

Deleterious Impacts Cost for Radon-222 Presence in a Number of Wells in the North Hilla City on Population Health

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Abstract

Radon-222 is a radioactive gas, with half life of 3.82 day, it is one of the twenty five highly radioactive isotopes. It is found in the decay of radium 226 which is also radioactive decay product of uranium 238. It emits alpha particles during its decay which cause harmful effects if it is hacked inside a body due to gamma ray. The long term exposure increases the risk of developing several dangerous diseases, like cancer. The high pollution rates could make any location contains it unsuitable for living. Therefore, it's important to measure the pollution rates in (10) wells with depth of (8-32 m) in the North Hilla by using a suitable technique like the " close cycle units" from among several techniques available options in order to evaluate the deleterious Impacts of radon on human health and treatment costs that must be taken in consideration to mitigation the concentration of Radon to make these sites suitable for living. The research study measures the cost of deleterious and treatment cost from the view of Environmental Accounting. The results are carried out with assistance of environmental specialist team who work in the environment Hilla office, and all the images adopted have been taken by PC a computer. The results show that eight wells out of ten have a high concentration of Radon. The well No.6 has a higher concentration total cost of treatment and mitigation than others. The highest concentrations of Radon caused a deleterious impacts on the health of population in the North Hilla City, it is a main cause for lung and inhalant cancer, with rates more than acceptable by EPA, that means it must adopt a treatment program to mitigate the Radon in the Wells .

Keywords: Deleterious Cost, Treatment cost, Radon 222, Environment Accounting, Alpha guard.

1. Introduction

While there is already considerable experience with Environmental Accounting, but water quality and emission accounts are still at a beginning phase. Although the system of Environmental-Economic Accounting (SEEA)-Water [SEEA 2012] [Daniela,R.,2013] guide is a key methodological related accounting for water, but it does not explain emission accounts more depth. Emissions and dissolved radioactive gas into water constitute a major environmental problem and cause the quality of water to deteriorate [EPA,2014], Some pollutants are dangerous and have a negative effects, such as the Radon-222, because it's a product from uranium , so it is a radioactive emittance. Radon-222 is a radioactive gas, with half life of 3.82 day and mass number 222, it is one of the twenty five highly radioactive isotopes. It is found in the decay of radium 226 which is also radioactive decay product of uranium 238. It emits alpha particles during its decay, Radon is unstable and releases energy by emitting alpha particles. The primary source of exposure to radon is from the soil beneath house, where it enters through cracks or openings in structures and concentrates in indoor air. The chemical properties of radon 222 are similar to barium element ,its density is 9.73gm/cm3 at 293K with cubic crystal structure. It has six levels of energy[US. PHS,1990] [Facts about Radon,2008] [Radon, All Measures,2008], Radon is also soluble in water and is often found in the ground water. When radon decays, it forms decay products which emit alpha particles, beta particles, and gamma rays. The characteristics of the Ra-226 chain show that 10 alpha disintegration and 9 beta disintegration down to Pb-206 with half-lives between some years and some fraction of a second. The measurements of natural radioactivity in soil have been performed by the (ATSDR) [ATSDR,1990,1999,2000] .The natural radionuclides present in soil are including Ra^{226} , Th^{232} , and K^{40} [NRC,1999][Reid, J.M,1986]. Gamma radiation emitted from these is naturally occurring radioisotopes called terrestrial background radiation which represents the main source of irradiation of the human body and contributes to the total absorbed dose via ingestion, inhalation and external irradiation. The calculations suggested by Qindos, L.S., and others that 50-80% of the total gamma flux at the earths surface arises from K^{40}, U^{238} ,and Th^{232} series in topsoil [Qindos,L.S.,et al,1994,2004]. Gamma ray background intensity depends on the geological and geographical and appears in many levels in soils. knowing gamma ray distribution in soils plays an important role in the protection from radiation [Rudge, S.A ,et al,1193]. Radon gas can be found in the soil because of the decay from the parent element uranium. Radon can also migrate from soil into groundwater, which can become another route of exposure if the groundwater is used as a water supply source. Radionuclide are undetectable by the human senses, so only analytical testing can determine if they are present in water. Because they are associated with rock, wells drilled into bedrock are more likely to contain elevated levels of radionuclide than shallow or dug wells. The studies of radiation levels and radionuclide distribution provide an information which is essential for understanding the human exposure to natural and man made sources of radiation [Casarett and Doull's, 2004].

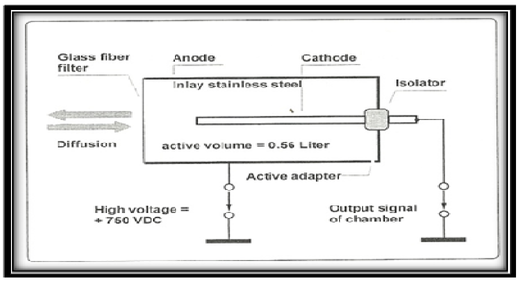
Because of the risks of radon-222 which is a human carcinogen, and it is dangerous and effects on population health because of the lack of regulating radon-222 in the drinking water in the North Hilla City, therefore , there is a need to cover this subject , and measure the pollution rates in (10) wells with depth of (8-32 m) by using a suitable technique like the " close cycle units" from among several techniques of available options, in order to evaluate the deleterious impacts of radon on region population, and calculate the treatment costs that must be taken in consideration to mitigate the concentration of Radon to make these sites suitable for living, through adopting a MCL to decrease the number of cancer- related deaths which are caused by inhalation and ingestion of radon from drinking water.

2. Materials and methods for measuring Radon concentration

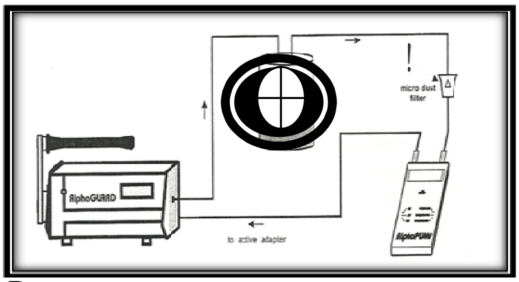
Many different techniques have been used to measure the Radon activity and concentrations[Jelle, B.P,2012][Martin S.,2013][Vasilyev, A.V, and Zhukovsky,, M.V .,2013]. The technique which is used for measuring Radon activity in this research is "portable radon monitor-Alpha guard ". According to its specification and application, the radon detector is based on a design optimized pulse ionization chamber. In regular operation the measuring gas gets in diffusion mode via large surface glass fiber into the ionization chamber , through the glass fiber filter the radon-222 is only passed, while the radon progeny products are prevented to enter the ionization chamber and at the same time this filter protects the interior of the chamber from contamination of dusty particles. The ionization chamber has an active volume 0.56 liter and has a potential of +750 V. The central electrode is connected with a signal input of the highly sensitive preamplifier unit. The signals are transmitted to an electronic network for further digital processing. For digital signal processing, there are three independent channels, to each belongs a specific analog digital convertor. Radon monitor is a compact portable measuring system and can be completed by further external sensors for pressure and temperature [Legarda, F, 2010][Heidary, s.,2011]. Radon monitor with method of operation are shown in Figure 1,2.

A-Photo of portable radon monitor

B-Experimental measurement with radon monitor experiment



C-Ionization chamber of the monitor



D-The setup scheme of the monitor in a closed gas cycle

Figure 1. Alpha Guard portable radon monitor and the measuring

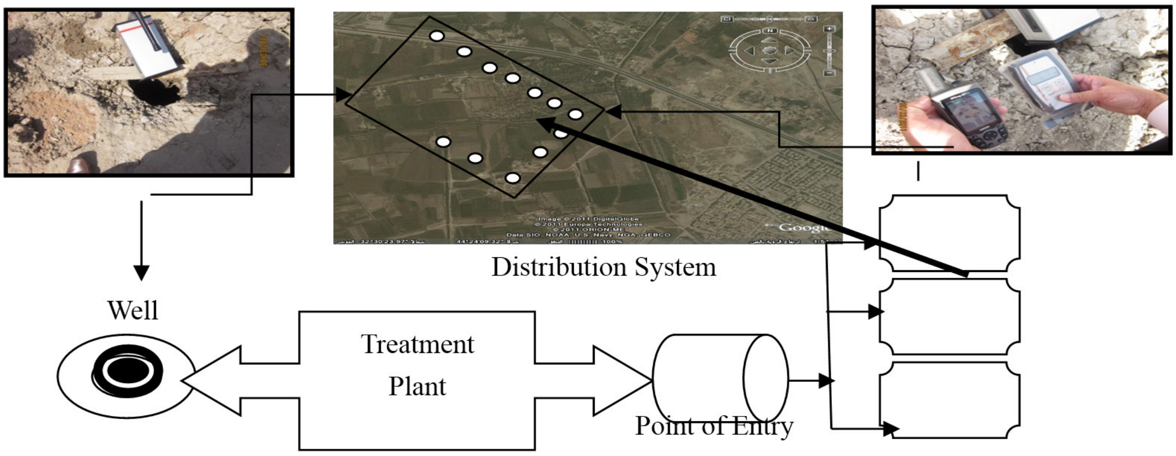


Figure 1. Community distribution water system for wells with different sizes of point of entry

The water systems in the North Hilla city (one of the Iraqi cities) that are created in vulnerable areas for contamination depend upon wells, in this sites 10 wells were drilled by distances equal and spaced from one another and depths of up to 8-32 m , the test has been done by using "closed gas cycle unit" which consists of alpha guard, fine fresh filter cartridge, and alpha pump. This unit is used for the purpose of knowing the radon concentration in different depths and drilled wells, all photographing materials and methods for testing this site are well documented, and all results are obtained in a high accuracy level . All the images adopted have been taken by PC computer. Each well from the ten wells is numbered and their depth are indicated in order to control and follow-up the measurement of radon concentrations and its levels before and after stages of establishing the drinking water systems. Radon concentrations are also tested at each point of entry according to their sizes (small, Medium, Large) in the selected site. all results are carried out and analyzed with an assistant from environmental specialist team who are employees in the environment Hilla office. The reading of "closed gas cycle unit" is well documented, each well concentrations are classified and embodied in table which summarize data such as Max, mean, and minimum concentrations of radon-222 for depths 8-32 m, as the data listed in Table.1 for well No.1 .

Program for treating and mitigating radon for wells drinking water systems was Suggested, and taken into consideration the variety of used treatment technologies for removing radon from drinking water on each well . the results have been documented and listed in Table No.2 and photographed as the diagram No.1.

Table 1. Max, Mean, & Minimum concentration for radon-222 at depths 8-32 m of Well No.1

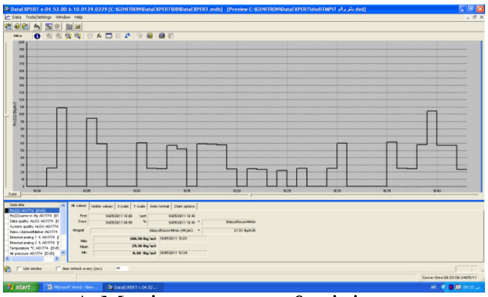
Well depth (m)	**Max. Concentration (Bq/m3)**	**Mean Concentration (Bq/m3)**	**Min. Concentration (Bq/m3)**
8	**209**	**45.31**	**0.1**
12	**580**	**270.14**	**18**
16	**848**	**336.18**	**2.33**
20	**784**	**341.99**	**4.59**
24	**352**	**266.40**	**1.81**
28	**916**	**416.64**	**5.81**
32	**1100**	**466**	**11.25**

Source: Calculated by the author with assistance of specialist team work in the environment Hilla office,

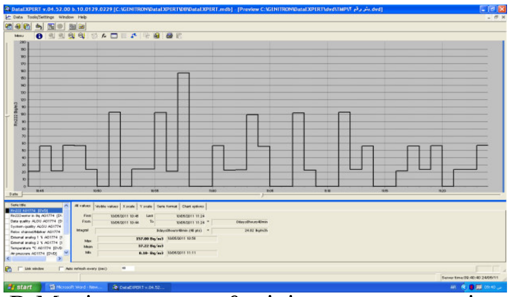
Table 2. Max, Mean, & Minimum concentration for radon-222 at depths 8-32 m of Well No.1-10

Well	**Max. Concentration (Bq/m^3)**	**Mean Concentration (Bq/m^3)**	**Min. Concentration (Bq/m^3)**
1	**108.50**	**29.36**	**0.1**
2	**257**	**37.22**	**0.1**
3	**277**	**39.29**	**0.07**
4	**281**	**46.58**	**0.1**
5	**97**	**22.88**	**0.1**
6	**193**	**38.40**	**0.1**
7	**199**	**29.17**	**0.1**
8	**154**	**28.09**	**0.1**
9	**299**	**50.34**	**3**
10	**108**	**30.35**	**0.1**

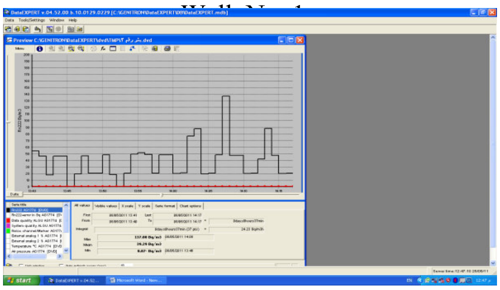
Source: Calculated by the author with assistance of specialist team work in the environment Hilla office,



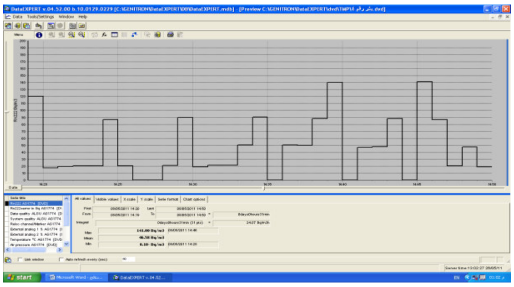
A-Maximum, mean &minimum concentration measured at the upper rim of Well No. 1



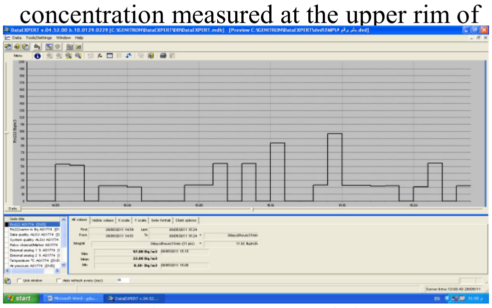
B-Maximum, mean &minimum concentration measured at the upper rim of Well No. 2



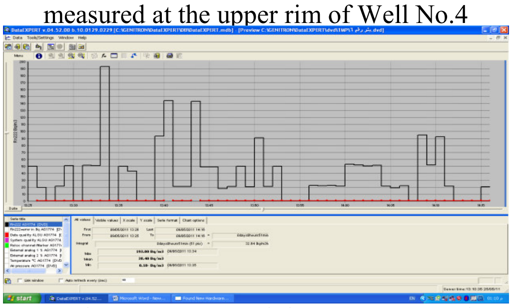
C- Maximum, mean &minimum concentration measured at the upper rim of



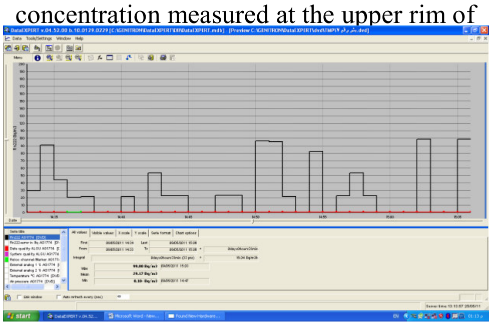
D- Maximum, mean &minimum concentration measured at the upper rim of Well No.4



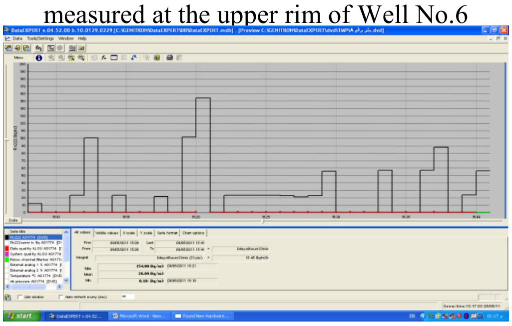
E-Maximum, mean &minimum concentration measured at the upper rim of



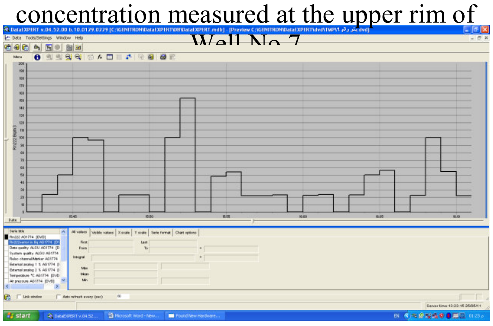
F-Maximum, mean &minimum concentration measured at the upper rim of Well No.6



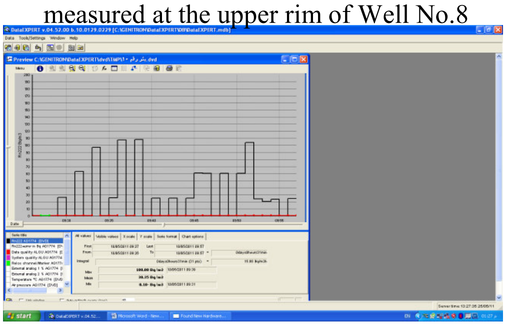
G- FMaximum, mean &minimum concentration measured at the upper rim of Well No 7



H- Maximum, mean &minimum concentration measured at the upper rim of Well No.8



I-Maximum, mean &minimum concentration measured at the upper rim of Well No. 9



J-Maximum, mean &minimum concentration measured at the upper rim of Well No. 10

Diagram. 1 Maximum , mean, and minimum radon concentration upper rim for tenth wells No 1-10 for North Hilla city site

3. Health Effects for Long Term Exposure to Radon and Risks on North Hilla City Population

Ionizing radiation is one of the most intensely studied carcinogens, classified in Group (1) by IARC [Tomatis, L.,1990][IARC,2000]. The energy released from the decay products results in damage to biological tissues which may lead to cancer. So the Ionizing radiation to radon-222 can cause toxicity when the particles pass into or through the body at high speed. If a collision occurs with the molecules of living cells, they may be damaged. These particular radionuclide emit radiation primarily in the form of alpha particles. Alpha radiation cannot pass through the dead outer layers of the skin. Therefore, these substances are a health risk only if they enter into the body by ingestion or inhalation. So the primary health effects of radon is lung cancer, resulting from inhalation of radon in indoor air originating from soil underneath the house or to a much lesser extent, the escape of radon gas into indoor air during household use of water like, showering, cooking, and washing. It can also cause stomach cancer when radon in water is ingested. In the recent years many studies on radon exposure has data and evidence that the greatest risk from radon is the lung and inhalant cancer [Field, R.W ,2010]. There is also an evidence from epidemiology and modeling studies that ingestion of radon can cause stomach cancer [Darby S, et al, 2006] [Krewski D,et al ,2006]. In many countries Radon is the second leading cause of lung cancer, since there is no safe level for Radon, the lung cancer can be resulted from exposures to low levels of the gas[USEPA,1999c]. If Radon gas is inhaled, its radioactive particles will be deposited in the respiratory tract and will irradiate in the lung, it takes years or even decades to elapse between the exposure and the onset of lung cancer [WHO ,2009], The situation varies among smokers and non smokers, it is a primary cause for nonsmokers [WHO 2009]. For more understanding the National Research Council evaluated the physical properties to the radon such as solubility in blood and tissue, and the behavior of radon in the body , in addition to the intake rates [NR, 1990b], so the major portion of the risk comes from residential drinking water exposure at the rate (89%). then from Ingestion of water contributes 11% of the total risk from radon in drinking water at home. Based upon above information, the USEPA in 1999 considered range of radon MCLs in regulating radon in drinking water, and reported levels of radon potential MCLs at levels 300, 500, 800, 1,000, and 4,000 pCi/L, and suggested the 300 pCi/L♣ or 148 (Bq/m^3). The estimated lifetime risks of exposure were used to predict the cancer risks for various concentrations of radon from ingestion and inhalation as in Table.3. [DEP,2009]

Table 3. Estimated Lifetime Cancer Risks from Radon in Drinking Water (Ingestion and Inhalation)

Radon in Water Concentration(pCi/L)	70 year Lifetime Risk Ever Smokers	70 year Lifetime Risk Never Smokers	70 year Lifetime All
100	1 in 10,000	3 in 10,000	7 in 10,000
300	3 in 10,000	8 in 10,000	2 in 10,000
500	5 in 10,000	1 in 10,000	3 in 10,000
800	8 in 10,000	2 in 10,000	5 in 10,000
1000	1 in 10,000	3 in 10,000	7 in 10,000
2000	2 in 10,000	5 in 10,000	1 in 10,000
3000	3 in 10,000	8 in 10,000	2 in 10,000
4000	4 in 10,000	1 in 10,000	3 in 10,000

Source: DEP,2009

While the results of Statistics, set in Table. 4, which documented the number of lung cancer patients at the site, indicate that there is an increase in the number of lung cancer patients, exceeded the limits set in the table 3.

♣Activity concentration is measured in Bq/m^3 but may be expressed in pCi/l.(pico curies per liter) the conversion is approximately 1pCi/L = 37 Bq/m^3. Pico curies per liter (pCi/L) = a Pico curie is one trillionth of a curie ,it is a unit of radioactivity, is a measure of how much radiation is in a liter

Table 4: Cancer Risks (ingestion and inhalation) for Radon in Drinking Water of North Hilla city

No. of Sites community	Population	No. of injuries	Rates	Stander Rates at 300 (pCi/L)
1	14 096	27	0.0019	0.0011
2	Less than 10 000	16	0,0016	0.0011
3	Less than 10 000	14	0,0014	0.0011
4	12 313	20	0,0020	0.0011
5	Less than 10 000	16	0,0016	0.0011
6	13 003	21	0,0021	0.0011
7	18 918	61	0,0061	0.0011
8	Less than 10 000	8	0,0008	0.0011
9	Less than 10 000	11	0.0011	0.0011
10	Less than 10 000	17	0.0017	0.0011
11	Less than 10 000	8	0.0008	0.0011
12	12 017	23	0.0023	0.0011
13	18 244	29	0.0029	0.0011
14	Less than 10 000	11	0.0011	0.0011
15	Less than 10 000	13	0.0013	0.0011
16	Less than 10 000	12	0.0012	0.0011
17	Less than 10 000	10	0.0010	0.0011

Source: Calculated by the author

4. Treatment and Mitigation Costs

The risks of radon may decrease according to the radon concentration decreases, by using a suitable treatment techniques. The Calculation of a projected cost of treatment is based on many factors affect the decision of choosing the appropriate treatment systems, and to evaluate the limits of treatment technology for the removal of radon from drinking water. The cost regards the importance Which includes the following effects on identifying it:

- Determining the water quality, and Radon concentration in the source water Where the costs are increasing with the increased radon concentration in the sources of water.
- The location of wells and numbers of points of entry (POE) pumping capacity (size)
- Design and size of the system.

In estimating Costs, all these factors are taken in consideration in order to determining the capital, operation and maintenance costs. So the costs for:

- Treating a small sized with (POE) pumping capacity up to 500,000 gallons per day for radon (500 house/1500 person) will cost about 624000 $.
- Treating medium sized with (POE) a pumping capacity of 600,000 to 1,500,000 gallons per day (600 to 1500 house/1800-4500 person), will cost about 1,200,000 $.
- And the costs for treating a large size with (POE) pumping capacity more than 1,500,000 gallons per day (more than 4500 person), will be about 1,800,000 $.

Although the larger POEs have higher treatment costs but larger populations decrease the cost per household (per family) as the size of a water system increases. By using the results of testing samples for Radon concentrations in Table 1,2. and the cost analysis of water treatment above to determined which (POE) would need to treat under a MCL of 100, 300, 500, 800, 1000 the Table 5,and Fig. 3,4. show both capital ,operation and maintenance costs for each size of point entry .

Table 5. Radon treatment costs

Concentration (Bq/m^3) 1pCi/L=37 Bq/m^3	♣ Point of entry size	Number of points of entry required for treatment	Capital, Operation, and Maintenance costs (million$)	Total cost (million$)
100	Small	3	1,872	2,808
	Medium	1	,624	
	Large	0.5	,312	
300	Small	9	5,616	11,016
	Medium	3	3,600	
	Large	1.5	2.700	
500	Small	15	9,360	19,860
	Medium	5	6,000	
	Large	2.5	4,500	
800	Small	24	14,976	31,776
	Medium	8	9,600	
	Large	4	7,200	
1000	Small	30	18720	39,720
	Medium	10	12,000	
	Large	5	9,000	

Source: Calculated by the author
Which:
Small Point of Entry Worth Cost per Point of Entry of 624000 $
Medium Points of Entry Worth Costs per Point of Entry of 1,200,000 $
Large Points of Entry Worth Costs per Point of Entry of 1,800,000 $.

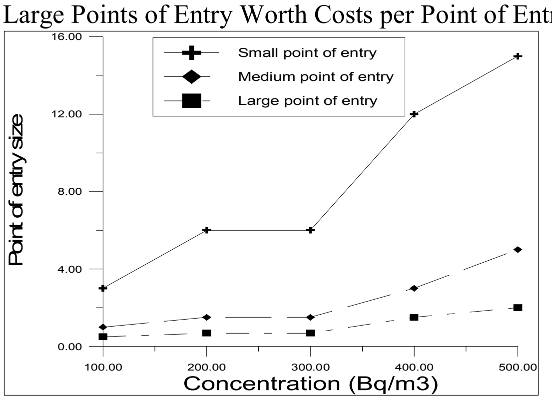


Figure 3. Size of entry points due to radon concentration

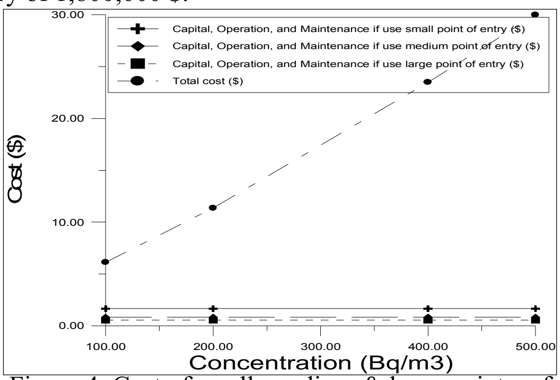


Figure 4. Cost of small, medium & large points of entry size needed to treat radon for multi concentrations

The amount of treatment needed to a water system may vary from one well to another of the ten wells. Some need only for treating Radon at few source. Other wells need for a whole treatment system, so they may need various treatments or combined treatments, therefore they vary in capital, operation and maintenance costs. The total number of large, medium, and small pumping capacity in each radon concentration was multiplied by the projected cost of treatment to determine the total cost. Based on above factors of calculation treatment cost, the estimated total costs for Well No.1 are shown in Table No.6., Fig No.5, and for ten Wells in Table No.7.,Fig No.6.

♣ **POE**: refers to a location after the well. Required monitoring often takes place at the POE

Table 6. The estimated Total cost of treatment & mitigation for Well No 1 at different depths 8m to 32 m

Well depth (m)	Max. Concentration (Bq/m^3)	Total cost (capital, maintenance& operation) (million $)	Total cost of mitigation in case of inhalation& ingestion (million $)
8	209	12	7
12	580	40	25
16	848	95	42
20	784	50	35
24	352	20	14
28	916	120	50
32	1100	150	65

Source: Calculated by the author

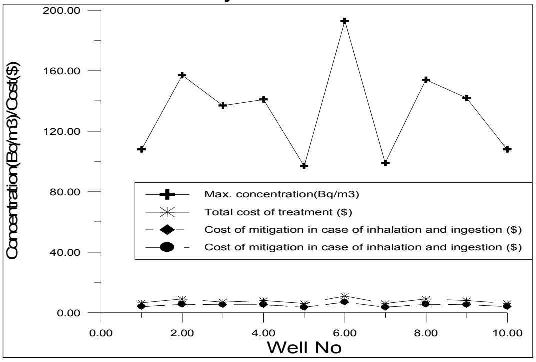


Figure 5. Total cost of treatment and cost of mitigation for Well No 1 with depths 8-32m

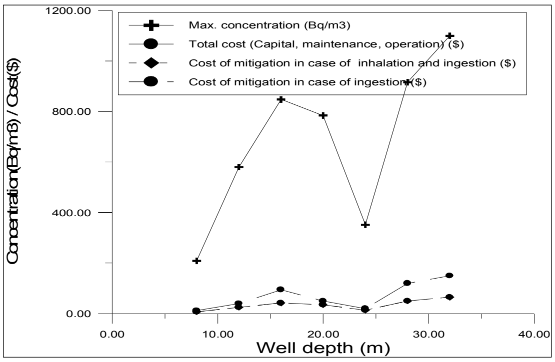


Figure 6. Total cost of treatment and cost of mitigation for Wells 1-10

Table 7. Total cost of treatment and cost of mitigation for Wells 1-10

Well No	Max. Concentration (Bq/m3)	Total treatment cost (capital, operation &maintenance (million $)	Total cost of mitigation in case of inhalation and ingestion (million $)
1	108.50	6.5	4.0
2	157	9	5.5
3	137	7	5.2
4	141	8	5.3
5	97	6	3.5
6	193	11	7.0
7	99	6	3.5
8	154	9	5.5
9	142	8	5.2
10	108	6.2	4.0
Total		**76.7**	**48.7**

Source: Calculated by the author

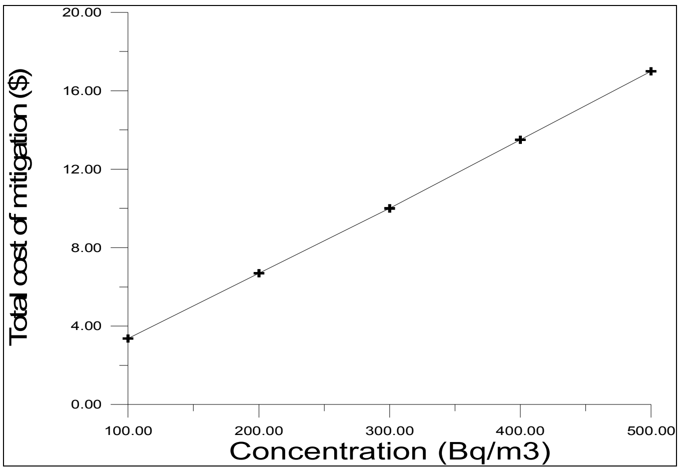


Figure 7. Total cost of mitigation in cases of inhalation and ingestion for multi concentration values ($)

In order to determine the cost per live saved, it needs to estimate the number and size of community water systems that would be required for treatment at a given potential MCL. Because compliance will be determined at the POE by using the previous estimated cost data, we calculated Lives saved over 70 years in case of inhalation and ingestion, The total cost of mitigation in case of inhalation and ingestion**,** in order to compared it with the lost lives, lives saved, the cost per life saved, and the difference in the total cost per life saved over 70 years across potential MCLs, are shown in Table No.8.

Table 8. Cost per life saved in case of both ingestion and inhalation and case of ingestion only

Concentration (Bq/m^3)	Lives saved over 70 years in case of inhalation &ingestion	Lives saved over 70 years in case of ingestion	Total cost of mitigation in case of inhalation and ingestion (million $)
100	-	-	3.36
200	-	-	6.7
300	-	-	10
400	-	-	13.5
500	-	-	17
11,100	370	40	374
18,500	275	30	200
29,600	200	20	100
37,000	140	15	70

Source: Calculated by the author

5. Conclusion

The testing results show that eight wells out of the tenth wells have a high concentration levels of Radon , which exceeded the proposed levels of USEPA (300 pCi/L) or (148 Bq/m3). The results also shows that the Well No.6 has a highest the concentration , in addition to that the Wells No.2 and 9as shown in Table 1,2. and diagrams in Fig 8, 9.

Based on these results, the sites is unsuitable for living by a population. The highest concentrations of Radon cause a deleterious impacts on the health of population in the North Hilla City. Radoon is a main cause for lung and inhalant cancer as shown in Table No 4, with rates more than acceptable by EPA. Thes results indicate that there is a needed to establish effective program for reducing the risks from Radon exposure and relative to treat and mitigate the high concentration. This program cost a mount (76.7 + 48.7) Million Dollars as calculated in Table No.7.

From analyzing the numbers of POE presented in Table No.5, all the values of pumping capacity of the POE are shown, distribution system of Radon results, population served, and treatment estimated costs based on the size of the POE are. So this analysis means that the cost of the lives saved is equal to the cost of the risk of Radon as present in Table No.7,8. The health risks from radon in the wells of North Hilla City are greater than the health risks from most chemical contaminants in drinking water. As a result the death rates reflux this from the higher rates of lung and inhalation cancer than that reported in the statistics of estimation to risk of radon in drinking water (Ingestion and Inhalation) presented in Table. No. 3 compared with Table. No. 4. Finally the risks of radon can decreased according to the decreases into radon concentration by using a suitable treatment techniques that requires a high cost.

References

SEEA-Water, (2012), "System of Environmental-Economic Accounting for Water", Department of Economic and Social Affairs Statistics Division, United Nations, New York,.

Daniela Russ,(2013), " Accounting for water quality", *The Economics of Ecosystems and Biodiversity* , Geneva, 6 January.

EPA, US Environmental Protection Agency, (2014), " Retrospective Study of the Costs of the EPA Regulation: A Report of four Case Studies ", National Center for Environmental Economics Office of Policy.

US. PHS, (1990), "Toxological profile for radon, Agency for Toxic Substances and Disease Registry", U.S. Public Health Service, In collaboration with U.S. Environmental Protection Agency, December.

Facts about Radon,(2008), www,facts-element-radon.htm. Retrieved.

Radon, All Measures, 2008-02-12, www.allmeasures.com/Formulae asp Retrieved .

(ATSDR), Agency for Toxic Substances and Disease Registry, (1990), "Toxicological Profile for Radium" Atlanta, GA. December.

(ATSDR), Agency for Toxic Substances and Disease Registry Atlanta, (1990), "Toxicological Profile for Radon", GA.

(ATSDR),(1999), Agency for Toxic Substances and Disease Registry Atlanta "Toxicological Profile for

Uranium" (Update), , GA. September.

(ATSDR), (2000), Agency for Toxic Substances and Disease Registry Atlanta, "Case Studies in Environmental Medicine: Radon Toxicity", GA. March.

Committee on Risk Assessment of Exposure to Radon in Drinking Water;(1999), "Risk Assessment of Radon in Drinking Water.", National Academy Press, Washington, D.C.

Reid, J.M. (1986), "The Atomic Nucleus", second edition, copyright by Manchester University Press , British Library cataloguing in publication data.

Qindos,L.S., Fernandez , P.L., Rodenas, C., Gomez-Arozamena, J. and Arteche, J., (2004),” Conversion factors for extra gamma dose derived from natural radionuclides in soils” *Journal of Environmental Radioactivity* , 71 : 139-145.

Qindos,L.S., Fernandez, J. Soto, C. Rodenas and J. Gomez, (1994) “ Natural Radioactivity in Spanish soils” Health Physics, 66:194-200.

Rudge, S.A,Johnson, M.S, Leah,, R.T. and Jones, S.R.,(1993), ” Biological Transport of Radiocaesium in a Semi-Natural Grassland Ecosystem” *Journal of Environmental Radioactivity*, 19:173-198 .

Casarett and Doull's , (2001), "Toxicology, The Basic Science of Poisons", Sixth Edition. Klaassen, C.D. ,ed. McGraw-Hill Publishing Co., Inc., New York.

Jelle, B.P, (2012), " Development of A model For Radon Concentration in Indoor Air" 416: 343-350,.

Martin Sanchez, A., etl, (2013), " Additional Contamination When Radon in Excess" 81: 212-215.

Vasilyev, A.V., Zhukovsky,, M.V, (2013), " Development of Mechanisms and Parameters Effect Radon Entry Into A room" :124 190-195.

Legarda, F., (2010), "An active Radon sampling Device For High Humidity Places" 45:122-128.

Heidary, s., etl, (2011), " Monitoring and Measurement of Radon Activity in Anew Design of Radon Chamber" 46:694-700.

Tomatis, L., (1990), IARC Cancer, causes occurrence and control. IARC Scientific Publications. Vol.100, Lyon: IARC .

IARC, (2000)," Ionizing Radiation, Part 1: X- and Gamma (g)-Radiation, and Neutrons", IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 75, Lyon: IARC.

Field, R.W., (2010)," Environmental Factors in Cancer: Radon", Reviews on Environmental Health, 25(1): 23-31.

Darby S, Hill D, Deo H, Auvinen A, Barros-Dios JM, Baysson H, Bochicchio F, Falk R, Farchi S, Figueiras A, Hakama M, Heid I, Hunter N, Kreienbrock L, Kreuzer M, Lagarde F Mäkeläinen I, Muirhead C, Oberaigner W, Pershagen G, Ruosteenoja E, Rosario AS, Tirmarche M, Tomásek L, Whitley E, Wichmann HE, Doll R., (2006), "Residential radon and lung cancer", Scand J Work Environ Healt, 32 Suppl 1:1-83.

Krewski D, Lubin JH, Zielinski JM, Alavanja M, Catalan VS, Field RW, Klotz JB, Létourneau EG, Lynch CF, Lyon JL, Sandler DP, Schoenberg JB, Steck DJ, Stolwijk JA, Weinberg C, Wilcox HB, J (2006), Toxicol Environ Health A 69 (7) : 533-97.

USEPA, US Environmental Protection Agency,(1999c), " Cancer Risk Coefficients for Environmental Exposure to Radionuclides ", Federal Guidance Report No. 13 ,EPA 402-R-99-001, September.

WHO, (2009),"WHO Handbook on Indoor Radon. A Public Health Perspective', Geneva: WHO .

WHO, (2009), "Radon and cancer", Fact sheet N°291, Geneva: WHO.

NR, National Research Council, (1999b), "Risk Assessment of Radon in Drinking Water", Washington, D.C.: National Academy Press.

Department of Environmental Protection,(2009) " Maximum Contaminant Level Recommendation Document on Radon-222". New Jersey Drinking Water Quality Institute, USA.