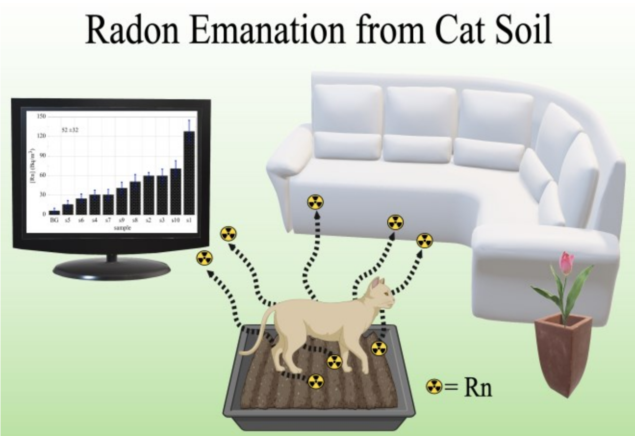
Global NEST Journal, Vol 27, No 1, 06744

Radioactivity and radon exhalation from cat litter – Is there an issue?

Sarrou I.[A], Varnava N.[A], Ioannidis I[A]* and Pashalidis I.[A]
[A]Department of Chemistry, University of Cyprus, P.O. Box 20537, Cy–1678 Nicosia.
Received: 30/08/2024, Accepted: 24/11/2024, Available online: 19/12/2024
*to whom all correspondence should be addressed: e-mail: iioann03@ucy.ac.cy
https://doi.org/10.30955/gnj.06744

Graphical abstract



Abstract

The main component of clumping cat litter is usually bentonite, which besides potassium (including K-40) contains uranium radium, and may also exhalate radon. Ten different cat litter samples, which are commercially available in Cyprus and have been imported from various countries, have been analysed regarding their uranium and radium levels, and the associated radon exhalation rates. The uranium levels varied between 2.5 mg/kg (32 Bq/kg) and 4 mg/kg (50 Bq/kg) and were determined by ICP-OES after acidic dissolution of the cat litter samples. The radioactivity concentration of radium in the samples (4 Bq/kg < [Ra-226] < 40 Bq/kg) was determined after EDTA extraction of radium from the litter matrix followed by the determination of the associated radon exhalation rates using a continuous radon monitor. Similarly, the radon exhalation from cat litter was measured using a defined amount of cat litter and the average radon levels emitted varied between (6 Bq m^{-3} < [Rn] < 128 Bq m^{-3}). However, even in the case of the cat litter with the highest radionuclide concentration, the contribution to indoor radon in an average room is estimated to be insignificant and subsequently the impact of the associated additional radioactive dose.

Keywords: Cat litter; uranium and radium content; radon exhalation; indoor radon levels

1. Introduction

Cat litter is usually made from bentonite, because it is a clumping clay litter is easy to clean up. However, clumping clay litter, which was developed in the 1980s, is heavy and creates dust and is not biodegradable. Nevertheless, bentonite is very attractive due to high swelling potential, good self-sealing ability and cation exchange capacity. Because of these properties, bentonite has also attracted great interest in nuclear waste disposal as buffer or backfill material (Yusof *et al.* 2020). Bentonite consists mostly of montmorillonite and quartz and calcite may be present as impurities.

However, due to strong cation adsorbing capacity bentonite usually contains uranium, thorium and potassium in varying concentrations (Turhan *et al.* 2022). On the other hand, uranium and thorium containing materials are consequently sources of radon and exhalate their gaseous radionuclide since Rn-222 and Rn-220 are members of the U-238 and Th-232 decay series, respectively. Exhalation of radon from bentonites/cat litter and ionizing radiation emitted from the short-lived progeny of radon could contribute to the radiation dose received and the associated health risks (NRC, 1999). Hence, cat litter containing thorium and uranium could act as a source of airborne radioactivity in indoor environments.

Although radon exhalation from building materials has been the subject of many studies, since exposure to increased radon (and progeny) levels has been linked to an increased risk of lung cancer (Al-Jarallah, 2001; Nielson *et al.* 1996), studies on the impact of radon exhalated from cat litter are very limited (Kitto and Menia, 2009). It is very difficult to estimate the health risk related to radon exhalation from cat litter, because of different parameters affecting the indoor radon levels such as uranium and thorium levels in a specific cat litter type, ventilation, additional radon exhalation sources (e.g. soil foundation, building materials, granite countertops etc.). According to EPA, radon, which enters a house from the soil underneath accounts for the major fraction of indoor radon, followed by building materials (Nielson *et al.* 1996). Nevertheless, it is of particular interest to investigate radon levels exhaled from cat litter and assess their contribution to indoor radon levels.

Since there is no data on the contribution of cat litter to indoor radon levels in Cyprus, this study aims to investigate the radon (Rn-222) exhalation from cat litter commercially available on the island. Furthermore, to the best of our knowledge and according to literature search (e.g. Scopus, google schollar etc.), there are no other publications in peer-reviewed scientific journals. What has been published appears on various websites. The exhalation measurements have been performed by putting a certain amount of cat litter in a tightly closed aluminium cylinder connected with a recirculating loop to a continuous radon monitor. In addition to the radon exhalation rates the radium and uranium content of the studied cat litter samples has been determined.

2. Experimental

Ten different cat litter samples were obtained from the local market. Two of them were produced locally (Cyprus) and eight of them were imported from different countries, including Bulgaria, France India, Italy and Turkey. The cat litter samples were analyzed without any (pre)treatment. Five grams of each sample were weighed in a plastic beaker, which was then placed in a closed loop radon emanation system. The radon emanation system consisted of a radon meter (RTM1688, SARAD), which was connected with thick wall silicon tubes to an aluminium cylinder 425 cm^3) (Lysandrou *et al.* 2007). A schematic illustration of the closed loop radon emanation system is presented in Figure 1. The measurements were obtained every two hours for about seven days.

In addition, radon exhalation measurements were performed after suspension of the samples in saturated EDTA solution (pH 4.5) to indirectly estimate the radium content of the cat litter as previously described (Liatsou and Pashalidis, 2015, Ioannidis *et al.* 2022). Specifically, 3g of each sample were undergone suspension in 50 mL 1 M EDTA solution and the steady state levels of radon (Rn-222) correlated to radon levels emanated in the same system from radium (Ra-226) solutions of defined/known radium concentration. Moreover, the total uranium concentration in cat litter samples by ICP-OES Thermo I Cap 6500 Series) after hydrochemical dissolution of 1g sample with aqua regia was determined (Varnava and Pashalidis, 2024).

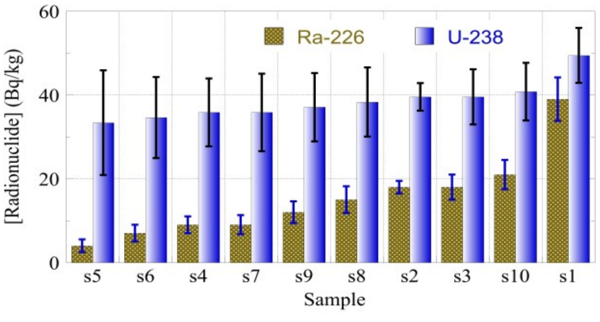


Figure 1. Uranium (U-238) and radium (Ra-226) concentration levels of in the studied cat litter samples. The uncertainties correspond to ±1s values

3. Results and discussion

The concentration of uranium (U-238) and radium (Ra-226) in the studied cat litter samples has been determined after total dissolution of a certain sample amount by aqua regia in the case of uranium and after EDTA-mediated sample dissolution and correlation of the radon emanation levels to the radium content in the sample, in the case of radium (Ra-226). Figure 1 shows the concentration levels of uranium (U-238) and radium (Ra-226) in the studied cat litter samples along with the concentration uncertainties (±1s).

These evaluated concentration levels are within the range of the corresponding concentration levels determined for uranium (U-238) and radium (Ra-226) in soils and building materials found in Cyprus (Tzortzis and Tsertos, 2004), assuming that the associated radioactivity impact is expected to be similar to the impact of the background radiation.

Although not determined in the present study, the impact of the ionizing radiation emitted by K-40 is expected to be similar to the background radiation of K-40, because potassium (along with its natural isotope K-40) is abundant and is also found at relatively increased levels in local soils and building materials (Tzortzis and Tsertos, 2004).

In addition, the radon emanation rates and radon steady state levels have been determined using a closed loop radon monitoring system. Figure 2 shows radon concentration profiles, which correspond to the sample with the highest (S1) and the lowest (S2) radon levels in the system. For comparison, Figure 1 includes also the radon activity concentration in the system in the absence of any sample (Background radon levels).

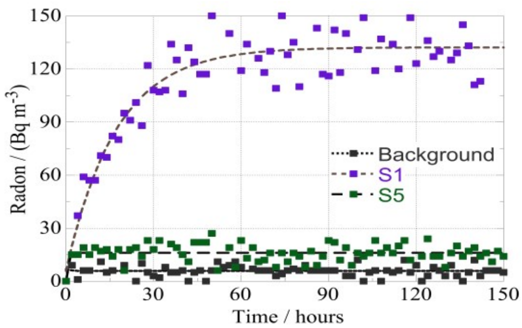


Figure 2. Radon activity concentration profiles of two representative cat litter samples, which correspond to the highest and the lowest levels of radon emanation, found in Cyprus. For comparison the background radon levels are also included

The maximum radon levels have been evaluated from the part of the curve at steady-state conditions (plateau) and are graphically summarized in Figure 3 along with their uncertainty (±1s). In addition, the radon exhalation rates of the cat litter samples have been calculated using the slope of the radon ingrowth for each curve and the associated values vary between 3 and 10 Bq m^{-2} h^{-1} with a value of 6 ± 2 Bq m^{-2} h^{-1}. The values of the radon emanation rates lie within the range of radon emanation rates given in the literature for soil samples (Sakoda *et al.* 2011; Thabayneh, 2018).

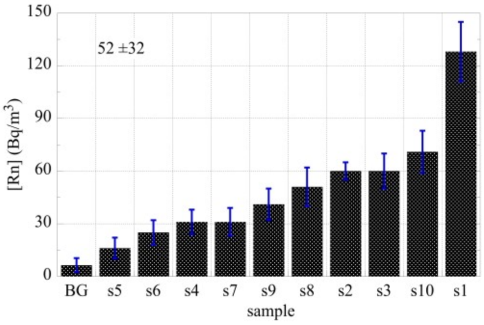


Figure 3. Mean radon activity concentration levels cat litter samples marketed in the market of Cyprus. For comparison the background radon levels (BG) are also included

Taking into account the highest steady-state radon emanated from the sample~~s~~ 1 (s1) the radon levels in a dwelling have been estimated. According to the estimation in a typical room (50 m^3) a common amount of cat litter used (5 kg) the contribution even of the strong emanating cat litter sample would be less than one Bq m^{-3} to the indoor air. This is an insignificant percentage of the indoor air radon levels (arithmetic mean value: (19±15) Bq m^{-3} and range: 4 Bq m^{-3} < [^{222}Rn] < 100 Bq m^{-3}) measured in Cyprus (Sarrou and Pashalidis, 2003). Moreover, the excess levels are below the design level for the construction of new buildings (200 Bq m^{-3}) and the reference level for existing buildings (200 Bq m^{-3}) according to the EU recommendation on indoor exposure to radon (ENHIS, 2009).

4. Conclusions

Cat litter samples commercially available in Cyprus emanate radon at variable rates depending on the concentration levels of the parent radionuclides (e.g. uranium and radium) they may contain. However, those levels are below the radon levels measured in Cypriot houses and the uranium (U-238) and radium (Ra-226) concentrations are within the range of the corresponding concentrations found in soils and building materials on the island. Hence, even cat litter samples that contain relatively increased levels of radionuclides are not expected to significantly contribute to external radiation doses and indoor radon levels, because of the low radon emanation rates and the increased ventilation of the dwellings due to the weather conditions existing on the island. The estimated radon levels are expected to be far below 200 Bq m^{-3}, which is the action level recommended by the EU.

Competing interests

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work.

References

Al-Jarallah M. (2001). Radon exhalation from granites used in Saudi Arabia, *Journal of Environmental Radioactivity*, **53**, 91–98.

Anastasiou T., Tsertos H., Christofides S. and Christodoulides G. (2003). Indoor radon (222Rn) concentration measurements in Cyprus using high-sensitivity portable detectors, Journal of Environmental Radioactivity, **68**(2), 159–169.

Efstathiou M., Sarrou I. and Pashalidis I. (2013). Emanation studies of radium-containing materials by a simple radon monitoring system, *Journal of Radioanalytical and Nuclear Chemistry*, **298**, 673–677.

European Environment and Health Information System (2009). Radon Levels in Dwellings: Fact Sheet 4.6.

Ioannidis I., Paschalidou P., Sarrou I. and Pashalidis I. (2022). Radiometric analysis of potassium, radium, and uranium levels in Brazil nuts, *Journal of Radioanalytical and Nuclear Chemistry*, **33**, 1405–1408. https://doi.org/10.1007/s10967-022-08699-y

Kitto M. and Menia T. (2009). Can cat litter be a source of indoor radon? In: Proceedings of the 21st International Radon Symposium, St. Louis, MO, January 2009.

Liatsou I. and Pashalidis I. (2015). Determination of radium by radon emanation after EDTA-mediated sample dissolution, *Journal of Radioanalytical and Nuclear Chemistry*, **306**, 445–449. https://doi.org/10.1007/s10967-015-4095-4

Lysandrou M., Charalambides A. and Pashalidis I. (2007). Radon emanation from phosphogypsum and related mineral samples in Cyprus, *Radiation Measurements*, **42**, 1583–1585;

Michael F., Parpottas Y. and Tsertos H. (2010). Gamma radiation measurements and dose rates in commonly used building materials in Cyprus, *Radiation Protection Dosimetry*, **142**(2–4), 282–291.

National Research Council (1999). Health Effects of Exposure to Radon, BEIR VI, National Academy Press, Washington, DC.

Nielson K., Holt R. and Rogers V. (1996). Contributions of building materials to indoor radon levels in Florida buildings, U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-96/107 (NTIS 97-104681).

Sakoda A., Ishimori Y. and Yamaoka K. (2011). A comprehensive review of radon emanation measurements for mineral, rock, soil, mill tailing, and fly ash, *Applied Radiation and Isotopes*, **69**, 1422–1435.

Sarrou I. and Pashalidis I. (2003). Radon levels in Cyprus, *Journal of Environmental Radioactivity*, **68**, 269–277;

Thabayneh K.M. (2018). Determination of radon exhalation rates in soil samples using sealed can technique and CR-39 detectors, *Journal of Environmental Health Science and Engineering*, **16**, 121–128. https://doi.org/10.1007/s40201-018-0298-2

Turhan Ş., Metin O., Hançerlioğulları A., Kurnaz A. and Duran C. (2022). Determination of elemental concentrations of radionuclides in Turkish bentonite and calculation of radiogenic heat generation, *International Journal of Environmental Analytical Chemistry*. https://doi.org/10.1080/03067319.2022.2140419

Tzortzis M. and Tsertos H. (2004). Determination of thorium, uranium, and potassium elemental concentrations in surface soils in Cyprus, *Journal of Environmental Radioactivity*, **77**(3), 325–338;

Varnava N. and Pashalidis I. (2024). Studies on parameters affecting uranium leaching from phosphogypsum, *Journal of Radioanalytical and Nuclear Chemistry*. https://doi.org/10.1007/s10967-023-09342-0

Yusof M.Y.M., Nasir A.M.A., Arifin M.A.M., Abdullah M., Rahim H.A.A. and Samad S.A. (2020). Study of material properties in polyethylene-based composites, *IOP Conference Series: Materials Science and Engineering*, **785**, 012020. https://doi.org/10.1088/1757-899X/785/1/012020