IMPACT OF RADIONUCLIDE WASTE SITE ON GROUNDWATER AND SOIL

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ABSTRACT

This study was carried out on a radionuclide waste site located in the Gaziemir district of Izmir Metropolitan Municipality, Turkey. Toxic wastes have been randomly stored on the site. The surface area of the site is around 80.000 square meters, and the total amount of waste deposited at the site since 1940 is approximately 10.000 m^3. The wastes are composed mainly of recycled battery waste which contains hazardous elements and radionuclides. The major risk of the waste is its closeness to residential areas and the media in Turkey have focused on this environmental disaster since 2012. The waste pile emplaced at the head of a tributary stream has caused channeling of leachate into the groundwater and stream, which is eventually used for irrigation of agricultural fields. A series of engineering studies were carried out to assess the effects of this waste on the groundwater and soil in 2013. Thirty-three trenches (depth range from 1.5m to 3m) and twelve core drillings (240 meters in total depth) were dug in order to determine the amount of waste and its effects on site. Eighty-seven soil samples were collected for heavy metal analysis, such as arsenic (As), lead (Pb), copper (Cu) and zinc (Zn), and forty-three samples of soil which included waste were collected to measure radioactivity in the trenches and drillings. Water samples were collected at eight points. Four observation wells (each 20m deep) were drilled in front of the waste site. Two of the wells, one deep-drilled hole and one present spring, were monitored for physical (pH, EC, temperature), chemical (major anion and cation, heavy metals) and radionuclide (Eu-152) properties of the groundwater.

The results show that soil and groundwater samples included high concentrations of hazardous elements such as lead, zinc and arsenic that exceed national and international limits. The highest radioactivity (Eu-152) was measured at the site where the waste was stored on the surface. The Eu-152 value of the waste is over the contamination limit level stated in the Council Directive 96/29/EURATOM. However, no radiation contamination was found in the groundwater.

Keywords: Radionuclide, heavy metals, groundwater, contamination, toxic waste

1. Introduction

Environmental and health hazards associated with illegal dumping of waste are well known (Appleyard, 1996; Christensen, 1989; Frempong, 1999). Illegal dumping and landfills are a threat to water resources when water percolates through waste, picking up a variety of substances such as heavy metals, organic chemicals and other toxic materials (Appelo and Postma 1999; Baba and Tokgoz, 1999; Baba, 2000; Baba, 2003; Christoph and Dermietzel, 2000; Chiocchini *et al*., 1997; Colten, 1998; Daniels *et al*., 2000; Kabata and Pendias, 2001; Kim *et al*., 2003; Langer, 1998; Massone *et al*., 1998; Khan *et al*., 2008; Wuanal and Okieimen, 2011; Ehirim and Itota, 2013). Excess heavy metal accumulation in water resources is toxic enough to cause risk to human health, plants, ecosystems and animals. In the environment, the heavy metals and radionuclides fundamentally become contaminants, because their rates of generation via manmade cycles are more rapid relative to natural ones, and the concentrations of metals in discarded products are relatively high compared to those in the receiving environment (D'Amore *et al*., 2005).

The expansion of Izmir Metropolitan Municipality over the last 40 years has been rapid and poorly-controlled in terms of local considerations, both geological and hydrogeological. There has been a lack of monitoring of the effects of wastes and inadequate attention has been paid to the disposal of wastes in the area. The area investigated in this study is located in the Gaziemir district of Izmir (Figure 1). A currently-inactive lead casting plant owned by a private company entered service in 1940. However, according to Ministry of Industry registration documents, the company was registered as #10503 on 20.03.1970 and the date of the company's establishment is given as 1956. Toxic wastes from this company were randomly stored on site. The surface area of the site is around 80.000 square meters, and the total amount of waste deposited at the site was approximately 10.000 m^3. The wastes consist mainly of recycled battery wastes containing hazardous elements and radionuclides. The major risk of the waste is its closeness to residential areas. Turkish media have been highlighting this potential environmental disaster since 2012.

The main objectives of this study are (i) to determine the exact extent of the contaminated site and amount of waste, (ii) to evaluate the effects of the radionuclide waste site on soil and groundwater contamination.

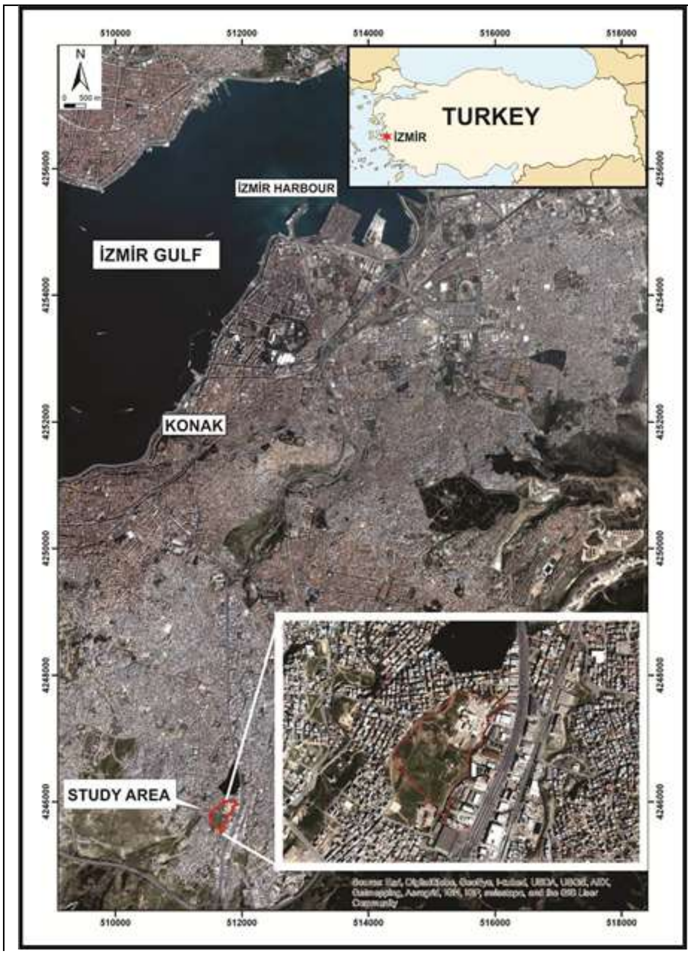

Figure 1: Location map of study area

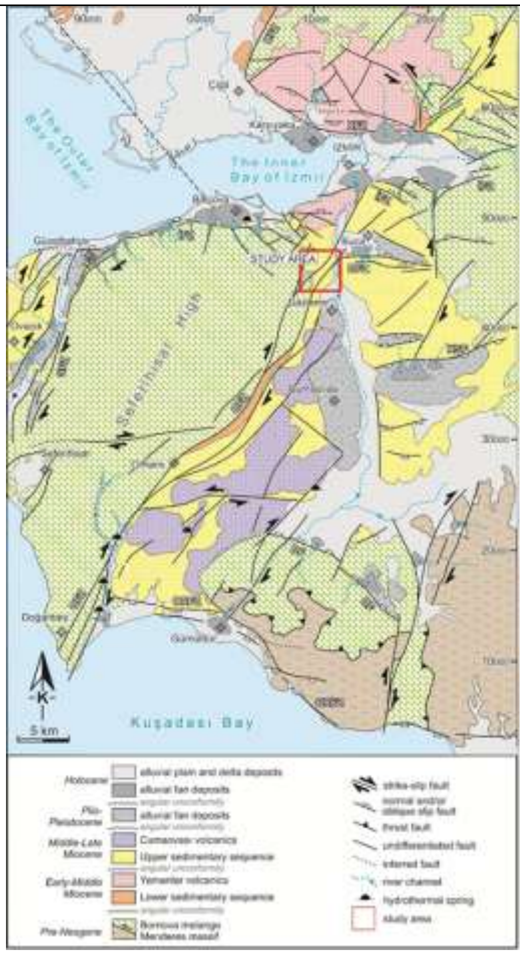

Figure 2: Geological map of study area (from Uzel *et al*., 2012).

2. Geological and hydrogeology

The rock units exposed in the study area are divided into two groups (basement and older basin fill materials). Bornova flysch zone (also called Bornova melange) is the basement of the study area. Bornova flysch zone is composed of various-sized blocks of limestone, cherts, submarine volcanics and serpentinites embedded in a flysch-type sedimentary matrix (Okay *et al*., 1996; Uzel *et al*., 2012). The Miocene stratigraphy of the older basin fill material is unconformably overlain by the Bornova flysch zone in the study area. The overlying unit is made up of brown sandstone, mudstone and conglomerate (Figure 2). Hazardous waste was stored randomly on top of older basin fill materials (see Figure 3).

From a hydrogeological point of view, the study area is mostly characterized by shallow and deep aquifers around the study area. Shallow aquifer is located along the floodplains of the surface drainage network. This aquifer has significant groundwater potential that is primarily used for irrigational and industrial water supply. The groundwater level of the shallow aquifer is in the range from 0.5 m to 16.8 m whereas the groundwater level reaches up 73 meters at the deep aquifer. The shallow aquifer is provided by the Miocene unit of the older basin fill material consisting of sandstone, conglomerate and mudstone; the deep aquifer, consisting of a low flow rate, is found in the Bornova flysch zone. Precipitation has affected the static water level in the shallow aquifer. After precipitation, the static water level increases by approximately 3 m in the study area. The flow rate of the wells is low (<Q=0.1). The flow direction of the surface water and shallow groundwater is in an E-NE direction, from the waste site to the stream.

3. Materials and methods

This research was based on field studies, laboratory analysis and spatial data assessment in order to assess the effect of the radionuclide site on soil and groundwater.

3.1. Water Sampling

Water samples were collected at eight points in order to examine the degree of groundwater contamination in front of the waste site (Figure 4). Four observations wells (each 20m; G-1-G-4), were drilled in the study area. In addition, two dug wells (G-6, G-7), one deep-drilled hole (G-8) and one spring (G-5) were used to monitor physical properties, major anions and cations, heavy metals and trace elements, and radionuclides (Eu-152).

3.2. Soil Sampling

A total of eighty-seven soil samples (thirty-three from trenches and forty from drillings) were collected from both trenches and core drill samples that represent all characteristics of the polluted area. Approximately 3 kg of soil samples were collected vertically at the trenches (AC), drilling sites (SK-1-SK-8) and observation wells (G-1-G4) (see Figure 4). The trench depth ranged from 1.5m to 3m in the study area. Twenty core drillings (240m in total) were made in order to observe the amount, area and effects on the water caused by the waste. The soil samples were analyzed in terms of heavy metals and radioactivity.

4. Results and discussion

4.1. Hydrogeochemical properties of water

The result show that the groundwater is predominantly alkaline and its pH is above 7 at the site. The EC values of the water samples ranged from 367 to 3450 µS/cm in the study area. EC offers the opportunity to examine the drinkable and irrigation properties of groundwater. High concentrations of heavy metals such as arsenic (As), lead (Pb), iron (Fe) and manganese (Mn) were measured at the observation wells at the dump site and its surroundings. These toxic elements exceeded both national and international standards. Almost every month, high arsenic, lead, iron and manganese, exceeded both national and international limits at GK-1 and GK-2. Furthermore, antimony and aluminum values exceeded the limits at GK-2. As for the GK-3 observation well, aluminum (avg= 29715,78 µg/L), antimony (avg=8µg/L), arsenic (avg=90,72 µg/L) and lead (539,35 µg/L) values exceeded both national and international water limits. Similarly, high lead (avg= 155,30 µg/L), aluminum (avg= 3471,95 µg/L), iron (avg= 2394,91 µg/L) and manganese (avg= 714,68µg/L) values were measured in GK-4. Although GK-5 is close to the dump site, this spring does not include any toxic elements except for selenium (avg=24,28 µg/L). GK-6 is located to the south of the study site and this observation well has not been affected by the waste. At the GK-7 well, dug within the operational area, only iron values (avg= 710,60 µg/L) exceeded the limits. The deep well (depth 160 m) numbered GK-8 has high arsenic (avg= 852,02 µg/L) and high iron (avg= 57640,43 µg/L) concentration.

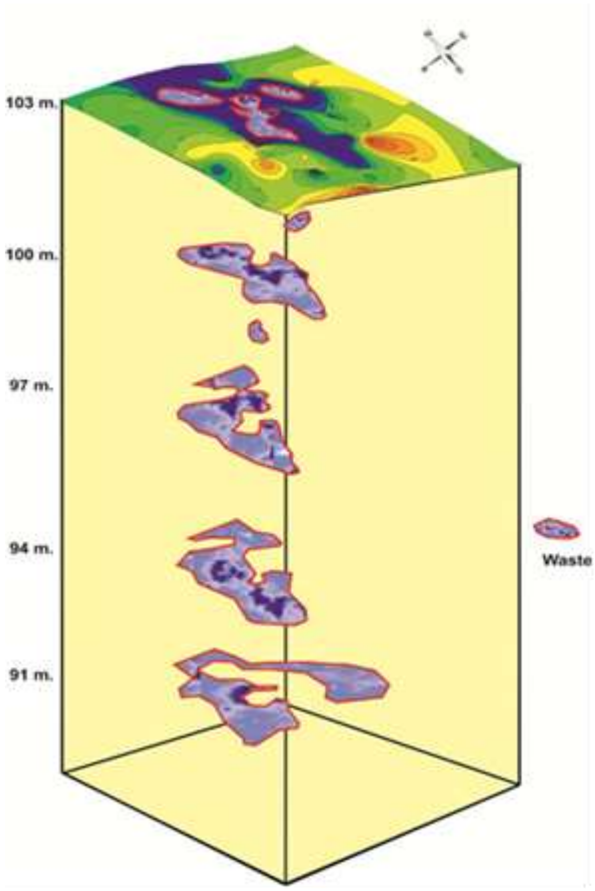

Figure 3: Spread of waste in study area according to depth

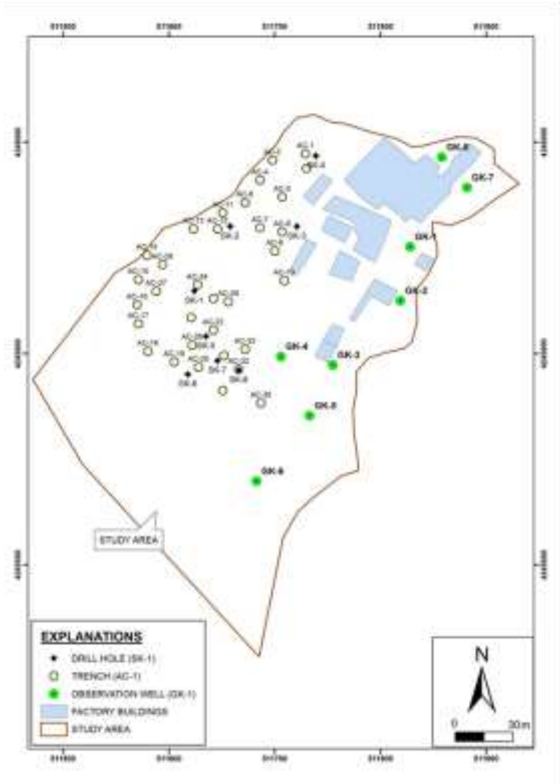

Figure 4: Map of sampling locations.

4.2. Physical and chemical properties of soil

The results show that high As (reach up to 4120 µg/L), Pb (reach up to 9996 mg/L) and Cu (reach up to 2256 mg/L) concentrations were found at SK-5, SK-6, SK-7 and SK-8, where wastes were stored. The pollutant concentrations at these sites exceeded the limit values of the Turkish Ministry of Environment and Urban Planning.

4.3. Radioactivity in water and soil

In order to determine the effects of radioactivity (especially Europium_Eu-152), samples were taken from water (in observation wells and drillings), soil (in drillings and trenches) and waste in the study area (see Figure 4).

It was seen that Eu-152 values ranged from 0.9 to 2.7 (Bq/Kg) in water samples from the drillings and observation wells. The highest Eu-152 values were observed in AC-19 (362,3 Bq/Kg), AC-20 (26,7 Bq/Kg), AC-21 (900 Bq/Kg), AC-23 (25,3 Bq/Kg) and AC-32 (835,9 Bq/Kg) trenches. In addition high Eu-152 was measured in the factory areas where the waste was stored randomly. It can be observed that Eu-152 values range from 2.2 to 15060 Bq/Kg in this randomly-stored area. The highest Eu-152 value was measured in the K-8 location of the study area. The Eu-152 values exceed Council Directive 96/29/EURATOM stated values for sample K-8.

5. Conclusion

Approximately 10.000 m^3 of radionuclides with toxic waste was discovered in the studied area of Gaziemir. High concentrations of toxic elements such as lead, arsenic, zinc and manganese were found in the water resources and soil. Furthermore, Eu-152 radioactive element was found in toxic waste and soil. Eu-152 was not found in the water sources.

The results show that the water in the shallow aquifers has been affected by toxic heavy metals which exceed both national and international drinking water limits. In addition, buried waste has also leaked into the soil at certain locations and heavy metal accumulation was observed in these locations.

The randomly stored waste contains high-level concentrations of toxic elements. Heavy metal contamination of soil and water is one of the biggest environmental risks for human health and the ecosystem. Local residents of Gaziemir district have been anxious about this environmental problem since 2012. Therefore, it is important to monitor and find an urgent remedy to the impact of waste materials stored in such close proximity to a densely populated residential area.

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