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Determination of radon gas and lead ion concentrations in building materials using biosensors

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▶ ***Technical note***

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ABSTRACT

Background: This study is focused on the design and manufacture of a biosensor to detect the presence of the two chemicals Pb^{+2} and ^{222}Rn in soil and building materials. ***Materials and Methods***: The biosensor is used on the basis of primers (ssDNA with high guanine). These are different sequences of nitrogenous bases. Biosensor-I and biosensor-II have sequences as follow: 5′-AGGGTTAGGGTTAGGGTTAGGG-′3 and 5′-GGTTGGTGTGGTTGG-′3, respectively. The results show that the average ^{222}Rn (BIOS-II) was higher than ^{222}Rn (BIOS-I). The average Pb^{+2} (BIOS-I) was higher than Pb^{+2} (BIOS-II). ***Results***: The ^{222}Rn and Pb^{+2} in the samples were ordered as following: Indian granite > soil loc 2 > Chinese granite > soil loc 1 > soil loc 3 > Iraqi mosaic > Iranian mosaic > Iraqi bricks > Iraqi thermostone blocks > Indian ceramic > cement1 > Iranian thermostone blocks > Turkish marble > Iranian ceramic > Iranian bricks > cement2 > Iranian marble. ***Conclusion***: The levels of Pb^{+2} and ^{222}Rn in Chinese and Indian granites are higher than the acceptable limits. This method can be used for detecting radioactive and organic materials. It can also exclude radiation damage from field testing.

INTRODUCTION

There are numerous types of toxic substances in our environment. These include various chemicals such as carbon dioxide and radon. Being exposed to these substances for a long period of time can lead to serious health issues [(1)]. The sensors can provide quick, reliable, and accurate detection [(2)]. Biosensor consists of two main elements, connected to each other. Biosensor is a device that uses two main components. The first one is the biological sensing component. The bio recognition process is responsible for the recognition of a substance. The second part is a transducer, this component can convert a bio recognition event into an electrical signal, which can be used to detect a dangerous compound [(3)].

Despite their importance, the traditional methods are still prone to various shortcomings when it comes to detecting dangerous compounds. It is necessary to build continuous monitoring systems to keep an environment clean [(4)]. It requires a comprehensive research program to develop novel techniques and procedures. Biosensors are becoming more prevalent in environmental monitoring. Their advancements in materials and technologies make them one of the promising components for developing a robust monitoring system [(5)]. This product is used for a variety of sensing biomaterial chemical elements or a mixture of both [(5)]. This study is focused on the design and manufacturing of a biosensor to detect the presence of ^{222}Rn and pb^{+2} in soil and building material. This work shows that biosensors with high sensitivity and efficiency can be used for detecting the presence of lead and radon. A biosensor is an instrument that can be used to monitor the chemical substances that are detected by a physicochemical detector [(6, 7)].

MATERIALS AND METHODS

In this study, F96 pro (Shanghai Kingdom Scientific Instrument Co., Zhejiang, China) was used to analyze the biosensor cell. The wavelength of this apparatus is 200 to 900 nm. The scanning rate is 60 to 3000 nm. The Pb ion solution peak was determined using a Mega 2100 UV-Vis spectrophotometer (Scinco Co, South Korea) with double beam type. The concentration of Pb ion was determined using a Mega 2100 ultraviolet spectrophotometer (double beam type). The wavelength range of this apparatus is between 190 and 1100 nm. Its radiation source is a combination of Deuterium and Tungsten (with a maximum scan rate 3000 nm/min). The biosensors were made using the Aptamers powder (Bioneer, South Korea), which has a purity of 99.9%. The solution was prepared by

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adding 1ml of deionized water and a centrifuge for 15 minutes at a rotation rate of 1,000 rpm. The first and second primer sequences are respectively known as (5′-AGGGTTAGGGTTAGGGTTAGGG-′3) and (5′-GGTTGGTGTGGTTGG-′3. The pH value of the soil and building materials (17 samples) was measured using a pH meter (Jenway 3505, England). 17 samples are collected from different sources for the construction of buildings and soil samples. These samples are taken from different locations in Basra city. The materials for the construction of houses are collected from the local market areas in Basra city while the samples for soil are collected from different sites in the area (table 1).

Table 1. Information about the samples.

Sample Code	Type	Company	Country of Origin
G1	Granite	Indo stone	India
G2	Granite	Loma company	China
C1	Ceramic	Cyper ceramic	India
C2	Ceramic	Mahdiss company	Iran
Mo1	Mosaic	Maher AL-Badran	Iraq
Mo2	Mosaic	Novinceram	Iran
M1	Marble	Srab stone company	Iran
M2	Marble	HMF	Turkey
B1	Brick	Ghapanchi Co.	Iran
B2	Brick	AL-Nakheel company	Iraq
T1	Thermostone Blocks	Silica Ara Co.	Iran
T2	Thermostone Blocks	Asad babel	Iraq
Ce1	Cement	AL-Mabrooka	Iraq
Ce3	Cement	Saman cement	Iraq
Loc1	Soil	Non	Iraq, Basrah
Loc2	Soil	Non	Iraq, Basrah
Loc3	Soil	Non	Iraq, Basrah

All samples were crushed first, then turned into a fine powder, using a manual grinding and electrical mixer (Sinico, Germany). The fine powder, after being sieved, was obtained with grain size of 300 µm for about 500 gm. The samples were dried at 100 C for 2 h using an oven (Model Memmert GmbH+ Co. KG, Germany). The biosensor cell was made using a tube filled with 0.2% acetic acid. Then, the samples were dried at 100 °C for 2 h using an oven (Model Memmert GmbH+ Co. KG, Germany). The biosensor cell was prepared by placing the sample in a plastic container and filling it with 0.2% acetic acid. The tube is covered with a cellulose acetate membrane Sartorius Stedim Biotech, Germany) to prevent the spread of other contaminants. The cellulose acetate membrane has a diameter of about 45 µm. It is placed in a vacuum chamber (JB Industries, USA) with a pressure gauge. The cell remained under a pressure of -50 bar for 8 days to obtain a large volume of radon gas. After the exposure time had expired, 2 milliliters of acid were added to two containers, and 20µl of Aptamer was then placed in an incubator at 37C. Then, 2 l of dilute malachite green dye (Avonchem, UK) was added and it was returned to the same temperature for 15 minutes. This technique can be used to identify the presence of lead ion and radon gas. It is characterized by its ability to give accurate readings. The sample is transferred to a fluorescent device to detect radon gas.

RESULTS

The BIOS-I and BIOS-II were calibrated using five different solutions of acetic acid. They were exposed to different levels of radon gas (50.78, 63.97, 88.98, 110.12, 142.45, and 161.87 Bqm^{-3}). The concentration ranges were measured using RAD7, and the calibration curve was also done using standard lead solution (20, 40, 60, 80, 100, and 120 nM) from Sigma-Aldrich Company in USA). Concentrations of various Aptamers (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2 µM) were measured using a fluorescence spectrophotometer. The ideal concentration for this drug is 0.6 M (figure 1).

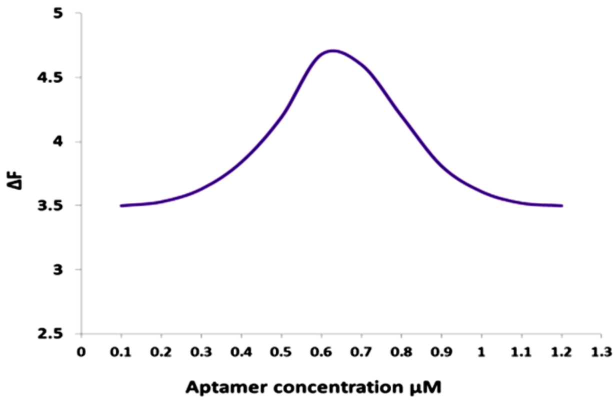

Figure 1. Optimization condition of Aptamer.

Table 2 shows the readings of radon gas using BIOS-I, relative humidity (RH%), and temperature (T) in soil samples and building materials. The concentration of radon gas was found to be varying from 138.55 Bqm^{-3} to 735.40 Bqm^{-3}. The lowest concentration of radon gas was 138.55 Bqm^{-3} in Iranian marble. The highest was 735.40 Bqm^{-3} in Indian granite. The humidity levels were found to be at 6.90% and 11.60 % respectively. The temperature values ranged from 18.4 degrees Celsius to 19.92 degrees Celsius.

Table 2 shows biosensor 2 (BIOS-II) is a biosensor that measures the radon gas concentration using a primer that contains 9 guanine bases. The highest radon gas concentration was found in Iranian marble at 705.64 Bqm^{-3} in the soil (Loc2). Humidity levels were found to be ranged from 6.90 to 11.60%. The temperature ranges were found to be 18.4 degrees Celsius to 21.9 degrees Celsius. Table 3 shows the concentration of lead in building materials and soil samples taken from different locations.

Pb^{+2} concentration was found to be varied from 21.55 nM to 93.49 nM. The lowest Pb^{+2} concentration recorded in Iranian marble was 21.55 nM. While, the highest Pb^{+2} concentration recorded in Indian granite was 93.49 nM. Humidity was found to be at 6.90% to 11.60%, average 9.42±0.30. The temperature was ranged from 18.4 Cº to 21.9 Cº with average

19.92±0.25. BIOS-II found to have the lowest Pb^{+2} concentration at 17.10 nM (table 3). The highest concentration of radon gas was found at 83.75 nM in Indian granite. Humidity was ranged from 5.6% to 17.7% with average of 10.5882±0.894. The temperature was ranged from 18.4 to 21.9 degrees Celsius.

Table 2. Radon gas concentration (Bqm-3) by BIOS-I and BIOS-II.

SC	BIOS-I		BIOS-II	
	^{222}Rn	±SE	^{222}Rn	±SE
G1	735.40	36.77	698.53	34.92
G2	725.22	36.26	686.14	34.30
Avg.	**730.32**	**36.51**	**692.33**	**34.61**
C1	259.52	12.97	209.72	10.48
C2	208.38	10.41	179.18	8.95
Avg.	**233.95**	**11.69**	**194.45**	**9.71**
Mo1	350.76	17.53	307.27	15.36
Mo2	286.93	14.34	250.54	12.52
Avg.	**318.84**	**15.93**	**278.90**	**13.94**
M1	138.55	6.92	116.12	5.80
M2	208.52	10.42	171.20	8.56
Avg.	**173.53**	**8.67**	**143.66**	**7.18**
B1	191.82	9.59	177.87	8.89
B2	270.96	13.54	241.32	12.06
Avg.	**231.39**	**11.56**	**209.59**	**10.47**
T1	239.54	11.97	197.26	9.86
T2	266.72	13.33	245.53	12.27
Avg.	**253.13**	**12.65**	**221.39**	**11.06**
Ce1	242.14	12.10	215.69	10.78
Ce2	189.21	9.46	171.06	8.55
Avg.	**215.67**	**10.78**	**193.37**	**9.66**
Loc1	661.15	33.05	630.34	31.51
Loc2	735.15	36.75	705.64	35.28
Loc3	636.17	31.80	615.57	30.77
Avg.	**677.49**	**33.86**	**650.51**	**32.52**
Avg.	**373.30**	**18.66**	**342.29**	**17.11**
Max.	**735.40**	**36.77**	**705.64**	**35.28**
Min.	**138.55**	**6.92**	**116.12**	**5.80**
WHO	**300**	**...**	**300**	**...**

Table 3. Lead in concentration (nM) by BIOS-I and BIOS-II.

SC	BIOS-I		BIOS-II	
	Pb^{+2}	±SE	^{222}Rn	±SE
G1	93.49	4.67	83.75	4.18
G2	85.18	4.25	76.25	3.81
Avg.	**89.33**	**4.46**	**80.00**	**3.99**
C1	30.01	1.50	25.71	1.28
C2	26.17	1.30	20.13	1.00
Avg.	**28.09**	**1.40**	**22.92**	**1.14**
Mo1	39.57	1.97	36.54	1.82
Mo2	33.19	1.65	28.24	1.41
Avg.	**36.38**	**1.81**	**32.39**	**1.61**
M1	21.55	1.07	17.10	0.85
M2	23.49	1.17	20.91	1.04
Avg.	**22.52**	**1.12**	**18.64**	**0.94**
B1	24.90	1.24	19.82	0.99
B2	31.47	1.57	26.33	1.31
Avg.	**28.18**	**1.40**	**23.07**	**1.15**
T1	27.96	1.39	23.40	1.17
T2	31.29	1.56	28.26	1.41
Avg.	**29.62**	**1.47**	**25.83**	**1.29**
Ce1	28.25	1.41	23.30	1.16
Ce2	22.02	1.10	18.34	0.91
Avg.	**25.13**	**1.25**	**20.82**	**1.03**
Loc1	77.53	3.87	71.35	3.56
Loc2	87.89	4.39	82.63	4.13
Loc3	61.74	3.08	51.37	2.56
Avg.	**75.72**	**3.78**	**68.45**	**3.41**
Avg.	**43.86**	**2.19**	**38.44**	**1.92**
Max.	**93.49**	**4.67**	**83.75**	**4.18**
Min.	**21.55**	**1.07**	**17.10**	**0.85**
WHO	**72**	**...**	**72**	**...**

DISCUSSION

Scientific experiments cannot be done without knowing the proper value of pH. The fluorescence results indicated that the best value is 7pH. Malachite green is a greenish-yellow dye with a metallic sheen [8]. For strong fluorescence, an interaction between green malachite and G-quadruplex was found [2]. The test of optimal conditions showed that the dye should be used at a volume of 22 µL. The highest ^{222}Rn level was found in various components of Chinese granite, soil, and Indian granite. These components are used as the synthesis elements for forming underground basaltic rocks. It is mainly composed of minerals such as feldspar, quartz, and amphibole. It has high concentrations of radon gas. Nuclear accidents are responsible for the 137Cs. However, the majority of these lands were bombed during the Gulf War and the 2003 war.

The lowest concentration of radon was found in the marble due to its geological nature. Due to the nature of the materials used for making ceramics, their radioactive content is low. The cement is made by mixing calcium aluminainosilicate with limestone and clay. DNA origami is an alternative method of creating crystals [9–11]. Biological engineering researchers have developed biosensing devices for breast cancer [12]. Biosensors are used for environmental monitoring. They are typically made up of a bio- or chemical materials [5]. A label-free colorimetric technique was used to detect radon, based on the presence of Pb^{+2} [13]. They found that the lowest concentration of radon was 0.71 $\times 10^4$ Bqm^{-3}, while the highest concentration was 25.2$\times 10^4$ Bqm^{-3}. The concentration of lead in solution was 0.28, 0.40, 0.78, 1.23, 1.64, 1.72, 1.76, 1.79, and 1.79 nmol L^{-1}. Biosensors were synthesized to detect the presence of ^{222}Rn. The study found that the lowest concentration of radon was 1.09$\times 10^4$ Bqm^{-3}, while the highest was 29.8$\times 10^4$ Bqm^{-3}. The lead concentration was ranged from 22.4 nmol L^{-1} to 475 nmol L^{-1} [13]. The fluorescence intensity shows a linear relationship between the lead ions and the radon concentration. This result was agreed with another study [14]. This method can be compared to the fluorescence biosensor detection method and the colorimetric biosensor method. It can also be utilized for the detection of radon. The approach can be used to measure the accumulated concentration of radon and lead ions. It can also be used to detect detection limits for lead and radon. This result was also agreed with another study [15].

CONCLUSIONS

It concluded that biosensors could be manufactured to detect the presence of Pb^{+2} and ^{222}Rn depending on the aptamer's base composition.

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The sensitivity of a biosensor depends on the first primer's composition. The first one is rich in guanine, which makes it more sensitive than the second one. The G-quadruplex can be sensitive to detect the presence of Pb^{+2} and ^{222}Rn in Chinese and Indian granites. Pb^{+2} and ^{222}Rn are higher than the WHO value in Chinese and Indian granites. The rest samples of Pb^{+2} and ^{222}Rn are within the recommended limits of WHO.

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***Ethical consideration**:* This study was approved by the Ethics Committee, University of Kufa. The study protocol was thoroughly explained for using samples in the study. This investigation was done according to the principals of the Declaration of Helsinki. All were informed about the aims and protocol of the study.

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Declaration of Interests: The authors declare no conflict of interest.

***Author contribution**:* Basim Almayahi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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