DETERMINATION OF NATURAL RADIOACTIVITY LEVELS OF SLUDGES COLLECTED FROM WASTEWATER TREATMENT PLANTS OF ANTALYA/TÜRKİYE

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Abstract – To determine whether the use of wastewater treatment sludge in agricultural areas poses any radiological risk or not, both natural ^{226}Ra, ^{232}Th, ^{40}K and artificial ^{137}Cs radionuclide activity concentration levels of the sludges, collected from wastewater treatment plants located in Alanya, Beldibi, Belek, Çamyuva, Göynük, Hurma, Kemer, Serik, Side and Tekirova districts of Antalya were assessed. Measurement results of the wastewater sludge samples indicate the existence of natural (^{226}Ra, ^{228}Ac, ^{40}K) and artificial radionuclides (^{137}Cs) from the Chernobyl accident and other nuclear activities. The calculated mean ^{226}Ra (10.8 Bq kg^{-1}), ^{232}Th (13.4 Bq kg^{-1}) and ^{40}K (135.7 Bq kg^{-1}) and ^{137}Cs (3.2 Bq kg^{-1}) activity concentrations of the sludges were observed to be below the world average. Findings were found to be consistent with the published results in the literature for Turkey and other countries. The absorbed gamma dose rate (D: 3.1 - 17.5 nGyh^{-1}), radium equivalent activity (Ra_{eq}: 6.4 - 37.7 Bq kg^{-1}), annual equivalent dose (AED: 3.8 – 21.4 μSv h^{-1}), internal (H_{in}<1.0) and external (H_{ex}<1.0) hazard indices were calculated by using sample activity concentrations. The radiological risk indices (D, Ra_{eq} and AED) are in the permissible limits published by IAEA. As a result, it was observed that the use of wastewater treatment sludge in agricultural areas would not create any risk in radiological terms.

Introduction

Urban wastewater sludge is an end product of urban wastewater treatment and contains many pollutants left over from wastewater treatment. Sewage sludge is a concentrated solids suspension, which consists mostly of organic solids loaded with mineral salts and whose density can vary in slurry or dry form depending on the treatment technique. Today, the agricultural use of sewage sludge is accepted as an economical alternative disposal method compared to other disposal methods. The common finding of the studies carried out to date is that sludge has an economic value in plant cultivation, but pollutants that can mix into the sludge significantly limit their use. Increasing interest and encouragement in the use of sewage sludge, which contains many pathogens and pollutants, is creating increasing social concern over the environmental consequences and potential health hazards of these recycling practices. The production of large quantities of sewage sludge in urban areas, which may contain relatively high levels of salt and heavy metals and other harmful organic pollutants, increases the need for solutions for the safe disposal of

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this material without causing new ecological problems.

In recent years, the use of sewage sludge in agriculture has been made safer with legal regulations regarding the use of sewage sludge in agricultural lands. However, studies on radioactive contamination of sewage sludge are very limited. In this study, sludge from treatment plants in Antalya region will be evaluated in terms of radioactivity pollution.

Materials and Methods

Sludge samples were collected from wastewater treatment plants located around Alanya, Beldibi, Belek, Çamyuva, Göynük, Hurma, Kemer, Serik, Side and Tekirova districts of Antalya province of Türkiye on a monthly basis for one year (Figure 1).

Figure 1 – Study area.

The sludges were numbered and labeled after they were transferred to the sample preparation laboratory of Akdeniz University, Faculty of Science, Department of Physics. Foreign substances and impurities in each sludge sample were removed. Before the measurements, all sludge samples were stored (air-dried) 4–7 d until they reached a constant weight in a ventilated room. All samples were homogenised with the grinding machine and then sieved through a 2-mm mesh in the sample preparation laboratory. The sieved samples were then filled into hermetically sealed (6cm x 5cm) 150 cc polyethylene cylindrical containers, labelled,weighed and stored for 4 weeks in order to reach secular equilibrium between ^{226}Ra and ^{222}Rn prior to counting. Approximately 5 g of sludge from each sample were put in 6-cm diameter cylindrical containers and dried at 80 ˚C for 14 h to determine the moisture rate of the samples.

Radioactivity measurement was conducted by using a p-type, coaxial, electrically cooled, high-purity germanium gamma-ray detector AMATEK-ORTEC with Full Width Half Maximum (FWHM) at 122 keV for ^{57}Co and 1.85-keV FWHM at 1332 keV for ^{60}Co. It is connected to an NIM consisting of ORTEC bias supply, spectroscopy amplifier, analogue-to-digital converter and a computer. The detector was placed into a 10-cm thick lead shield with an inner surface covered by a 2-mm thick copper foil to shield from the x-rays originating in lead. Data acquisition and analysis were carried out with MAESTRO32 software.

All samples were placed to the front face of the detector and counted for 50 000 s. Background intensities were obtained with an empty beaker for 50 000 s under the same conditions before and after measurement of the samples. Then, the average of the background counts was subtracted from the sample spectrums. ^{238}U and ^{232}Th activity concentrations were determined from their daughter products indirectly, while ^{137}Cs and ^{40}K were determined directly by their gamma-ray peaks. To determine the activity concentration of the ^{238}U nuclide, daughter nuclides ^{214}Pb and ^{214}Bi were used, while ^{228}Ac concentration was chosen for the parent ^{232}Th. The gamma transitions of 351.9 keV ^{214}Pb and 609.3 keV ^{214}Bi were used to determine the concentrations of ^{238}U. The gamma transition of 911.2 keV ^{228}Ac was used to determine the concentration of ^{232}Th. 661.6 keV and 1461.0 keV gamma transitions were used to determine the concentration of ^{137}Cs and ^{40}K, respectively. Details of the activity and dose calculations were presented by Ozmen et.al.

Results and Discussion

Measurement results of the wastewater sludge samples indicate the existence of natural (^{226}Ra, ^{228}Ac, ^{40}K) and artificial radionuclides (^{137}Cs) from the Chernobyl accident and other nuclear activities. Activity concentration levels of the sludges were presented in Figure 2.

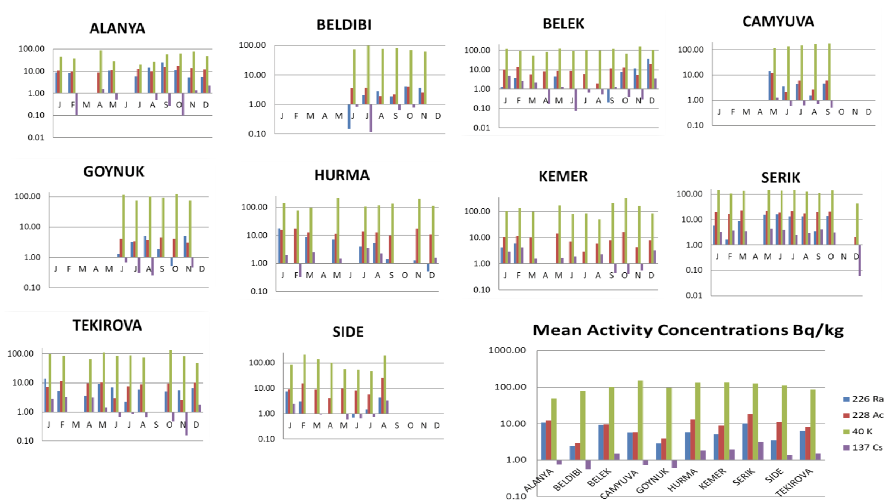

Figure 2 – ^{226}Ra, ^{228}Ac, ^{40}K and ^{137}Cs activity concentrations of Sludges in Bq/kg.

The calculated mean ^{226}Ra (10.8 Bq kg^{-1}), ^{232}Th (13.4 Bq kg^{-1}) and ^{40}K (135.7 Bq kg^{-1}) and ^{137}Cs (3.2 Bq kg^{-1}) activity concentrations of the sludges were observed to be below the world average UNSCEAR (2000). Findings were found to be consistent with the published results in the literature for Türkiye and other countries (Table 1).

Table 1 – Radionuclide activity concentrations of soil samples from Literature (in Bq/kg).

Country	^{226}**Ra**	^{232}**Th**	^{40}**K**	**Reference**
Türkiye	29	22	464	Yaprak & Aslani (2010)
Greece	16	55	305	Ioannides et.al. (1997)
Hong Kong	59	95	530	Wong et.al. (1999)
India	57	87	143	Singh et.al. (2005)
Pakistan	51	59	665	Chauhry et.al. (2002)
Serbia	60	49	379	Dugalic et.al. (2010)
Yugoslavia	39	53	554	Bikit vet.al. (2001)
Bosnia Herzigova	32	32	331	Kasumovic et.al. (2015)
Italy	79	48	640	Guidotti et.al. (2015)
World Mean	35	30	400	UNSCEAR (2000)
Present study	2.4-5.7	3.0-5.8	79-150	

In order to determine the health effects, radiologic risk parameters (D, Raeq,AED, Hex and Hin) of the sludges are calculated and results were presented in Figure 3.

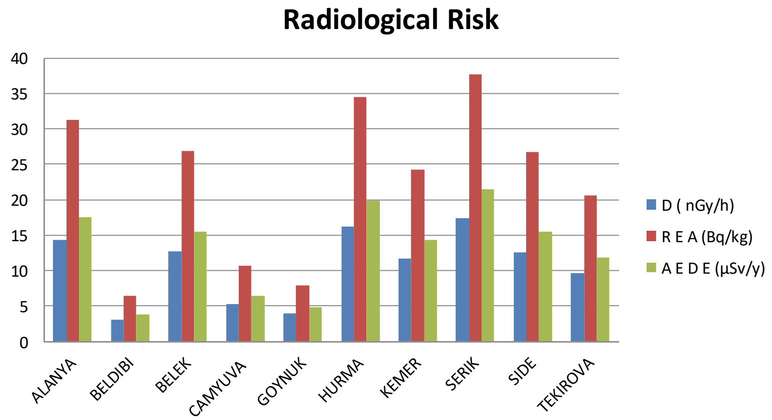

Figure 3 – Mean D, Ra_{eq} and AED values of Sludges.

The absorbed gamma dose rate (D: 3.1 - 17.5 $nGyh^{-1}$), radium equivalent activity (Ra_{eq}: 6.4 - 37.7 Bq kg^{-1}), annual equivalent dose (AED: 3.8 – 21.4 μSv h^{-1}), internal (H_{in}<1.0) and external (H_{ex}<1.0) hazard indices were calculated by using sample activity concentrations. The calculated average values for D, Ra_{eq} and AED are in the permissible limits published by IAEA.

Conclusion

Radionuclide concentrations of waste water sludge samples around Antalya were determined by the present study. Findings were lower or comparable to the literature levels for soil samples around the world. Moreover, annual effective dose exposure due to the radioactivity content of sludges was not very high to pose a serious health risk.

We can conclude that the use of wastewater treatment sludge in agricultural areas would not create any risk in radiological terms. In terms of chemical properties, the Cs element is remarkably similar to the element K, which is a plant nutrient and is consumed significantly by plants. Since sewage sludge contains ^{137}Cs even in low concentrations, it is obvious that care should be taken both in its use in agricultural areas and in discharges to the open sea and similar situations.

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References

[1] Bikit IS, Vesković MJ, Slivka JM, Krmar MD, Ćèonkić LU, Ćurćić SM (2001) *The radioactivity of Vojvodina agricultural soil*. Archives of Oncology 9(4):261–265.

[2] Chauhry ZS, Khan MH, Aslam M, Jabbar A, Orfi SD (2002) *Terrestrial absorbed dose rate measurements in the Jhangar valley of Pakistan*. J Radioanal Nucl Chem 253(3):497–499.

[3] Dugalic G, Krstic D, Jelic M, Nikezic D, Milenkovic B, Pucarevic M, Zeremski-Skoric Z (2010) *Heavy metals, organics and radioactivity in soil of western Serbia*. J Hazar Mater 177(1–3):697–702.

[4] Guidotti L, Carini F, Rossi R, Gatti M, Cenci RM, Beone GM (2015). *Gamma-spectrometric measurement of radioactivity in agricultural soils of the Lombardia region, northern Italy*. J Environ Radioact 142:36–44.

[5] Ioannides KG, Mertzimekis TI, Papachristodoulou CA, Tziallab CE (1997) *Measurement of natural radioactivity in phosphate fertilizers*. Sci Total Environ 196(1):63–67.
[6] Kasumović A, Adrović F, Kasić A, Hankić E (2015) *Natural radioactivity and radiation hazards assessment of soil samples from the area of Tuzla and Lukavac, Bosnia and Herzegovina*. Isot Environ Health Stud 51(3):469–477.
[7] Ozmen, S. F. (2020). *Ecological assesment of Akkuyu nuclear power plant site marine sediments in terms of radionuclide and metal accumulation*. Journal of Radioanalytical and Nuclear Chemistry. doi:10.1007/s10967-020-07201-w
[8] Singh S, Rani A, Mahajan RK (2005) *^{226}Ra, ^{232}Th and ^{40}K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry*. Radi Meas 39:431–439.
[9] UNSCEAR 2000. *Sources and effects of ionizing radiation. Report to General Assembly, with Scienti_c Annexes*. United Nations Scienti_c Committee on the Effect of Atomic Radiation.
[10] Wong MC, Chan YK, Poon HT et al (1999) *Environmental gamma absorbed dose rate in air in Hong Kong*. Environmental Radiation Monitoring in Hong Kong. Technical Report No. 17.
[11] Yaprak G, Aslani MAA. 2010. *External dose-rates for natural gamma emitters in soils from an agricultural land in West Anatolia*. J Radioanal Nucl Chem 283: 279-287.