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# Assessment of Radioactivity Levels of Wastewater Treatment Plants Sludges of Eastern Antalya

Bulent TOPCUOGLU[1], Suleyman Fatih OZMEN[2,3]

[1]Department of Plant and Animal Production, Vocational School of Technical Sciences, Akdeniz University, Antalya, 07058 (Türkiye)
[2]Nuclear Technology and Radiation Safety, Vocational School of Technical Sciences, Akdeniz University, Antalya, 07058 (Türkiye)
[3]Turkish Accelerator and Research Laboratory, Ankara (Türkiye

***Abstract***: *Both natural $^{226}$Ra, $^{232}$Th, $^{40}$K and artificial $^{137}$Cs radionuclide activity concentration levels of sludge collected from wastewater treatment plants operating in Alanya, Belek, Serik and Side districts were determined in order to determine whether the wastewater treatment sludge, used as fertilizer in agricultural areas recently, poses any radiological risk. The measurement results of wastewater sludge samples, the presence of $^{137}$Cs activity concentration levels as well as natural ($^{226}$Ra, $^{228}$Ac, $^{40}$K) radionuclides indicate the continuation of the effects of the Chernobyl accident and other nuclear activities in the region. The calculated mean activity concentrations of the sludge for the examined area were determined as 8.5 Bq kg$^{-1}$ for $^{226}$Ra, 12.1 Bq kg$^{-1}$ for $^{232}$Th, 96.9 Bq kg$^{-1}$ for $^{40}$K and 1.7 Bq kg$^{-1}$ for $^{137}$Cs and observed to be below the world average. Findings were found to be consistent with the literature. The calculated mean absorbed gamma dose rate (D), radium equivalent activity ($Ra_{eq}$) and annual equivalent dose (AED) levels were 14.2 nGyh$^{-1}$, 30.7 Bq kg$^{-1}$ and 17.5 µSv h$^{-1}$, respectively. The radiological risk indices (D, $Ra_{eq}$ and AED) are all in the permissible limits reported by IAEA. It was observed that the use of wastewater treatment sludge in agricultural areas as fertilizer would not create any risk in terms of radiological hazard.*

***Keywords:*** *Radioactivity activity, treatment sludge*

## 1. 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 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 Western Antalya region will be evaluated in terms of radioactivity pollution.

## 2. Materials and Methods

Sludge samples were collected from wastewater treatment plants located in Alanya, Belek, Serik and Side districts (Eastern part of Antalya province) of Türkiye on a monthly basis for one year (Figure 1). 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 ml 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$^{0}$C for 14 h to determine the moisture rate of the samples.


Fig. 1: Study area

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 [1].

## 3. Results and Discussion

Measurement results of the wastewater sludge samples indicate the existence of both 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.

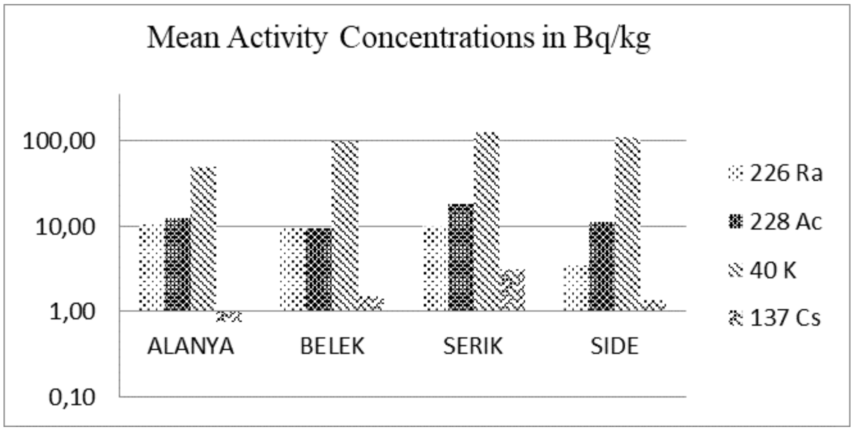


Fig 2 – $^{226}$Ra, $^{228}$Ac, $^{40}$K and $^{137}$Cs activity concentrations of Sludge in Bq/kg

The calculated $^{226}$Ra activity concentrations were ranged from 5.5 to 11.2 with a mean (10.8 Bq kg$^{-1}$) for Alanya district, from BDL to 37.1 with a mean (9.5 Bq kg$^{-1}$) for Belek district, from 1.7 to 16.3 with a mean (10.3 Bq kg$^{-1}$)for Serik district and from 0.7 to 7.5 with a mean (3.5 Bq kg$^{-1}$)for Side district.

The calculated $^{232}$Th activity concentrations were ranged from 9.0 to 17.6 with a mean (12.4 Bq kg$^{-1}$) for Alanya district, from 1.9 to 19.9 with a mean (9.6 Bq kg$^{-1}$) for Belek district, from 2.0 to 23.2 with a mean (18.4 Bq kg$^{-1}$) for Serik district and from 5.8 to 26.1 with a mean (11.1 Bq kg$^{-1}$)for Side district.

The calculated $^{40}$K activity concentrations were ranged from 20.4 to 87.9 with a mean (49.6 Bq kg$^{-1}$) for Alanya district, from 52.8 to 155.5 with a mean (100.4 Bq kg$^{-1}$) for Belek district, from 44.0 to 151.1 with a mean (125.8 Bq kg$^{-1}$) for Serik district and from 47.2 to 195.8 with a mean (112.0 Bq kg$^{-1}$)for Side district.

The calculated $^{137}$Cs activity concentrations were ranged from BDL to 2.2 with a mean (0.8 Bq kg$^{-1}$) for Alanya district, from BDL to 4.9 with a mean (1.5 Bq kg$^{-1}$) for Belek district, from BDL to 4.3 with a mean (3.2 Bq kg$^{-1}$) for Serik district and from 0.6 to 3.4 with a mean (1.4 Bq kg$^{-1}$)for Side district.

The calculated $^{226}$Ra, $^{232}$Th, $^{40}$K and $^{137}$Cs activity concentrations of the sludges were observed to be below the world average [2]. Findings were found to be consistent with the published results in the literature for Türkiye and other countries (Table 1).

TABLE I: Radionuclide activity concentrations of soil samples from Literature (in Bq/kg).

| **Country** | **$^{226}$Ra** | **$^{232}$Th** | **$^{40}$K** | **Reference** |
|---|---|---|---|---|
| Türkiye | 29 | 22 | 464 | [3] |
| Greece | 16 | 55 | 305 | [4] |
| Hong Kong | 59 | 95 | 530 | [5] |
| India | 57 | 87 | 143 | [6] |
| Pakistan | 51 | 59 | 665 | [7] |
| Serbia | 60 | 49 | 379 | [8] |
| Yugoslavia | 39 | 53 | 554 | [9] |
| Bosnia Herzigova | 32 | 32 | 331 | [10] |
| Italy | 79 | 48 | 640 | [11] |
| World Mean | 35 | 30 | 400 | [2] |
| Present study | 8.5 | 12.1 | 96.9 | |

By using the radionuclide activity concentrations, radiologic risk parameters: The absorbed gamma dose rate (D), The radium equivalent activity ($Ra_{eq}$) ,The annual equivalent dose (AED), External hazard index ($H_{ex}$) and Internal hazard index ($H_{in}$) of the sludges wwere also calculated and results were presented in Figure 3.

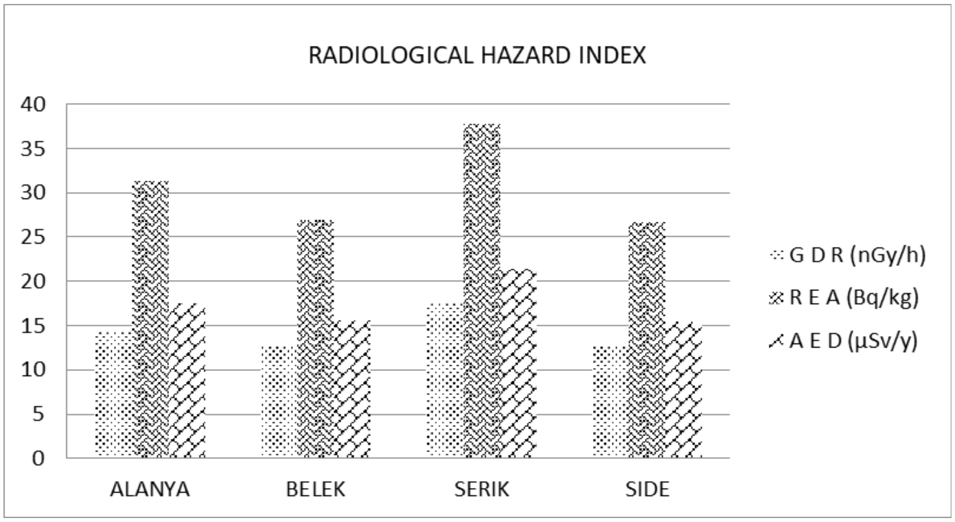


Fig 3 – Mean D, $Ra_{eq}$ and AED values of Sludges

The calculated mean absorbed gamma dose rate (D), were ranged from 12.7 $nGyh^{-1}$ (Belek) to 17.5 $nGyh^{-1}$ (Serik) with a mean (14.2 $nGyh^{-1}$), radium equivalent activity ($Ra_{eq}$) were ranged from 26.7 Bq $kg^{-1}$ (Side) to 31.3 Bq $kg^{-1}$ (Alanya) with a mean 30.7 Bq $kg^{-1}$, annual equivalent dose (AED) levels were ranged from 15.4 µSv $h^{-1}$ (Side) to 21.4 µSv $h^{-1}$ (Serik) with a mean 17.5 µSv $h^{-1}$, internal ($H_{in}$<1.0) and external ($H_{ex}$<1.0) hazard indices were less then unity. The radiological risk indices (D, Raeq and AED) are all in the permissible limits reported by IAEA.

# 4. Conclusion

Radionuclide activity concentrations of waste water sludge samples of Eastern 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 as fertilizer would not create any risk in terms of radiological hazard. 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.

# 5. Acknowledgements

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