Original Research

Assessing the Impacts of Seasonal Variations on Predicting Leachate Generation in Gumushane Open Dump Using Water Balance Method

Salim Serkan Nas[1]*, Evin Nas[2]

[1]Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Gümüshane University, 29100 Gümüshane, Turkey
[2]Department of Construction Technologies, Karadeniz Technical University, 61300 Trabzon, Turkey

Received: 15 July 2013
Accepted: 21 March 2014

Abstract

Leachate quality varies depending on many factors such as the depth and the content of solid waste, seasonal variations in solid waste, and the duration of storage of solid waste; design and operation of storage space; geological and hydrogeological characteristics of storage area; and environmental interaction of leachate, which affect each other. One of the two major sources of leachate is the moisture content of the waste stored and the other is the mass of water entering the storage area from outside. A major part of the mass of water entering the storage area from outside is the infiltration of rain water through the storage area.

The purpose of this study is to assess the seasonal variation in leachate of Gümüshane (Central) open dump area using the 'water balance method' for the determination of the factors affecting the seasonal variation in leachate of landfill, which particularly holds a higher risk of contaminating the environment. In addition, some of the measures to be taken in solid waste storage areas in order to minimize the mass of leachate are presented.

Keywords: water balance method, leachate, open dump, sanitary landfill

Introduction

In most parts of the world today, solid wastes are disposed of either in open dumps or sanitary landfills, or by incineration. As incineration and sanitary landfilling are expensive – both in initial investment and throughout their operation – their use is mostly confined to developed countries, while open dumping is the method used in economically developing countries, mainly due to its simplicity and low cost. Developing countries' traditional means of disposing of solid waste has been to dump it at these open sites or at sea and in rivers. For this reason, few studies of waste characteristics or management alternatives have been conducted [1-3]. While the need for water resources is continuing to grow in our country as is the case in the world, adverse environmental pressures on limited resources are also increasing. One of these negative environmental pressures is the leachate occurring in solid waste storage areas [4-6]. Pollutants found in leachate are transported in the short and long term in various ways and have negative effects on the soil, living things, and our major sources of water, namely surface and underground water sources [3, 7-9].

Organic wastes constitute a major part of municipal solid waste. They cause some unwanted problems both in sanitary or unsanitary landfilling and incineration of municipal solid waste. Some of the problems in sanitary or unsanitary landfilling are leachate, which have polluting potential

*e-mail: serkannas@gmail.com

for groundwater and superficial water sources, generated as a result of degradation and decomposition of organic materials and uncontrolled release of landfill gases, which may cause serious health problems when inhaled, such as hydrogen sulphur (H_2S), carbon dioxide (CO_2), and methane (CH_4) [4, 10, 11]. Some of the problems in incineration are that additional fuel is needed due to the fact that organic materials have high moisture content and low caloric value, and air pollution, which is caused by some unwanted gases generated as a result of incineration [5, 10, 12, 13].

Today, incineration, composting, unsanitary storage, pyrolysis, plasma arc, sanitary storage, and recycling methods can be used for the disposal of solid waste [3, 4]. Sanitary storage (landfill) is regarded as the most common, economical, and environmentally friendly practice implemented all over the world for the disposal of solid waste. Unsanitary storage for the disposal of solid waste, on the other hand, is the process of randomly discharging solid waste in the open land without taking any measures [4, 5, 14-16]. Leachate and gases occurring in such uncontrolled waste storage areas may accumulate and become very dangerous for the environment [13, 17]. Over the past 20 years experimental testing and field pilot studies have been conducted to develop and improve landfill techniques and designs, the goal being to control the negative effects of landfill sites on the environment. Increasingly, landfills are considered to be bioreactors improving waste degradation [18].

On the other hand, many settlements in our country do not have sanitary solid waste storage areas yet. Leachate originating from irregularly stored masses of solid waste may pose a significant threat to the environment. One of the two major sources of leachate is the moisture content of the waste stored and the other is the mass of water entering the storage area from outside [5, 19, 20]. Leachate may contain high amounts of pollutants originating from storage areas and contaminate water sources. It is very expensive to eliminate the environmental pollution occurring in such situations and to clean the water sources [21, 22]. High-tech solutions applied for leachate treatment (i.e. reverse osmosis or ozonation) are expensive and energy consuming, thus they are not suitable at many landfill sites, especially in rural areas [21].

Heavy metals are one of the most important contaminants in water and soil. Heavy metals are discharged to the environment by several industries and landfills. The removal of heavy metals from wastewaters and leachate are of critical importance due to their high toxicity and tendency to accumulate in living organisms [9, 23-25]. Solid waste landfills become rich in heavy metals such as cadmium, nickel, and zinc within a few years; and surface and ground waters are subject to potential risk due to the movement of heavy metals depending on the leaching capacity of organic matter. Due to a number of unsanitary storage areas in many parts of the world that lack a system for leachate collection, the leachate containing organic and inorganic pollutants negatively affect the quality of water resources and soil layers [11, 26-28]. Previous studies have provided evidence of organic carbon dissolved at high concentrations in underground water sources, which suggest contamination due to solid waste leachate [5, 28].

In case excess mass of water above the water holding capacity of the landfill infiltrate the solid waste piles, the solid waste cannot retain this excess water and release it to the environment. This excess water defined as leachate is exposed to certain physical, chemical, and biological processes during the infiltration through solid wastes and contains many elements and compounds originating from the content of solid wastes. These pollutant compounds are dissolved or suspended in water and transported outside the storage area [4, 5, 29-31]. A temporary perched leachate zone may appear in an intermediate layer. This situation is emphasized in very high landfills where, due to the consistent decrease of effective porosity, the water infiltration into the upper waste layers due to precipitation can be significantly higher than the water moving down toward the lower layers [11, 32, 33]. Some factors affecting the formation of leachate in the solid waste dump site and the movement of leachate toward the base of the area are shown in Fig. 1 [3, 6, 7].

The composition of landfill leachate is diverse and depends on type of waste, the volume of infiltrating water, the age of the landfill, waste storage technologies, and susceptibility of waste to degradation [17, 33, 34]. The quality of leachate is highly variable and it has a wider range of pollution load in comparison to many types of industrial wastewater. The quality of the leachate varies depending on many factors, such as the depth and content of the solid waste, seasonal variations in solid waste, the duration of storage, the mass of leachate transferred back to the area, the design and operation of storage space, geological and hydrogeological characteristics of the storage area, and environmental interaction of leachate, which all affect each other [11, 18, 25, 34].

One of the two major sources of leachate is moisture content of the waste stored. The other is the mass of water entering the storage area from outside. The water that enters the storage area is comprised of infiltration of rainwater through the storage area and waters originating from surface waters and high levels of underground waters. Among these different sources of water, rainwater is observed to be

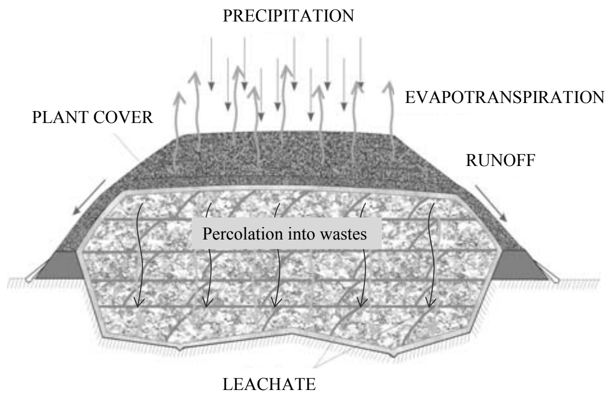


Fig. 1. A generalized pattern of leachate formation.

the most important factor affecting the mass of solid waste leachate. Although the concentration of leachate is diluted due to rainfall in the storage areas, the excess water from rainfall causes this pollution to be transported over long distances [3, 6, 7]. In addition, in storage areas that lack an upper cover layer, above the saturation point, 100% of the rainfall on the solid waste percolates and mixes with surface and underground waters [9, 15, 31, 32, 34].

The purpose of this study is to assess the seasonal variation in leachate of Gümüshane (Central) open dump area using the 'water balance method' for the determination of the factors affecting the seasonal variation in leachate of landfill which particularly has a higher risk of contaminating the environment. The most effective measures that can help reduce the mass of leachate are determined as a result of the findings.

Materials and Methods

Methodology

The factors affecting the formation of leachate in solid waste storage areas can be listed generally as precipitation, surface runoff, groundwater recharge, decomposition of the organic parts of the waste, liquid wastes, sludge, evaporation, infiltration, moisture retention, and permeability [3, 6, 7].

In order to determine the mass of leachate occurring in Gümüshane open dump site, moisture contents and densities obtained from measurements made during the months of May 2004 to April 2005 and precipitation and evaporation figures of Gümüshane between 2000 and 2004 obtained from the Directorate of Meteorology were used (Fig. 2) [35]. In addition, using a handheld GPS device, coordinates of the area were manually determined and the effective drainage area of the open dump area was identified (Fig. 3).

Length and depth values that were read for approximate cross-sections taken from the 1/25,000 topographic map of the solid waste open dump area were used in (1) to obtain the areas; and substituting these areas in (2), approximate volumes of solid waste were obtained. Using the coordinates in Table 1 in the calculation of the formula (1), the effective drainage area was found.

Table 1. The coordinate points of the effective drainage area of Gümüshane open dump site.

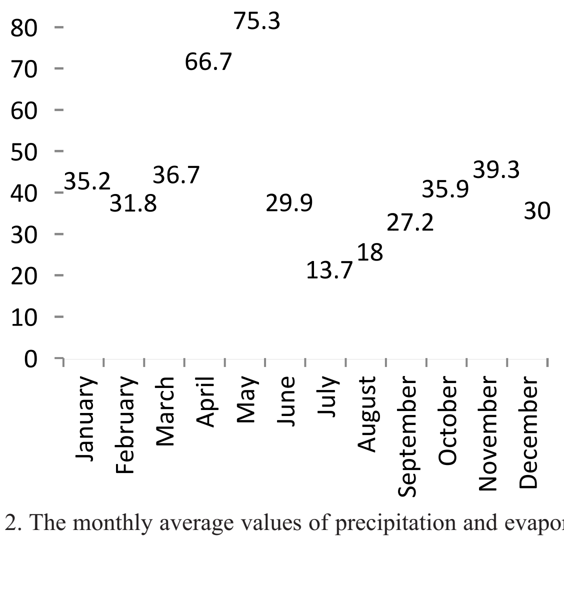
Points	X	Y	Z
1	540611	4480624	1156
2	540610	4480628	1155
3	540570	4480643	1151
4	540550	4480646	1550
5	540577	4480600	1552
6	540594	4480574	1551
7	540603	4480572	1550
8	540598	4480584	1551
9	540599	4480599	1552
10	540608	4480615	1554

$$2S = \sum X_i \times (Y_{i+1} - Y_{i-1}) \text{ or}$$
$$2S = \sum Y_i \times (X_{i+1} - X_{i-1}) \quad (1)$$

...where:
X_i – apses value of the coordinate of the ith point
Y_i – ordinate value of the coordinate of the ith point
S – area

$$V = \sum_{i=1}^{n} \left(\frac{S_i + S_{i+1}}{2} \right) \times l \quad (2)$$

...where:
V – volume
S_i – area of the ith cross section
l – the distance between cross sections



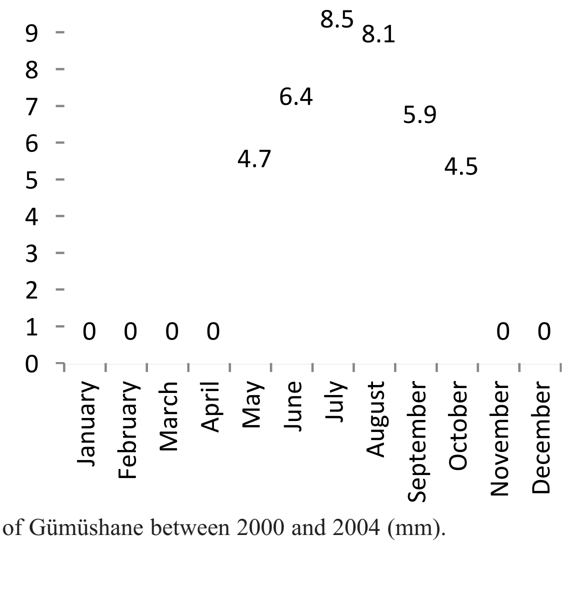


Fig. 2. The monthly average values of precipitation and evaporation of Gümüshane between 2000 and 2004 (mm).

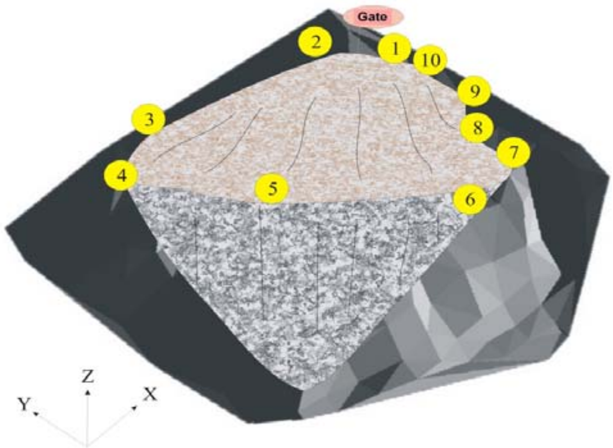


Fig. 3. The coordinate points of the effective drainage area of Gümüshane open dump site.

Leachate quantity is usually modelled and/or determined using a simple water balance approach taking into account the amounts of water entering the landfill (i.e. precipitation, waste moisture in excess of moisture holding capacity of the waste, and additional water input such as water in wastewater treatment plant sludges if allowed) and the amounts of water leaving the landfill (i.e. water consumed in biochemical reactions and evaporation) [36, 37]. The determination of leachate quantities are done by using the hydrologic evaluation of landfill performance (HELP) and the water balance method (WBM). HELP model is the most widely used tool to predict leachate quantity and analyze water balance in landfill lining and capping systems [38, 39]. HELP model as the most widely used model employs the same concept of water balance excluding the biochemical reactions and computes the leachate quantity based on a detailed meteorological and MSW characteristics data [36]. The water balance method, as developed in the soil and water conservation literature, is based upon the relation among precipitation, evapotranspiration, surface runoff, and soil moisture storage [40-42]. Precipitation represents that mass of water added. Evapotranspiration, the combined evaporation from the plant and soil surfaces and transpiration from plants, represents the transport of water from the earth back to the atmosphere, the reverse of precipitation. Surface runoff represents water that flows directly off the area of concern. The soil moisture storage capacity represents water that can be held in the soil. The Water Balance Method equation giving variations of leachate in landfills is generally written as follows [3, 5, 6, 31, 37, 38, 41-43]:

$$L = P \times S_1 + L_R - E \times S_2 - R + Wa \pm B \pm W \qquad (3)$$

...where:

L – leachate (m^3/year)
P – precipitation (rainfall) (m^3/m^2/year) or (mm)
S_1 – the effective drainage area of landfill (m^2)
L_R – leachate recirculation (m^3/year)
E – actual evapotranspiration (mm)
S_2 – the average landfill (m^2)
R – surface runoff (mm)
Wa – percolation in sanitary landfill during compression (m^3/year)
B – the amount of water produced or consumed in the biological decomposition
W – the mass of water held in waste (kg)

The rational method for estimating the surface runoff is given as follows:

$$R = c \times P \qquad (4)$$

...where:

R – surface runoff (mm)
c – the runoff coefficient depending on the permeability and infiltration capacity of the cover soil, the slopes, and the amount and type of vegetation cover
P – precipitation (rainfall) (m^3/m^2/year) or (mm)

The mass of water held in the waste and the field capacity are calculated with the following equations, respectively [38].

$$W = FC \times D \qquad (5)$$

$$FC = 0.6 - 0.55 \times \frac{A}{10000 + A} \qquad (6)$$

...where:

W – the mass of water held in waste (kg)
FC – field capacity
D – dry weight of MSW (kg)
A – average weight of MSW (kg) (without cover material)

Study Area

Gümüshane, located in the Eastern Black Sea Region of Turkey, lies between the 38º45′ and 40º12′ eastern longitudes and 39º45′ and 40º50′ northern latitudes. Gümüshane is characterized by a rugged topography. The area of Gümüshane is 6,437 km^2 at an elevation of 1,210 m. The lowest and highest elevations in the zoning plan are 1,105 m and 1,455 m, respectively. The temperature and other climatic conditions of Gümüshane vary drastically: the mean minimum temperature is found to vary from -15ºC in February months to 9ºC in August, and the mean maximum temperature is found to vary from 10ºC in January to 37ºC in July. Gümüshane receives a yearly mean rainfall of 461 mm (Fig. 4) [35, 44].

In Gümüshane Province and its towns, open dump is the only option that is presently undertaken for the management of the municipal solid wastes. The solid waste collection method used in Gümüshane is the curb-side collection method. Gümüshane's municipal solid waste generally consists of wastes generated from residential and commercial areas, parks, and streets. There are six open dumps in Gümüshane Province and its towns, Torul, Kürtün, Kelkit, Siran, and Köse. Total 70 tons/day municipal solid waste is generated in central locations, 25 tons/day of which is generated in the center of the city. About 20-25 tons of solid waste collected within the boundaries of Gümüshane municipality is disposed in the valley of Kurudere on the southwestern slopes of

Fig. 4. The open dump and residential areas of the Municipality of Gümüshane.

Parmaklik Hill, located between Topal and Rufene neighborhoods north of Gümüshane Central. The area is approximately 40-45 hectares and able to meet the need for 50-100 years in the case of open dumping. The distance of tour is approximately 4.5 kilometers from the municipality (Fig. 5) [35, 44, 45].

Results and Discussion

In the studies conducted between May 2004 and April 2005, the distribution of moisture content in organic matter, which is one of the sources of leachate in a solid waste dump site and the densities of solid waste were determined.

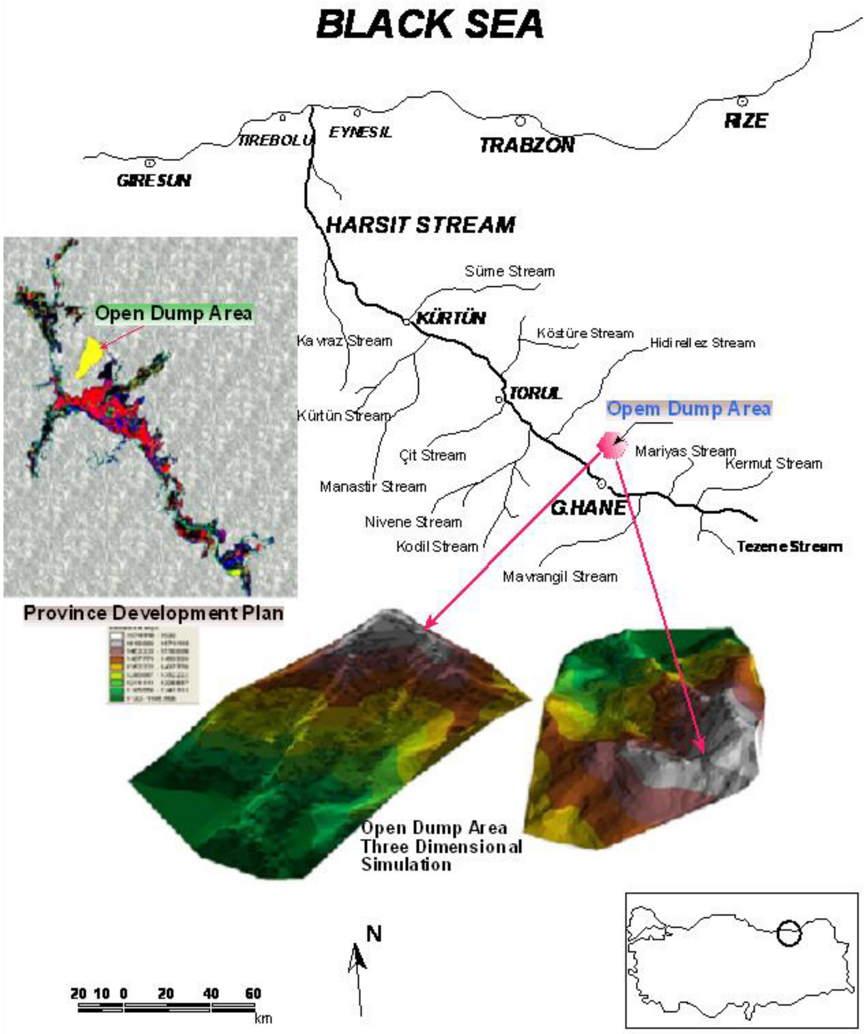


Fig. 5. The open dumping area of the Municipality of Gümüshane (all aspects).

In order to determine the composition of the MSW, approximately 4,500 kg of solid waste samples were collected from the open dumping area, Kurudere valley to the southwest of Parmaklık hill, during the year. Four samples were simultaneously taken in every week, and a total of 208 samples were taken in a year. Containers with 0.72 m^3 capacity were used in the sampling process. In order to obtain a representative sample, 0.288 m^3 of the MSW was collected promptly after disposal. However, some large-volume materials (e.g., car tires, old household items) and medical wastes were excluded. The collected samples were transported to an indoor area. The samples were then spread out on a plastic sheet and manually separated into their components. The sorting process was performed by a team of two people who were instructed on the sorting requirements.

The components were divided into nine categories: food and yard, paper and cardboard, metals, glass, plastics, textiles, ash and scoria, diaper and others (wood, bones, battery, construction and demolition wastes, stone, etc.). The wastes were reduced in size by pre breaking and were manually homogenized in a plastic container. A sample of 4-5 kg was used for coarse grinding. Four samples of 125 g were taken from the coarsely ground homogenized wastes and dried in an oven for 24-48 h at 75ºC until a constant weight was obtained. The dried samples, called dry matter (DM), were then placed into desiccators for cooling, ground to obtain a particle size of less than 0.2 mm, and stored in desiccators until needed. The moisture content of the samples was determined from the decrease in weight. Organic matter content of the dried matter was determined by igniting the material at 550ºC in a furnace. After all, the distribution of the moisture content of organic wastes was found 78.5% on average; the average density was found to be 0.313t/m^3 (Fig. 6). All values in Fig. 6 were calculated from the weekly sampling and sorting results, and are presented on a monthly basis.

The organic fraction of biological origin constitutes almost 30% of the total MSW on average, which is lower than the average for Turkey. Organic constituents account for more than 50% of MSW in Turkey. In Gümüshane, people utilize the organic fraction, especially food remains and grass clippings, as feed for their animals. It was found that a large amount of the wastes are organic because the yearly mean organic matter content of the dried wastes is 92.1% (89.2% in the spring, 92.3% in the summer, 93.9% in the autumn, and 93.0% in the winter). In Gümüshane, ash and scoria constitute a large amount of the MSW generated in the winter and spring seasons, because those seasons are cold and solid fuels (coal/wood) are usually used in heating. Ash and scoria are almost never generated in summer. The percentage of ash and scoria generated is 53.85% in the winter, 38.42% in the spring, and 10.31% in the autumn. The major constituents of the MSW are organic and constitute approximately 50% of the total MSW, except in Gümüshane, whereas recyclable materials constitute almost 25% of the total MSW in medium-sized cities and 33% of the total MSW in big cities. The yearly mean moisture content of the wastes is 78%. The moisture content of the wastes is increased by rainfall.

In general, the climate in Gümüshane Province is fairly dry in the summer with an average rainfall of 62 mm, but rainy in winter, spring, and autumn with an average rainfall of 97 mm, 181 mm, and 121 mm, respectively, and total average rainfall is 461 mm based on data for 1996-2005, as collected from the Turkish State Meteorological Service (TSMS) weather station in Gümüshane Province. Therefore, the climate increases the moisture content of the compostable wastes especially in spring, autumn, and winter as the lids of containers are open. Although the climate is fairly dry during the summer, the mean moisture content of the compostable wastes for the summer season reaches the highest value (83%) due to the wastes having higher inherent water content. Because the optimum moisture content for aerobic composting is in the range of 50-60%, the moisture content of 78% for the compostable wastes is fairly high for composting and the excess moisture must be removed. However, anaerobic digestion rather than aerobic composting may be considered to handle the compostable wastes so the moisture content would not be a problem and need not to be removed.

The calculation method, which was followed using the properties of solid waste of Gümüshane (Central), is given

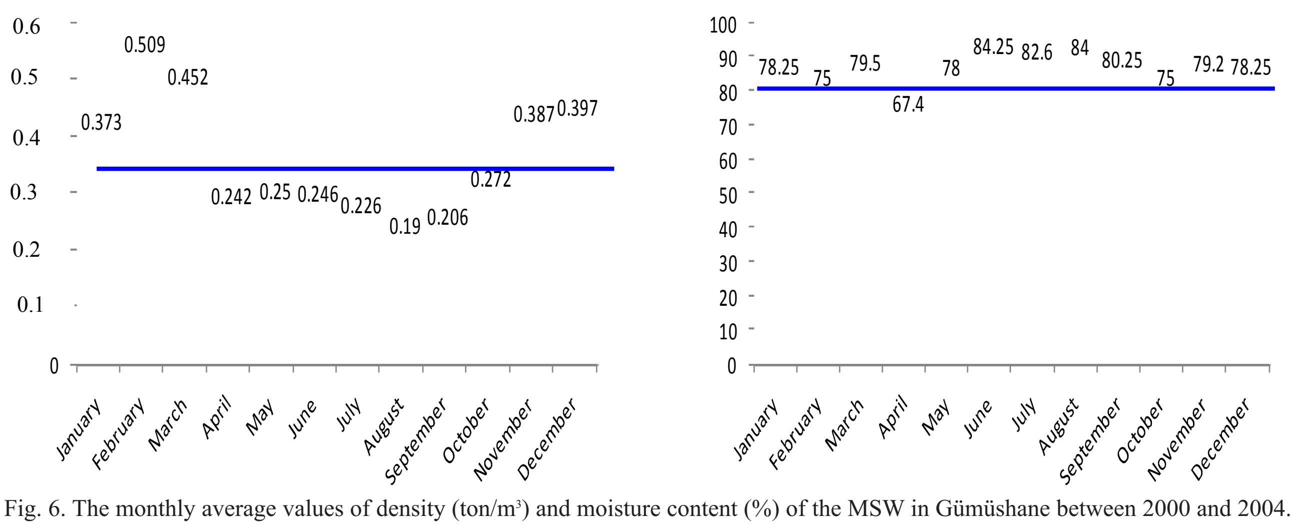


Fig. 6. The monthly average values of density (ton/m^3) and moisture content (%) of the MSW in Gümüshane between 2000 and 2004.

Table 2. The spread of the mass of leachate in Gümüshane solid waste disposal site.

Months	Precipitation (P)	Total mass of precipitation ($P \times S_1$)	Amount of surface runoff ($R = c \times (P \times S_1)$)	Evapotranspiration (E)	Evapotranspiration from area ($E \times S_1$)	Monthly average weight of MSW	Monthly average moisture content of MSW (*MC*)	Monthly dry weight of MSW (*D*)	Average weight of MSW (*A*)	Field capacity (*FC*)	Mass of water held in MSW (*W*)	Leachate (*L*) (kg/year)	Leachate (*L*) (m^3/ha/day)
January	35.2	68851.2	20655.36	0	0	750000	0.7825	163125	409425.6	0.06311317	10295.33	37900.5	6.46
February	31.8	62200.8	18660.24	0	0	750000	0.75	187500	406100.4	0.06321796	11853.36	31687.19	5.40
March	36.7	71785.2	21535.56	0	0	750000	0.795	153750	410892.6	0.06306747	9696.622	40553.02	6.91
April	66.7	130465.2	39139.56	0	0	750000	0.674	244500	440232.6	0.06221591	15211.78	76113.85	12.97
May	75.3	147286.8	44186.04	4.7	9193.2	750000	0.78	165000	448643.4	0.06199189	10228.66	92867.4	14.26
June	29.9	58484.4	17545.32	6.4	12518.4	750000	0.8425	118125	404242.2	0.06327726	7424.625	33458.05	3.57
July	13.7	26797.2	8039.16	8.5	16626	750000	0.826	130500	388398.6	0.06380527	8326.587	10422.95	-1.06*
August	18	35208	10562.4	8.1	15843.6	750000	0.84	120000	392604	0.06366107	7639.327	16998.17	0.20
September	27.2	53203.2	15960.96	5.9	11540.4	750000	0.8025	148125	401601.6	0.06336244	9385.561	27850.78	2.78
October	35.9	70220.4	21066.12	4.5	8802	750000	0.75	187500	410110.2	0.06309180	11829.71	37320.07	4.86
November	39.3	76870.8	23061.24	0	0	750000	0.792	156000	413435.4	0.06298899	9826.283	43983.28	7.50
December	30	58680	17604	0	0	750000	0.7825	163125	404340	0.06327412	10321.59	30754.41	5.24

*The negative sign indicates that this is evaporated water

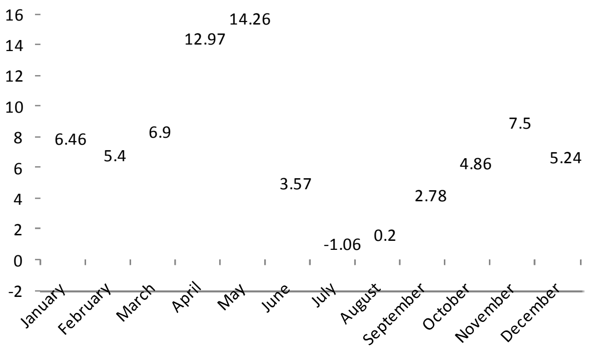


Fig. 7. Leachate quantity (m^3/ha/day) estimated for Gümüshane open dump site using the water balance method.

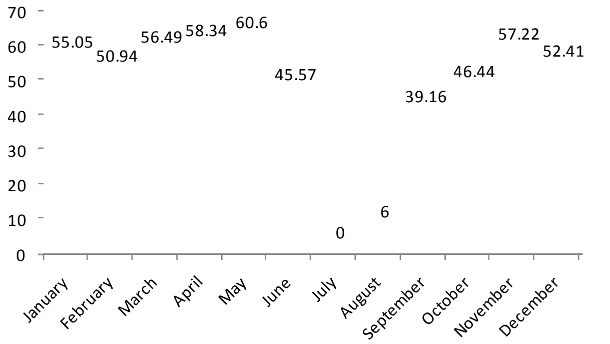


Fig. 8. The monthly average mass of precipitation that contributes to the leachate in Gümüshane, including infiltration and evaporation (%).

in Table 2. Monthly total precipitation and monthly total solid waste quantities were used in the calculation. Since it was not possible to obtain the seasonal variation of solid waste, the daily average was assumed to be 25 tons, and 750 tons/month was used in the calculations. Rainfall and evaporation data was obtained from the General Directorate of State Meteorological Service and the average values of the data for 2000-04 were used.

Gümüshane open dump area still continues to be filled up and due to the fact that there is no effective upper cover layer, a large proportion of the rainfall permeates to the body of the storage area. For this reason, the coefficient c, used for the calculation of runoff with the rational method, was taken as 0.30 in order to take into account the most negative conditions. Determining an average weight for each month, moisture holding capacity of the waste and the mass of water held in waste using this capacity were determined. As a result, for the calculation of the mass of leachate, the mass of surface runoff was calculated by subtracting the losses due to evaporation and the mass of water that can be held in the waste from the total mass of precipitation [35, 43, 45].

Since it is not possible to precisely determine most of the variables given in formula (3) for calculating the mass of leachate, some empirical equations and formulas were developed to determine the mass of leachate. Depending on how the waste is compressed, the waste is capable of holding 25-60% of the rainfall under the most inimical conditions. In addition, a range of 0.5-15 m^3/ha/day is given in the literature for the mass of leachate. Considering the mass of leachate recorded in various European countries, the mass of leachate is low in arid areas under hot climate and high in areas with high levels of precipitation. In addition, the presence of a final cover layer and the degree of non-permeability significantly affect the mass of leachate [3, 6, 7, 36, 38, 41, 42]. The variation in the mass of leachate obtained using the water balance method given in Table 2 and the mass of leachate originating from the precipitation occurring in Gümüshane are given in Figs. 7 and 8. All values in Figs. 7 and 8 are presented on a monthly basis.

Conclusions and Recommendations

The mass of leachate is proportional to the mass of precipitation, and therefore it should be limited. For this purpose, if possible, areas with low precipitation should be chosen, an upper covering layer and a blanket should be prepared, the area should be covered with grass after storage, adequate surface drainage should be performed, disposal of sludge and similar wastes should be limited, and waste should be sufficiently compressed. In addition, in regions with unfavorable topography, the heads of valleys where surface waters are less should be selected; if possible, areas with low base-permeability should be preferred, and the mass and location of groundwater should be determined.

An average solid waste of 20-25 tons/day is estimated to be produced in the city center of Gümüshane province. As a result of approximate calculations made in accordance with these amounts, a considerably large difference is observed between the annual amount of waste to be produced in Gümüshane and the approximate calculations made using topographic maps. Previous density of the waste, the mass of solid waste, and the exposure of solid waste to biological degradation should be taken into consideration for such a small amount of waste pile formed in 20 years.

The effective drainage area is found to be 1,956 m^2. The average annual mass of solid waste leachate in Gümüshane is 5.76 m^3/ha/day and it is observed to reach its highest level in May with 14.26 m^3/ha/day. Looking at the most effective factor in the formation of leachate, i.e. the precipitation, it is observed that the precipitation is at its highest level in spring and in particular in May. Again it is observed that there is no evaporation in Gümüshane during this month, the proportion of organic matter in the solid waste is around 30%, the ash is around 20%, the density of solid waste is 0.250 ton/m^3, and the moisture content is 78%.

When the monthly average mass of precipitation that contributes to the leachate in Gümüshane is considered, it is observed that the highest figure is calculated for May. Therefore, the necessary precautions should be taken against the leachate, which may occur in the area due to the high amount of sudden precipitation observed particularly in this month.

An effective management should be established for solid waste collection and disposal operations and the negative impacts of solid wastes on environment should be reduced by means of activities such as recycling.

As can be seen from the calculations, the mass of leachate is increasing in proportion to the mass of precipitation in open dump areas due to the fact that the necessary measures are not taken to prevent the entry of precipitation in the area. To prevent/reduce the mass of rain entering the storage area, dikes should be opened around storage areas, the mass of water that may enter the area from outside should be reduced and, if possible, intermediate cover layers should be prepared.

Care must be taken for the disposal of hazardous wastes in accordance with the relevant regulations. Hazardous wastes such as medical wastes that can be found in masses of solid waste negatively affect the quality of leachate and increase the harm to the environment and people.

Since the leachate of solid waste storage areas depends on many variables, the resulting leachate should be removed from the area by means of establishing collection systems in storage areas and the changes in this leachate should be examined and monitored. In order to determine the effects of solid waste storage area on the environment, the required EIA reports should be prepared and it should be kept in mind that more effective solutions can be implemented to reduce the negative effects of wastes. The Solid Waste Control Regulation is applied properly in the stages of collection and transportation, but the main problem is preparation of the sanitary landfills and rehabilitation of the open dumps because of insufficient financing. Educational programs on solid waste collection, separation, and recycling will be helpful to decrease the waste loads on the open dumping area.

References

1. KOCASOY G., CURI K. The Umraniye-Hekimbası open dump accident. Waste Manage. Res. **13**, (4), 305, **1995**.
2. KANAT G., DEMIR A., OZKAYA B., BILGILI M.S. Addressing the operational problems in a composting and recycling plant. Waste Manage. **26**, (12), 1384, **2006**.
3. TCHOBANOGLOUS G., THEISEN H., VIGIL S.A. Integrated solid waste management: Engineering principles and management. McGraw-Hill, New York, **1993**.
4. KHOURY R., EL-FADEL M., SADEK S., AYOUB G. Temporal variation of leachate quality in seawater saturated fills. Adv. Environ. Res. **4**, (4), 313, **2000**.
5. VEEKEN A., HAMELERS B. Sources of Cd, Cu, Pb and Zn in biowaste. The Sci. Total Environ. **300**, (1), 87, **2002**.
6. TCHOBANOGLOUS G., O'LEARY P. Landfilling, in Hand book of solid waste management (Ed.: TCHOBANOGLOUS, G., KREITH, F.). McGraw-Hill, New York, pp. 1-93, **2002**.
7. AMALENDU B. Design of landfill and integrated solid waste management. John Wiley & Sons, New Jersey, **2004**.
8. KURNIAWAN T.A., LO W., CHAN G.Y.S. Physico-chemical treatments for removal of recalcitrant contaminants from landfill leachate. J. Hazard. Mater. **129**, (1), 80, **2005**.
9. SANDERSON J., HETTIARATCHI P., HUNTE C., HURTADO O., KELLER A. Methane balance of a bioreactor landfill in Latin America. J. Air Waste Manage. **58**, (5), 620, **2008**.
10. CHRISTENSEN T.H., KJELDSEN P., BJERG P. Biogeochemistry of landfill leachate plume. Appl. Geochem. **16**, (7-8), 659, **2009**.
11. MOHAN S., GANDHIMATHI R. Removal of heavy metal ions from municipal solid waste leachate using coal fly ash as an adsorbent. J. Hazard. Mater. **169**, (1-3), 351, **2009**.
12. COMSTOCK S.E.H., BOYER T.H., GRAF K.C., TOWNSEND T.G. Effect of landfill characteristics on leachate organic matter properties and coagulation treatability. Chemosphere **81**, (7), 976, **2010**.
13. FELLNER J., BRUNNER P. Modeling of leachate generation from MSW landfill by a 2-dimensional 2-domain approach. Waste Manage. **30**, (11), 2084, **2010**.
14. TINMAZ E., DEMIR I. Research on solid waste management system: to improve existing situation in Corlu town of Turkey. Waste Manage. **26**, (3), 307, **2006**.
15. YANG Z., ZHOU S. The biological treatment of landfill leachate using a simultaneous aerobic and anaerobic (SAA) bio-reactor system. Chemosphere **72**, (11), 1751, **2008**.
16. FRANCISCA F., GLATSTIEN D. Long term hydraulic conductivity of compacted soils permeated with landfill leachate. Appl. Clay Sci. **49**, (3), 187, **2010**.
17. GABKA D., WOLSKI K. Use of turf grasses in landfill leachate treatment. Pol. J. Environ. Stud. **20**, (5), 1161, **2011**.
18. FLIPKOWSKA U. Effect of recirculation method on quality of landfill leachate and effectiveness of biogas production. Pol. J. Environ. Stud. **17**, (2), 199, **2008**.
19. TATSI A.A., ZOUBOULIS A.I. A field investigation of the quantity and quality of leachate from a municipal solid waste landfill in a Mediterranean Climate (Thessaloniki, Greece). Adv. Environ. Res. **6**, (2), 207, **2002**.
20. MOO-YOUNG H., JOHNSON B., JOHNSON A., CARSON D., LEW C., LIU S., HANCOCK K. Characterization of infiltration rates from landfills: supporting groundwater modelling efforts. Environ. Monit. Assess. **96**, (1-3), 283, **2004**.
21. ABBAS A.A., JINGSONG G., PING L.Z., YA PAN Y., WISAAM S.A. Review on landfill leachate treatments. Am. J. Appl. Sci. **6**, (4), 672, **2009**.
22. WOJCIECHOWSKA E., GAJEWSKA M., PEMPKOWIAK H.O. Treatment of landfill leachate by constructed wetland: three case studies. Pol. J. Environ. Stud. **19**, (3), 643, **2010**.
23. BILGILI M.S., DEMIR A., INCE M., OZKAYA B. Metal concentrations to simulated aerobic and anaerobic pilot scale landfill reactors. J. Hazard. Mater. **145**, (1), 186, **2007**.
24. POLAT H., ERDOGAN D. Heavy metal removal from waste waters by ion flotation. J. Hazard. Mater. **148**, (1-2), 267, **2007**.
25. LI Y., LOW G.K., SCOTT J.A., AMAL R. Arsenic speciation in municipal landfill leachate. Chemosphere **79**, (8), 794, **2010**.
26. MATTHEWS R., WINSON M., SCULLION J. Treating landfill leachate using passive aeration trickling filters; effects of leachate characteristics and temperature on rates and process dynamics. Sci. Total Environ. **407**, (8), 2557, **2009**.
27. FLYHAMMAR P. Estimation of heavy metal transformations in municipal solid waste. Sci. Total Environ. **198**, (2), 123, **1997**.

28. PALMA L., MECOZZI R. Batch and column tests of metal mobilization in soil impacted by landfill leachate. Waste Manage. **30**, (8-9), 1594, **2010**.
29. OZKAYA B., DEMIR A., BASTURK A., BILGILI M.S. Investigation of leachate recirculation effects in Istanbul Odayeri sanitary landfill. J. Environ. Sci. Heal. A **39**, (4), 869, **2004**.
30. BERKUN M., ARAS E., NEMLIOGLU S. Disposal of solid waste in Istanbul and along the Black Sea Coast of Turkey. Waste Manage. **25**, (8), 847, **2005**.
31. TRÄNKLER J., VISVANATHAN C., KURUPARAN P., TUBTIMTHAI O. Influence of tropical seasonal variations on landfill leachate characteristics-results from lysimeter studies. Waste Manage. **25**, (10), 1013, **2005**.
32. KALE S.S., KADAM A.K., KUMAR S., PAWAR N.J. Evaluating pollution potential of leachate from landfill site, from the Pune Metropolitan City and its impact on shallow basaltic aquifers. Environ. Monit. Assess. **162**, (1), 327, **2009**.
33. BELLA G.D., TRAPANI D.D., MANNINA G., VIVIANI G. Modeling of perched leachate zone formation in municipal solid waste landfills. Waste Manage. **32**, (3), 456, **2012**.
34. ZHANG S.J., PENG Y.Z., WANG S.Y., ZHENG S.W., GUO J. Organic matter and concentrated nitrogen removal by shortcut nitrification on denitrification from mature municipal landfill leachate. J. Environ. Sci. **19**, (6), 647, **2007**.
35. NAS S.S., BAYRAM A. Municipal solid waste characteristics and management in Gümüshane, Turkey. Waste Manage. **28**, (12), 2435, **2008**.
36. DE VELÁSQUEZ T.O., RIVERA R.C., VALENCIA N.R., RAMÍREZ I.M., GÓMEZ J.S. Serial water balance method for predicting leachate generation in landfills. Waste Manage. Res. **21**, (2), 127, **2003**.
37. BLIGHT G.E. Graded landfill requirements in South Africa – the climatic water balance classification. Waste Manage. Res. **24**, (5), 482, **2003**.
38. COSSU R., ROSSETTI R.D. The PAF model: An integrated approach for landfill sustainability. Waste Manage. **23**, (1), 37, **2003**.
39. CARDOSO A.J., LEVINE A.D., RHEA L.R. Batch test assessment of waste-to-energy combustion residues impacts on precipitate formation in landfill leachate collection systems. J. Air Waste Manage. Assoc. **58**, (1), 19, **2008**.
40. BABOROWSKI M., BÜTTNER O., EINAX J.W. Assessment of water quality in the Elbe River at low water conditions based on factor analysis. Clean **39**, (5), 437, **2011**.
41. OJOAWO S.O., AGBEDE O.A., SANGODOYIN A.Y. A System dynamics modeling approach for dumpsite waste generation and its attendant challenges in Ogo Oluwa Local Government Area, Nigeria. J. Environ. Sci. Water Resour. **1**, (4), 80, **2012**.
42. ALSLAIBI T.M., ABUSTAN I., MOGHEIR Y.K., AFIFI S. Quantification of leachate discharged to groundwater using the water balance method and the hydrologic evaluation of landfill performance (HELP) model. Waste Manage. Res. **31**, (1), 50, **2013**.
43. YILDIZ E., UNLU K., ROWE R. Modeling leachate quality and quantity in municipal solid waste landfills. Waste Manage. Res. **22**, (2), 78, **2004**.
44. NAS S.S., BAYRAM A., BULUT V.N., GÜNDOĞDU A. Heavy metals in compostable wastes: a case study of Gümüshane, Turkey. Fresen. Environ. Bull. **16**, (9a), 1069, **2007**.
45. NAS S.S., BAYRAM A. Environmental problems from the open dump in Gümüshane province and investigation of biological recycling for the organic solid wastes. Environ. Earth Sci. **7**, 1055, **2011**.