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Evaluation the Effect of Landfill Leachate on the Surface Water Quality: A Case Study in Tonekabon Landfill

Mahsa Alizadeh[1], *Seyed Abolghasem Mirhoseini*[2], *Maryam Dolatabadi*[3], *Ali Asghar Ebrahimi*[4*]

[1,2] Department of Environment, Yazd Branch, Islamic Azad University, Yazd, Iran.
[3,4] Environmental Science and Technology Research Center, Department of Environmental Health Engineering, Shahid Sadoughi University of Medical Sciences, Yazd, Iran.

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***Corresponding Author:**
Ali Asghar Ebrahimi

Email:
ebrahimi20007@gmail.com

Tel:
+983538209100

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ABSTRACT

Introduction: Leachate is a liquid coming out of accumulated wet wastes which contains several chemical and dangerous elements. Furthermore, it causes the aquatic ecosystem contamination. The purpose of this study is to give an indication of the effects of Tonekabon landfill on the surface water, so evaluating the amount of leachate polluting in surface waters was investigated.

Materials and Methods: In the current study, after 4 sampling periods at 4 stations, parameters of pollutants including BOD_5, COD, TSS, TDS, pH, and EC at different stations and in different seasons were investigated and analyzed.

Results: The results revealed that there was no significant difference between 4 stations in pH mean values, while values of other parameters were significantly different in various stations. Based on Duncan's test, the station of 3 and 4 were significantly different in the same group, and the stations of 1 and 2 were each in separate groups. On the other hand, an examination of the difference in data mean based on sampling season shows that there is a significant difference between the mean values of pH between summer and spring, while in other parameters there is no significant difference.

Conclusion: This landfill is important due to its location in the forest area near the rural and agricultural centers. The results showed that leachate could be transported to farther places in order to prevent soil and aquatic ecosystem contamination.

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Introduction

Collecting and disposing of urban wastes due to population growth and industrialization, and consequently the increase of waste generation per capita, has become one of the most important issues of municipal waste integrated management [1, 2]. It is clear that Iranian municipal waste management system is in a relatively critical situation [3, 4]. This gets more complicated when its negative and harmful effects are examined in relation to other existing systems, including the environmental system [5, 6]. One of the main problems of landfills is waste leachate. Waste leachate is a kind of wastewater with high concentrations of organic and mineral compounds, and sometimes contains a high level of toxic pollutants such as arsenic, lead, cadmium, and chlorinated organic compounds [7-10]. Many parameters affect the quality and quantity of leachate, such as climate, landfill and compression methods, buried waste composition, landfill structure, and the type of soil in the area [11-13]. The main risk of leachate from landfill is its infiltration into groundwater or mixing

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with surface water and soil pollution. In addition, numerous animal and plant species around aquifers that are polluted by contacting with leachate are severely exposed to pollution which ultimately will have adverse effects on humans themselves [14-16]. Limited activities have been carried out in Iran regarding leachate control. Due to population growth and industries development, the amount of waste produced has also increased and, as well as the number of landfill sites, and large amounts of leachate discharged into the environment. This issue has increased environmental and health risks [17-19]. The study of landfill site and leachate pollutants is one of the requirements of urban communities to avoid leachate risks and other environmental problems.

Parvaresh et al. studied the concentration of heavy metals in urban waste leachate and their removal methods. According to the results of the study, the concentration of elements studied in the leachate far exceeded the standards of the US Environmental Protection Agency (EPA). The use of coagulant alum can eliminate the concentration of heavy metals in waste leachate with considerable efficiency [20]. Shokouh et al. studied the quality of leachate from urban landfills and the compost plant in Mashhad. In this study, the amount of leachate pollutants in winter and spring was measured. The results showed that the produced leachate had much more organic material than other landfills in other countries [21]. Haji Nejad et al. conducted a study on the effects of landfill leachates on the quality of groundwater in Bojnourd. They sampled two upstream wells and two downstream wells at landfill site and measured the parameters NH_3, NO_3^-, PO_4^{3-}, SO_4^{2-}, Mg^{2+}, Cl^-, K^+ و N^+. Their results showed that the concentration of most pollutants was higher than standard, causing the release of leachate from landfill to groundwater and contamination of adjacent wells [22]. Salem et al. conducted a study in Algeria to analyze the contamination of Landfill leachate. The area studied was on the site (Ouled Fayet) West of Algeria, which has been active over the past 5 years, and has received non-hazardous, urban and assimilated wastes from 34 municipal districts with 363,000 tons of waste per year. Several samples have been taken at Landfill entrance and exit locations. The results showed that the leachate contains organic materials and a high level of biodegradable materials; furthermore, it was stated that longer durability did not reduce the level of the parameters. A chemical deposition approach was also proposed to prevent the effects of heavy metals pollution in future [23]. Melnyk et al. examined the chemical pollution and toxicity of leachate samples resulted from urban solid waste in Bangladesh in 2007-2011. Sampling was carried out in two stages. In the first stage, the sample was taken before entering water to the landfill, and in the second stage the sample was taken at the outlet of the water stream at the landfill site. The pollution resulted from toxicity in 2007 to 2012 was much higher than the samples taken in 2010- 2012 [24]. Munir et al. examined leachate and leachate pollution index at landfill site in Lahore, Pakistan. They analyzed the characteristics of leachate and calculated its pollution potential by leachate pollution index (LPI) at two landfills sites. The pH value in one site was alkaline, and in another was acidic, all three landfill sites had very low dissolved oxygen. In all three landfills, pH, BOD_5, COD, PO_4^{3-}, NO_3^-, Cl^- in winter and summer were significantly higher than the standards of Environmental Protection Agency (EPA) in the U.S [25]. De et al. in Kolkata, India, examined leachate and dominant pollutants using leachate pollution index for uncontrolled landfill sites. The results of physicochemical and biological analysis of leachate showed that the analyzed parameters of TDS, BOD_5 COD, TKN, NH_3-N, Cl^-, Pb و Hg in all landfill sites ,were higher than the standard leachate discharge for surface waters set by principles of 2013 solid urban waste. In addition, total concentrations of Cr and Zn are higher than the leachate release standard for landfill sites. In terms of contamination rating, total bacterial coliform, TKN, NH_3-N and Hg were identified as dominant pollutants and the most important contributing factors in leachate pollution index [26].

Considering the necessity of evaluating the landfill site in Tonekabon, due to its slope towards the river (Do Hezar and Se Hezar), eventually these surface waters reach Caspian Sea; furthermore, high humidity and high rainfall and high level of underground water in the region have become a

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research priority for respective organizations and have been of particular importance. The present study was conducted to investigate the status of landfill-borne pollutions at landfill site in Tonekabon. It was conducted to make authorities aware of the situation in the region in order to have a proper management despite time, place, and financial constraints in a one-year period.

Materials and Methods

Area of study

Tonekabon is located in west of Mazandaran province. The city is bounded to Caspian Sea from north, from south to Alborz Mountains, from the center to Qazvin province, from east to Chalous, and from west to Ramsar city. The city consists of four districts (Markazi, Khorramabad, Abbasabad and Nashta), nine villages and cities of Tonekabon, Abbasabad, Nashtarood, Clarabad, Khoramabad and Salman Shahr. The northern part of Tonekabon is a plain in which there are urban areas and most of villages.

Regarding the climate and based on the information from climatology station in Khoshkedaran, Tonekabon has a very humid climate, which holds truer about northern areas of the city and southern areas of the city have somewhat cold and mountainous weather. The average annual rainfall is 1131 mm. The studied landfill is in Pardehsar, a suburb of Khorramabad in Tonekabon which is located on Do Hezar road, with latitude of 36 degrees, 41 minutes and 54 seconds, and a longitude of 50 degrees, 49 minutes and 12 seconds. The selected area for the study is 500 meters above the sea level and the surrounding area is quite forested and pluvial (Figure 1). The slope of the landfill site from the south is towards the north and field slop is about 45%, with 8 hectares of land. The distance from the village is about 500 meters and from Tonekabon, it is 12 kilometers. The major rivers of the area include the rivers of Do Hezar and Se Hezar, and local streams. The soil of the region is generally clayey which reduces the penetration rate of leachate into groundwater. At this landfill site, municipal waste is collected from Tonekabon and is buried (Interview with Tonekabon Municipality experts). According to the authorities in Mazandaran province, 3,100 tons of waste is produced per day, 75 percent of which are wet wastes.

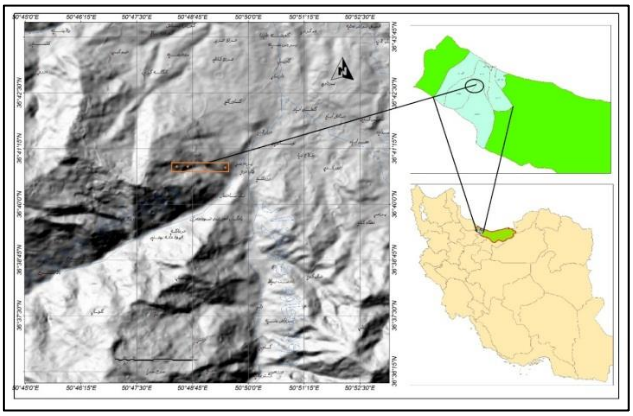

Figure 1: Location of the study area in country, province and city

Research method

This is a field-lab research. At first, based on the test design, samples were taken and analyzed from the landfill leachate. Based on the standard methods of water and waste, the specimens were stored at 4°C and sent to the lab for chemical analysis [18]. The experiments used standard methods in the book (APHA, 1995). The parameters analyzed in this study included 6 parameters BOD_5, COD, TSS, TDS, pH, EC, which were analyzed in Kavire jonoub laboratory using pH, EC and Winkler (BOD_5, COD) and gravimetric (TSS, TDS) and their results are presented separately for each parameter.Sampling intervals were divided into four stages, (summer (1), autumn (2), winter (3) and spring (4)) and spatial distances were divided into four sampling stations

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(stations 1, 2, 3 and 4) and the dependent variable including six water qualitative parameters was analyzed. After sampling and transporting the samples to the laboratory, their quantitative results were recorded. Finally, data analysis was done by SPSS (version 16) software using ANOVA.

Results

The qualitative parameters measured in all the chapters under study include BOD_5, COD, TSS, TDS, pH, EC, the results of which are given in the following. In order to investigate the level of leachate penetration into surface waters, four samples were studied, as shown in Fig. 1. The first sample is taken from the end of the site where the waste is disposed of and leachate is flowed. (station 1), the second sample is from about 450 meters downstream the landfill (station 2), the third sample is from a 600 meters distance (station 3) and the fourth was sampled at a distance of 1700 meters, where the surface water containing leachate interferes with Do Hezar river (station 4). It should be noted that sampling time interval was set to be during a year and in four periods from the summer of 1916 to the spring of 1917, with each season being sampled in four specific places. Table 1 shows the results of the measurement average at sampling stations in four seasons and at four stations.

Table 1: the results of various parameters measurement

Parameter	Season	Station 1	Station 2	Station 3	Station 4	Mean
TDS	Summer	16591	10258	1950	362	7290.2
	Autumn	10140	9450	2650	260	5625
	Winter	11071	3407	609	291	3844.5
	Spring	11951	4678	671	267	4391.7
Mean		12438.2	6948.2	1470	295	-
TSS	Summer	385	360	102	48	75.2
	Autumn	285	526	160	28	75.3
	Winter	298	319	183	54	21.5
	Spring	206	473	120	69	217
Mean		293.5	419.5	141025	49.75	-
pH	Summer	8.05	7.99	8.02	8.01	8.0
	Autumn	8.2	8.19	8.12	7.99	8.1
	Winter	8.21	8.36	8.12	8.28	8.2
	Spring	8.14	8.3	8.18	8.01	8.1
Mean		8.15	8.21	8.11	8.07	-
EC	Summer	20100	13200	3290	1347	9484.2
	Autumn	19140	16180	4300	412	10008
	Winter	13180	4580	886	452	4774.5
	Spring	14060	6120	959	415	5388.5
Mean		16620	10020	2358.7	656.5	-
BOD_5	Summer	1681	1162	274	109	806.5
	Autumn	2062	1641	412	18	1033.2
	Winter	1364	445.14	54.35	20.4	470.9
	Spring	1359.4	450.9	48.95	14.6	468.5
Mean		1616.6	924.76	197.3	40.5	-
COD	Summer	2856	1800	400.5	94	1287.6
	Autumn	3390	2650	678	25	1685.7
	Winter	2142	715.3	85.2	30.6	743.3
	Spring	2131.2	748.8	82.8	20.3	745.8
Mean		2629.8	1478.5	311.6	42.475	-

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Due to the normality of the variable data include (TDS, PH, TSS, EC, BOD_5 and COD) One-way ANOVA and Duncan's tests have been used.

Table 2: Smirnov-Kolmogorov test results for physical-chemical parameters.

variable	TDS	pH	EC	BOD_5	COD	TSS
Number	16	16	16	16	19	16
Mean	5278.8	8.13	7413.8	694.8	1115.61	226
Standard deviation (SD)	5392.0	11.0	7257.9	719.7	1178.8	157.0
Significant	0.551	0.867	0.454	0.239	0.282	0.964

One way ANOVA was used to determine the significant difference between mean values of each parameter in the study based on the sampling station. The results are presented in Table 3.

Table 3: One-way analysis of variance of parameters studied at four stations

Parameter	Source	Sum of square	Df	Mean square	F-Value	p-value
pH	Between group	0.042	3	0.014	0.998	0.427
	Inter group	0.166	12	0.014	-	-
	Total	0.208	15	-	-	-
EC	Between group	651044122	3	217014707	18.72	0.000
	Inter group	139110283	12	11592523	-	-
	Total	790154406	15	-	-	-
BOD_5	Between group	6312894	3	2104298	17.3	0.000
	Inter group	1457001	12	121416	-	-
	Total	7769896	15	-	-	-
COD	Between group	16889828	3	5629942	17.08	0.000
	Inter group	3955697	12	329641	-	-
	Total	20845526	15	-	-	-
TDS	Between group	373558712	3	124519570	23.88	0.000
	Inter group	62550791	12	5212565	-	-
	Total	436109503	15	-	-	-
TSS	Between group	320980	3	106993	26.24	0.000
	Inter group	48917	12	4076	-	-
	Total	369898	15	-	-	-

Based on the contents in Table 3, the significance level in one-way ANOVA test was to detect the difference between the means only for pH values at the quadruple sampling stations higher than 0.05, which means that the mean values of pH at different stations were not significantly different. However, for all other parameters (EC, BOD_5, COD, TDS and TSS), the significance was less than 0.05. Therefore, there is a significant difference between their mean in triple stations. Therefore, Duncan's test was used to check this difference. The results are shown in Table 4.

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Table 4: Duncan's test to compare the mean of studied parameters

Parameter	Station .No	Grouping 1	Grouping 2	Grouping 3
pH	4	8.072	-	-
	3	8.110	-	-
	2	8.150	-	-
	1	8.210	-	-
EC	4	656.5	-	-
	3	2358.7	-	-
	2	-	10020	-
	1	-	-	16620
BOD_5	4	40.5	-	-
	3	197.3	-	-
	2	-	924.7	-
	1	-	-	1616
COD	4	42.47	-	-
	3	311.6	-	-
	2	-	1478.5	-
	1	-	-	2629
TDS	4	295	-	-
	3	1470	-	-
	2	-	6948	-
	1	-	-	12438
TSS	4	49.7	-	-
	3	141.2	-	-
	2	-	293.5	-
	1	-	-	419

As the results of Duncan's test (Table 4) for quadruple stations show, the average values of pH for sampling stations are in the same group, which means that the mean of all stations is in the same group. In the EC parameter, the stations studied are classified into three groups: the first group-the third and fourth stations; the second group - the second station; the third group-the first station.

BOD_5: According to Table 4, the investigated stations are classified into three groups: the first group-the third and fourth stations; and the second group-the second station; the third group-the first station

COD: According to Table 4, the examined stations are classified into three groups: the first group-the third and fourth stations; and the second group - the second station; the third group - the first station.

TDS: According to table 4, the studied stations are classified into three groups: the first group-the third and fourth stations; and the second group-the second station; the third group-the first station.

TSS: According to table 4, the investigated stations are classified into three groups: the first group-the third and fourth stations; and the second group - the second station; the third group-the first station.

Investigating the difference between the data mean based on quadruple seasons by ANOVA

In order to evaluate the significance of the difference between mean values of each parameter studied seasonally, one-way ANOVA was used, the results of which are presented in Table 5.

Table 5: One-way analysis of variance of different parameters in quadruple seasons

Parameter	Source	Sum of square	Df	Mean square	F-Value	p-value
pH	Between group	0.104	3	0.035	3.99	0.035
	Inter group	0.104	12	0.009	-	-
	Total	0.208	15	-	-	-
EC	Between group	88337525	3	29445841	0.503	0.687
	Inter group	701816880	12	58484740	-	-
	Total	790154406	15	-	-	-
BOD_5	Between group	913374	3	304458	0.533	0.668
	Inter group	6856521	12	571376	-	-
	Total	7796896	15	-	-	-
COD	Between group	2520267	3	840089	0.55	0.658
	Inter group	18325258	12	1527104	-	-
	Total	20845526	15	-	-	-
TDS	Between group	28038121	3	9346040	0.275	0.842
	Inter group	408071382	12	34005948	-	-
	Total	436109503	15	-	-	-
TSS	Between group	3225	3	1075	0.035	0.991
	Inter group	366672	12	30556	-	-
	Total	369898	15	-	-	-

According to table 5, the significance level in one-way ANOVA test to examine the difference between the means only for pH values in quadruple seasons is less than 0.05, which means that the mean values of pH in different seasons are significantly different. However, for all other parameters (EC, BOD_5, COD, TDS and TSS), the significance level is greater than 0.05, which means that the mean values of EC at different stations are not significantly different. Therefore, Duncan's test was used to determine the difference between the mean values of pH. The results of Duncan's test for quadruple seasons indicated that the mean values of pH for sampling seasons were in two groups, where the first season, the summer, compared to the fourth season, spring, have mean difference, while the first season along with the second and third are in one group. On the other hand, the second and third seasons, along with the fourth season, are in another group. Regarding the other 5 parameters (EC, BOD_5, COD, TDS and TSS), the mean values of the seasons examined are in one group, which shows that the mean values of this parameter are not significantly different.

Discussion

Today, waste management is very important in the most parts of Iran. The Landfill in this study in Parde sar, Tonekabon, is also of great importance, because it is located in a forest area near rural and social and agricultural centers. The extent to which this landfill produces leachate and how difficult it is to manage must be investigated. The results of the experiments from the four landfill leachate samples showed that in the first station, due to its proximity to downstream landfills, the analyzed qualitative parameters showed very high values, while the other stations due to penetration into groundwater and contact with surface waters and local streams had lower ones. Therefore, the fourth station, which was sampled at the confluence with Do Hezar river, has even lower values than the standard. Although the fourth station is about 1700 meters away from Landfill, it still has significant amounts of contamination qualitative parameters.

Conclusion

The fact that this landfill has been used for about two decades, it is a potential and actual source for contamination of the surrounding area and surface water and groundwater, and also considering that the area under study has a high tourism potential, this can have irreparable effects on the tourism industry; therefore, it is necessary to take necessary measures to eliminate this pollution problem. The results of the study are similar to EPA standards and other studies, and the values of the parameters are higher than the standard. Among the effective measures to be taken are, waste sorting plan at source, a reduction in the production of waste at source, the construction of recycling and compost plants, the application of new technologies to disinfect wastes and to bring recyclable waste back to the production cycle. The results of the study clearly showed that contamination from leachate could spread for kilometers and contaminate soil, surface water and underground water, therefore necessary prevention and effective measures should be taken to prevent this catastrophe.

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Conflict of interest

The authors of this article declare that there is no conflict of interest.

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