement results, calculated mean values, time duration, material monitored (soil, water, or air), and any additional comments. A dash symbol is used to indicate missing data.

Furthermore, we have grouped locations into three regions[2]: northern, middle and southern regions. In the northern region, radon concentration levels have been measured at nine locations (cities or towns): Soum region (Abumurad, 2005), Irbid city (Al-Kofahi, 1992), Malka town (Al-Zubaidy, 2012b), Hakama town (Al-Zubaidy, 2012a), Ajloun city (Abumurad, 1997), Ajloun district (Al-Khateeb, 2012), Jerash city including the historical part (Alzoubi, 2013), Jerash city (Abumurad, 1997) and the northern part of the Jordan Valley (Kullab, 2005). In this region, the minimum indoors, measured mean value of radon concentration levels in air was 16.21 $Bq.m^{-3}$ in the northern Jordan Valley, and the maximum recorded reading was 911.4 $Bq.m^{-3}$ in Soum region. In soil-air, the minimum mean value was 1.53 $kBq.m^{-3}$ measured in Malka town, and the maximum was 6.9 $kBq.m^{-3}$ in Soum region.

Measurements in the middle region of Jordan have been performed at the following locations: As-Salt suburbs (Ya'qoub, 2009), As-Salt city (Abumurad, 1997), Mafraq city (Abumurad, 1997) (Al-Zubaidy, 2012), Amman (Abumurad, 1997), Zarka city (Kullab, 2005) (Elzain, 2011), Al-Ruseifa (Kullab, 2005) (Kullab, 2001), Madaba city (Abumurad, 1997) and Dead Sea (Al-Taj, 2004) (Al-Bataina, 2005) (Akawwi, 2014). In this part, the minimum mean value for radon concentration in air was measured to be 27.25 $Bq.m^{-3}$ in Zarka city, and the maximum was 386 $Bq.m^{-3}$ in Al-Ruseifa suburb of Zarka city. In deserted mines of Al-Ruseifa, concentration levels reach much higher values. Soil minimum concentration levels recorded in spring season in Al-Ruseifa phosphate mines was 0.2 $kBq.m^{-3}$, and the maximum value was 44.31 $kBq.m^{-3}$ in the Eastern Jordan Rift (Dead Sea).

We grouped a number of locations into the southern region, and found that measurements have taken at the following locations: Karak city (Abumurad, 1997), Tafila city and suburbs (Abumurad, 1997; Abu-Haija, 2010; (Salameh, 2011), Ma'an city (Abumurad, 1997), and Aqaba city (Abumurad, 1997). We include in this region the study conducted on radon concentration levels in water throughout Jordan (Al-Bataina, 1997). In this region, the minimum mean value for radon concentration levels was measured to be 26.28 $Bq.m^{-3}$ in Tafila city, and the maximum was 99.68 $Bq.m^{-3}$ in Karak city. The mean value of radon concentration in water of various resources was calculated to be 4.5 $kBq.m^{-3}$.

According to the survey (Appendix A), the highest mean value was calculated in Al-Ruseifa (386.2 $Bq.m^{-3}$). Moreover, there are four localized values: 501, 212, 556, and 440 $Bq.m^{-3}$ recorded in As-Salt, Madaba, Karak and Ma'an respectively. Our main concern henceforth is whether or not dwellers at these locations are aware of radon gas and its respective health hazards. To answer this question, we designed a tool and an experiment to test the level of awareness of radon and its effects among a set of participants who come from many regions of Jordan including Al-Ruseifa town.

This work ultimately contributes to establishing a quantitative estimate of the level of public awareness relevant to radon, presents a survey of previous work on radon data in Jordan, and identifies factors leading to lacking information among the Jordanian public of radon and its respective effects.

3. Method

Justified by the absence of content on the radioactive nature of radon in the Jordanian science curriculum[3], poor government and media performance on raising public awareness in Jordan have led us to assume that Jordanians have in general poor knowledge about radon and its respective health effects. To test this hypothesis, we have designed an experiment whereby a sample of participants has been surveyed for their knowledge about radon, using a questionnaire prepared for this purpose.

The questionnaire consists of three sections measuring participants' knowledge of (i) radon; (ii) its respective hazards; and (iii) prevention control. Questions 1-3 and 17 tests whether participants have any previous, basic knowledge about the gas itself. Question 17 is equivalent to Question 2 for testing reliability of participants' responses. The second section is comprised of six questions (4-9) that test participants' information on dangers caused by high levels of radon concentration. The third section has seven questions (10-16) and addresses prevention control against radon hazards. The questionnaire has been improved over a period of two years, through experts' feedback and trial runs on groups of freshman university students. Furthermore, we have carefully paraphrased questions such that participants have no hint of what radon might be. Once matured enough, the questionnaire has been used in hypothesis testing.

The sample selected for this experiment is random and comprised two hundred university freshman students from Zarka University College (ZUC); one of Al-Balqa Applied University colleges. ZUC is located in Zarka city adjacent to Al-Rusiefa town; the main location of phosphate deposits in Jordan. It is a densely populated area with mines scattered throughout the town. The majority of ZUC students come from the capital Amman, Zarka city and Al-Rusiefa. The rest come from nearby cities such as Mafraq, Jerash and Madaba. In our opinion, the sample is representative of the Jordanian society because: (i) a considerable percentage comes from an area of high radon concentration levels, (ii) participants are freshman students whose test results are indicative of their knowledge acquired from school education, and (iii) representative of Jordanians of that age who do not pursue higher education in fields related to the topic of this study. Table 1 shows percentages of participants of the sample for each city.

The experiment has been run by randomly choosing groups of freshman students from a number of lecture rooms. Before the experiment started, we have taken measures to improve the reliability of the results by instructing participants to turn off their laptops and/or mobile devices to prevent any searches on the Internet. Moreover, participants have no previous knowledge of trial runs of the experiment conducted while finalizing the questionnaire.

Table 1. Participants vs. city

Region (city)	Percentage of participants
Amman	38.24
Zarka	34.13
Al-Ruseifa	11.76
Mafraq	11.76
As-Salt	1.76
Madaba	1.18
Jerash	1.18

4. Discussion

The key goal of this study is to determine whether city dwellers in areas of high radon concentration are aware of radon and its harmful effects. An experiment on a group of ZUC, freshman students has been conducted using a questionnaire designed for this purpose. ZUC is a competitive university college of Al-Balqa Applied University (BAU), whose students come from many regions of Jordan, including regions known of their high concentration levels of radon. A group of two hundred participants were involved in this study, aging between 18 and 32 years old, and coming from many regions of the country, most of them were from the capital Amman, Zarka city and Al-Ruseifa town. The later is known for its highest mean value of radon concentration level. A set of 200 questionnaires have been distributed to the targeted group on their first day at ZUC and 188 have been collected at the end of a 30 minutes session. Participants had no Internet connection and they were instructed to keep their mobile devices turned off. Collected questionnaires have been carefully checked to exclude incomplete or outlier questionnaires. Data of the remaining questionnaires has been collected, marked and analysed; and represented diagrammatically to show percentages of correct (positive) and wrong (negative) answers per question. Figure 1 depicts the analysis result.

Figure 1 shows that 59.2% of the participants do not know the basic physical properties of radon (Question 1), 67% have no idea of radon natural sources (Question 2), 74.3% do not know how radon is created (Question 3), and 64.3% lack information on where radon can be found (Question 17). Notice that questions 2 and 17 are equivalent but paraphrased differently as a measure of reliability, which has confirmed nearly the same result. The overall result of questions 1-3 and 17 indicated that participants lack basic information on radon gas. Therefore, it is highly likely that their answers on dangers of radon will mostly be negative.

The second section of the questionnaire consists of questions 4-9. The range of percentages of negative answers for questions 4-7 is 43% to 51.4%, which is relatively lower than expected. In particular, 51.4% do not know which organ of the body can be damaged by radon (Question 4), 49.7% do not know which disease is caused by radon (Question 5), 49.2% have no idea where a person can get exposed to radon (Question 6), and 43% negative answers on who is most likely to be harmed by radon. We believe that participants have studied carefully their answers for these questions and found that they can choose among the worst provided choices: lungs, lung cancer, miners, and the elderly respectively. Henceforth, explaining lower than expected negative percentages. However, when it comes to answering questions on places of high radon concentration levels and how radon enters dwellings, 91.6% and 77.1% failed to answer questions 8 and 9 respectively; henceforth, confirming results of the questionnaire's section 1.

The third section (questions 10-16) on prevention control has received high percentages of negative answers ranging from 31.2% to 85.5%. The upper limit was on Question 13 which is on methods of testing radon concentration levels and the lower limit was for Question 10 which is about prevention control. The remaining questions address a number of topics, including: regions of high radon concentration (Question 11) with 64.8% of negative answers, dwelling rooms of highest radon concentration (Question 12) with negative answers of 79.9%, locations in dwellings suitable for placing radon detection devices (Question 14) with 60.9% negative answers, which room in multi-story buildings is most probable to be exposed to radon (Question 15) with 56.4% negative answers, and the relation between smoking and radon (Question 16) with 59.2% of negative answers.

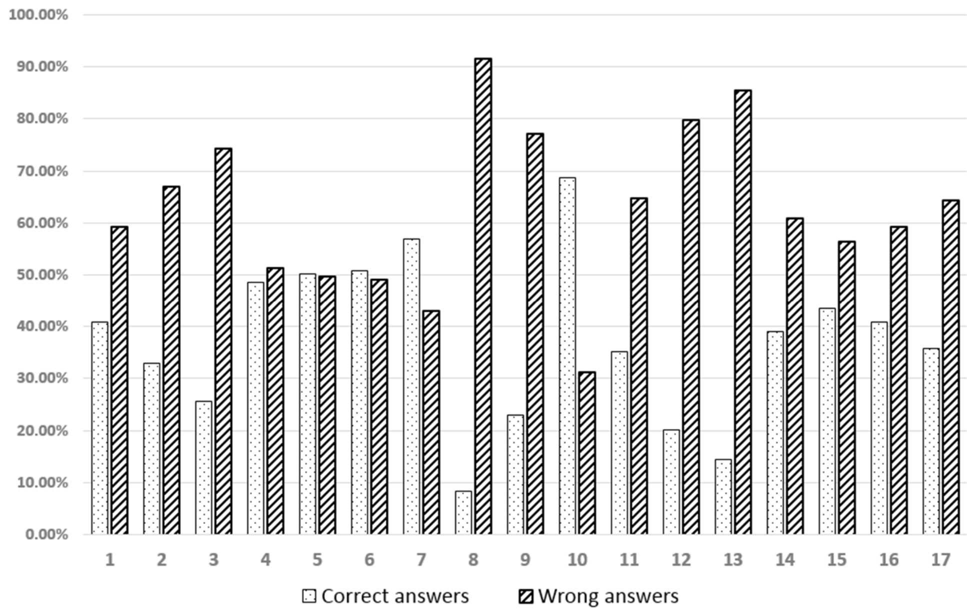

Figure 1. Data analysis result showing negative and positive answers per each question

Table 2. Percentage values of negative answers on section 1 of the questionnaire.

City	Percentage (%)	Percentage of negative answers to		
		Question 1	Question 2	Question 3
Amman	38.24	64.62	67.69	70.77
Zarka	34.13	46	62.07	74.14
Al-Ruseifa	1.761	60.0	55.0	65.0
Mafraq	11.76	65.0	70.0	90.0
As-Salt	1.76	0	100.0	100.0
Madaba	1.18	100.0	100.0	100.0
Jerash	1.18	50.0	100.0	50.0

The mean values of negative answers for every section of the questionnaire are 66.4% on basic knowledge on radon, 60.3% on radon hazardous effects, and 62.6% on prevention control. These figures lead to a mean value of 63.1% of the participants lacking information relevant to radon; which is considerably high.

Participants come from many regions of Jordan, including cities and towns of the highest radon concentration levels: Al-Ruseifa town in Zarka district, Mafraq city, As-Salt (Al-Balqa district) and Madaba city. Therefore, our next concern is to find out the level of basic knowledge on radon for participants coming from these areas. Table 2 shows cities, and percentages of negative answers for questions 1-3 (Question 17 has been excluded) against cities. Results show negative answers in the range of 55% to 100% (ignoring 0% for Question 1 of As-Salt). These results confirm low level of knowledge on radon regardless of participants' living cities and towns.

Clearly, the overall result on all sections of the questionnaire is considerably low. These results can be attributed to many factors. Firstly, the Jordanian science curriculum for the secondary school lacks any content on radon physical properties, especially its radioactive nature. In Jordan, the science curriculum is the main source of science knowledge for school students, and lacking a critical content on a given important topic will lead low or no knowledge on that topic. Secondly, there are no government initiatives to inform the public of hazards originating from radon natural sources and its devastating effects on human health. Recently however, EMRC has compiled a map showing radiation levels in Jordan. But, the map does not reflect information on radioactivity originating from radon nor does it show its locations. Thirdly, Jordanian media does not address this issue, perhaps because of other more important priorities. We believe these factors together have resulted in low public awareness level of radon and its respective health hazards.

5. Conclusions

There is an evident lack of knowledge on radon and its health hazards in Jordan. With a high percentage of participants not knowing what radon gas is, its hazards or prevention control, it is clear that the educational system, government initiatives, and Jordanian media are rather performing poorly on the topic and henceforth, an immediate reassessment is needed. An overall estimate of the level of awareness on radon information among Jordanians is 63.1%, which is quite low.

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Notes

Note 1. http://www.emrc.gov.jo/index.php/en/

Note 2. Not necessarily relating to official districts of Jordan.

Note 3. Science textbooks of the last three school years (secondary level) of the scientific stream have been scanned for information on radon in particular and its health hazarad.

Appendix A

Survey of radon concentration levels recorded in Jordan by Jordanian researchers.

Region	Location	Range ($Bq.m^{-3}$)	Mean value ($Bq.m^{-3}$)	Season	Measured material	Comment
North	Soum region [3]	22.2 in Spring - **911.4** in Winter 4k in Spring - 21k in Fall	144 air 6.9k soil	Autumn and Winter and Spring	Dwellings Soil	indoors and passive monitor High in Fall and lowest in Winter
	Irbid district[8]	3.09 - 163.93	33.28	Summer	Dwellings	indoors and passive monitor
	Malka Irbid[12]	30±18.2 - 62 ±27.7	45.9	Fall	Dwellings	indoors and passive monitor
		0.8 ±0.1k - 2.9±0.2k	1.53± 0.4k	Fall	Soil	outdoors
	Hakama city [11]	25.7 - 30.2	27	Summer	Dwellings	indoors and passive monitor
	Jordan Valley (North) [16]	8 - 41	16.21	Autumn	Dwellings	-
	Ajloun city[2]	12 - 160	40.08	Autumn	Dwellings	indoors and passive monitor
	Ajloun district[7]	33.9 ±6.4 - 45.7 ±6.7	36.3 ±2.3	Summer	Dwellings	indoors and passive monitor
		2.08 ±0.12k - 3.62±0.13k	2.55 ±0.2k		Soil	outdoors
	Jerash [2]	24 - 116	48.64	Autumn	Dwellings	indoors and passive monitor
	Jerash [13]	8.39 - 95.24	49.21	-	Dwellings	indoors and passive monitor
		0.43k – 4.55k	2.29k	-	Soil	outdoors
Middle	As-Salt district [20]	31 - **501**	111 ±4	Spring	Dwellings	indoors and passive monitor
	As-Salt [2]	24 – 128	46.08	Autumn	Dwellings	indoors and passive monitor
	Mafraq [2]	28 – 80	50.64	Autumn	Dwellings	indoors and passive monitor
	Mafraq city [10]	40.4 ±13.5 - 60.1 ±24.4	49 ±17.4	Winter	Dwellings	indoors and passive monitor
		0.1 ± 0.1k - 3.0 ± 0.3k	1.4 ± 0.5k - 1.7 ± 0.8k		Soil	outdoors
	Amman [2]	20 - 84	39.52	Autumn	Dwellings	indoors and passive monitor
	Zarka [14]	6.9 - 113.1	31.66	all seasons	Shops	indoors and passive monitor
	Zarka [16]	12 - 56	27.25	Autum	Dwellings	-
	Al-Ruseifa [17]	46.3 in Fall to 1532.9 in Winter 4 in Summer to 892 Fall 0.2k in Spring to 37.8k in Fall	**386.2** the highest mean value for Winter	- - -	Dwellings Dwellings Soil	indoors and passive monitor indoors and active monitor outdoors
	Jordan valley Dead Sea Fault [9]	5k Southern- 40k Northern	-	Summer	Soil	outdoors and passive monitor
	Dead Sea Wadi Araba[5]	0.4 ±0:06k - 1.8 ±0.07k	-	Summer	Soil and rock	outdoors and passive monitor
	Eastern Jordan Rift [4]	0.28 ±1.5k - 44.31±3.2 k	6.2± 2.5k	Summer	Ground water	outdoors and active monitor
	Madaba [2]	28 - **212**	92.64	Autumn	Dwellings	indoors and passive monitor
South	Karak [2]	24 - **556**	99.68	Autumn	Dwellings	indoors and passive monitor
	Tafila [2]	24 - 180	47.28	Autumn	Dwellings	indoors and passive monitor
	Tafila [1]	20.45 - 32.41	26.28	Winter	Dwellings	indoors and passive monitor
	Tafila region [19]	11.30 - 49.09	27.57	Fall	Dwellings	indoors and passive monitor
	Tafila city [19]	9.95 - 68.15	28.77±3.99k	Fall	Dwellings	indoors
	Ma'an [2]	40 - **440**	96.48	Autumn	Dwellings	indoors and passive monitor
	Aqaba [2]	12 - 64	29.36	Autumn	Dwellings	indoors and passive monitor
	Water in Jordan [6]	3.7k – 5.4k	4.5 ±0.9k	-	Different natural water	outdoors and passive monitor