Study of potential capacity as adsorbent of *Moringa oleifera* substrates for treatment of radon contaminated air in indoor spaces: preliminary test

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Abstract

Radon is a radioactive gas known to be a human carcinogenic element that causes lung cancer. The Directive 2013/59/EURATOM stablishes action plans for its monitorization and control in water and air specially at workplaces. There are several techniques to reduce the concentration of radon in air mainly based on improving ventilation rates. However, intelligent and energy-efficient buildings are well insulated and have centralized ventilation systems where air is recirculated continuously. This strategy has a negative influence on radon accumulation at indoor spaces. So, ventilation systems should be composed by filters with suitable materials to adsorb radon from indoor air. This work studies the radon adsorption ability of the most used adsorbent (activated carbon) and some not-processed substrates coming from *Moringa oleifera,* a natural plant with high potential as adsorbent for heavy metals and coagulant in and water treatment. The radon adsorption efficiency of the different solids is analyzed, showing promising results for radionuclide removal from air.

Keywords: Moringa, Radon, air, adsorption

1. Introduction

Radon is a radioactive gas which comes from the natural radium disintegration. It is considered as a human carcinogenic element by the World Health Organization (WHO) (WHO, 2009) since, after inhaled, its progeny emits alpha particles that are deposited in lungs causing cellular damage; in fact, it is the second cause of lung cancer after smoking.

In order to control and minimize radon inhalation by people, the Directive 2013/59/EURATOM sets action plans and limit values for radon exposure for buildings and workplaces in order to control and minimize radon inhalation by exposed workers.

There are several techniques to reduce the concentration of radon in air, that include increasing the rate of ventilation of the closed spaces with fresh air, sealing of basements to avoid exhalation to indoor air from soil and bed rock or selection of appropriate construction materials (Guyot et al., 2018). Nowadays, intelligent and energy-efficient buildings are well insulated and have centralized ventilation systems where air is recirculated continuously. These energy saving strategies have a direct influence in the quality of the indoor air, because fresh air supply from the outside is needed for ensuring air quality and a healthy indoor climate (Cucoş et al., 2015). If air exchange rate is uncontrolled or ventilation system doesn't work properly an accumulation of contaminants in the air takes place. This is especially relevant in the case of Radon. When Radon is present in indoor air because is exhaled for example from construction materials, concentration of this gas will reach significant and dangerous levels at houses and workplaces (Cucoş et al., 2015). Centralized ventilation systems are composed by ducts, air particle filters, conditioning system and fan that are not capable to remove radon from air. As activated carbon has demonstrated to be a very good adsorbent for radon in water (Karunakara et al., 2015), the use of carbon filters coupled with the recirculated air system will be useful to reduce radon concentration in indoor air up to safe levels.

Although carbon has a high adsorption capacity for most of substances, it is possible that other adsorbent materials have higher adsorptive ability to remove radon gas. Moreover, the high cost of activated carbon has led to the development of new materials with similar characteristics but lower costs.

Moringa oleifera is a multipurpose tree with different applications for its nutritional, pharmaceutical and water purification properties. Different substrates from seeds, husk, wood and roots have shown ability as adsorbents in water treatment for heavy metals-removal (García-Fayos et al., 2016). In spite of its probed adsorbent capacity, no previous studies have been found that analyze the ability of this plant to remove radionuclides from water or air.

This work proposes the study of radon adsorption from air by using several adsorbent materials from Moringa, as a way to improve indoor air coupled with mechanical ventilation systems. Radon adsorption capacity of active carbon and different Moringa substrates are compared in terms of radiation adsorption and Radon measurement. Furthermore, humidity adsorbed by each solid during exposition to radiation is analyzed in order to predict possible influence of this parameter on radon adsorption, as it is known by other works (García-Tobar, 2014).

2. Material and methods

2.1. Adsorbent preparation

Moringa oleifera seeds were collected in Burkina-Faso. They were manually dehusked, and then stored for being later conditioned. As several parts of the plant have potential for water treatment, different adsorbent materials have been prepared for experimental tests:

a) Husk. To remove humidity from the husk, it was dried in a heater (*Digitronic*) at a temperature of 100º C during 24 hours. Then, the dried husk was grinded with an electrical mill (*Moulinex Super Junior "S"*) and after, it was washed with distilled water since turbidity values of washed effluent were lower than 1 NTU. The husk was again dried in the heater, following the procedure described before. Finally, the sample was manually powder and sieved, thus obtaining a fraction of size between 125 to 250 µm of diameter. This fraction was stored for being used later as biosorbent ("Moringa husk").
b) Wood. Wood of the *Moringa oleifera* trunk was cut and dried at 60º C during 3 hours in an oven. After the dried wood was grinded with an electrical mill (*Moulinex Super Junior "S"*) and after, it was washed with distilled water since turbidity values of washed effluent were lower than 1 NTU. The wood was again dried in the heater, following the procedure described before. Finally, the sample was manually powder and sieved, thus obtaining a fraction of size of 1 mm of diameter. This fraction was stored for being used later as biosorbent ("Moringa wood").
c) Seeds without oil. Since oil can interfere in the potential of seeds as coagulants for water treatment, it was extracted before adsorption tests. Oil extraction from *Moringa oleifera* seeds was performed by using a Soxhlet apparatus and ethanol as solvent. 50 g of *Moringa oleifera* crushed seeds were fed to a lab-scale Soxhlet extractor fitted in a 500 mL round bottom flask with 350 mL of solvent. Extraction time was 6 hours, and 20 cycles were performed. Defatted solid obtained after extraction is used as bioasorbent ("Solid without oil").

d) Seeds without coagulant and without oil. Deffated solid it is also used for preparing a liquid extract that works as coagulant for water treatment. A 5% (w/v) suspension using distilled water was prepared, mixed with a magnetic stirrer for 60 minutes and left to settle for 20 minutes. Liquid extract is filtered through a 0.45 μm cellulose acetate filter (Spartan 30 B, VWR International) and solid stored for being used as bioasorbent ("Solid without coagulant and without oil").

2.2. Experimental tests

Radon adsorption tests have been performed in an experimental set-up that allows to measure radon that exhalates from soil to the air.

All measurements have been done using a high density plastic deposit impermeable to radon. A pitchblende stone has been deposited just on the bottom of the deposit, covered with no radioactive soil sample as it is shown at Fig. 1. The device used for adsorbent location was a canister, which is one of the most used detectors for radon measurements.

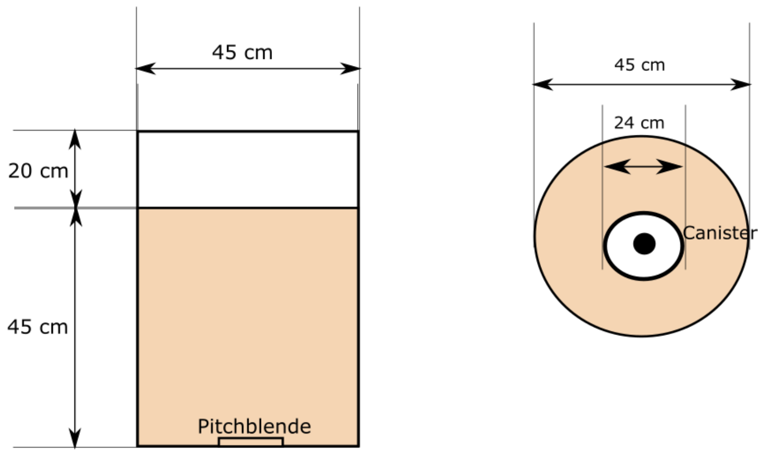

Fig. 1. Radon adsorption experimental set-up

Before each test, the canister was dried in an oven for 8 hours at 110 ° C. Later, it was weighed to know the mass of solid before adsorption. After this the canister was inserted on the surface of uncontaminated soil and covered with a high-density container not permeable to radon, in order to accumulate it inside during the exposition period. During this time of exposition, radon escapes from the interstitial space of the grains and is transported to the surface, being adsorbed by the material inside the canister. After this, the canister was weighed again in order to calculate how much humidity it has absorbed, as radon adsorption is significantly influenced by this parameter.

2.3. Radon measurements

Before performing radon measurement, it is necessary to wait 3 hours until the radon reaches equilibrium with its descendants. After this time, it was analyzed by gamma spectrometry using a scintillation detector. The concentration of radon gas is determined from its descendants, 214Pb and 214Bi, whose gamma peaks are located at 242, 294, 352 and 609 kEv as it is shown in Fig. 2.

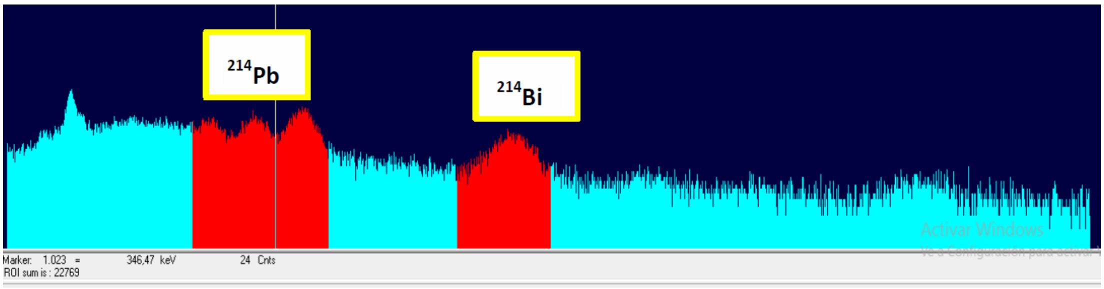

Fig. 1. Gamma spectrometry results for radon descendants

From the obtained counts by the regions of interest of descendants' gamma peaks, subtracting the background level, and considering the exposure time of the canister, as well as the humidity correction coefficient, the radon concentration has been calculated.

The net counts rate (N) for the exposed recipient is calculated as the difference between the background rate and the counts rate of canister accounts exposed to radiation. The initial net account rate is given by Eq. 1

$$N_0 = \frac{N}{e^{-\lambda t}} \quad \text{(Eq.1)}$$

Where N_0: initial count rate (cps), N: net count rate (cps), t: time elapsed between the end of the exposure and the moment of measurement and λ: decay radón constant (time $^{-1}$), which is calculated by Eq.2.

$$\lambda = \frac{\ln 2}{3{,}8 \text{ days}} \quad \text{(Eq.2)}$$

Radon concentration has been calculated as:

$$C_{Rn} = \frac{N_0 - N_{background}}{E_f \cdot C_f} \cdot 1000 \quad \text{(Eq.3)}$$

Where, C_{Rn} is radon concentration (Bq/m^3); E_f detector efficiency and C_f: correction factor correction for the absorbed humidity

3. Results

In this point, experimental results of radon adsorption are presented. First of all, it is analyzed the adsorption capacity of each tested substrate as well as the radon concentration resulted from each measurement. Later, humidity adsorbed by each solid during exposition to radon and its influence in the adsorption capacity is discussed.

3.1. Adsorption capacity

Table 1 shows values of adsorption ability for each substrate expressed as number of counts per hour of exposition to radon and per gram of adsorbent, as well as result of radon concentration measurement in Bq/m^3 obtained by equation (1).

Table 1. Adsorption ability of each tested adsorbent

Adsorbent	Adsorption ability (counts/(h·gram))	Radon concentration (Bq/m^3)
Moringa husk	70,53	402,68 ± 10,68
Moringa wood	67,93	352,68 ± 09,91
Solid without oil	58,07	444,42 ± 10,70
Solid without oil and without coagulant	60,82	457,22 ± 10,99
Activated carbon	425,27	3770,59 ± 21,41

As it can be seen in Table 1, the adsorption ability of the different substrates of *Moringa oleifera* is very similar, ranging between 58 and 70,5 counts/(h·gram). On the other hand, activated carbon has shown adsorption ability between 6-7 times higher than Moringa substrates. Something similar is shown in values of radon concentration as they are proportional to number of counts.

In this point, it is important to consider that the activated carbon is a processed solid whereas the solids of Moringa used in the tests have not been processed as adsorbents and have been used in their natural state. As these not processed materials show a certain adsorption potential, they can be considered as promising natural adsorbents for radon caption, not reported before. Future studies should be done to determine the porosity and specific area of each solid in order to analyse their influence on adsorption capacity in terms of these parameters.

3.2. Influence of humidity

Table 2 shows the percentage of humidity adsorbed by each substrate during the time of exposition to radiation.

Table 2. Humidity adsorbed by substrates during radon exposition

Adsorbent	Humidity adsorption during exposition (%)
Moringa husk	1,991
Moringa wood	0,284
Solid without oil	0,934
Solid without oil and without coagulant	1,353
Activated carbon	1,793

As it is shown in Table 2, there are significant differences in the percentage of humidity adsorbed by each substrate during radon exposition. The Moring husk is the solid that has adsorbed the high amount of humidity (close to 2%) whereas Moringa wood is the one that has adsorbed less humidity (below 0,3%). This can be explained by the different structure of both solids, since the husk of Moringa has a more opened structure than the wood so it can adsorb a higher amount of humidity. It is especially relevant the lower amount of humidity adsorbed by the wood, which increases its potential as radon adsorbent because it would have lower influence of this parameter in its adsorption efficiency.

4. Conclusions

In this work, different solids has been tested in order to analyzed their potential use for radon caption trough air filters for decreasing concentration of this hazardous radionuclide from indoor air.

The novelty of the work is the application of *Moringa oleifera* substrates as adsorbents, with the aim of finding natural materials which can be used without the complex and costly processes of conditioning that adsorbents such as activated carbon required.

The results of the work have shown that Moringa substrates have capacity to adsorb radon from air, specially Moringa husk. With respect to humidity adsorption, some parts of the plant adsorb radon even with a humidity adsorption rate higher than activated carbon.

These screening results show for the first time the ability of Moringa to adsorb radionuclides (in this case radon from air) and set the base to develop research to improve *Moringa oleifera* radon adsorption capacity.

Future studies should be done to study the influence of particle size, porosity and specific area of each material on the adsorption capacity of Moringa substrates.

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