Assessment Of Sanitary Landfill Leachate Characterizations And Its Impacts On Groundwater At Alexandria

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ABSTRACT

The total amount of solid waste generated in Alexandria is 2820 tons/d which increases to 3425 tons/day during summer. In the past, 77% of the collected solid wastes was open dumped. The open dumping sites did not have the minimum requirements for pollution control. Following the exacerbation of the problem, the Alexandria Governorate contracted a company to carry out the solid waste management. The contracted company transferred 75% of the daily generated solid wastes to a new constructed sanitary lanfill. The site receives a daily average of 1910 tons. The landfilling is performed by trench method in the form of cells. The produced leachate is discharged into two lined aerated lagoons. The biogas formed from biodegradation of landfilled solid wastes is burned and the produced heat is used for drying the lagoons leachate. The remaining residues are re-landfilled. The study aims at assessment of the solid waste sanitary landfill leachate characterization and its impacts on the groundwater.
The analysis of the collected data confirms that leachates from the landfill are severely contaminated with organics, salts, and heavy metals. The fluctuations in concentration levels of the different parameters were attributed to aging and thickness of waste layers, stage of decomposition, and re-landfilling of the concentrated residues from the drying lagoons.

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The concentrations of NH_4-N (600 mg/l) indicated that the process of stabilization was still in the initial stages and attributed to the compaction process. The high BOD_5 results (28,833 mg/l) indicated that the process of stabilization was in the initial stages which were very slow. The high COD results (45,240 mg/l) can be attributed to the compaction of the wastes which also retards the degradation of the solid wastes. The BOD and COD values indicated clearly severe contamination. The BOD_5/COD ratio measured in the current study (0.64) indicated that the leachate of the present study was biodegradable and unstabilized, and required time and favourable conditions for anaerobic biodegradation. Heavy metals were lower compared with what have been observed in other countries. Re-landfilling of the residue after drying the leachate in lagoons and the short time of biodegradation in the landfill site were factors which effected the high strength of most of the parameters concentrations of the leachate. Assessment of groundwater contamination through piezometer wells around the active cells indicated that there was no contamination from the leachate to the groundwater surrounding the site. The study recommended emphasizing the importance of adjusting the biodegradation factors, the monitoring program, the prohibition of disposing heavy metals, determination of the leachate generation rate, and treatment of leachate.
Key words: landfill, leachate, solid waste, groundwater.

INTRODUCTION

Alexandria Governorate Report in 2000 indicated that the total amount of solid waste generated in Alexandria was 2820 tons/day which increased to 3425 tons/day during summer. A study by Onyx company in 2000 recorded that the households generated the highest daily amount of solid wastes (1680 tons/day), which amounted to about 70% of the total amount of generated solid wastes.(1)

In the past, 23% of the collected solid waste in Alexandria was disposed off by composting while the rest (77%) was open dumped on the banks of water bodies and three different open dump sites. This was the crux of solid waste problems in Alexandria.(2)

The three sites did not have the minimum requirements for pollution control, besides that all the sites are located not far from residential and commercial areas. This open dumping created many problems as dumping of solid wastes near the surface water bodies was a direct pollution source.(3) Pollution of dumping sites presented a health problem for workers involved in this operation.(4) They were responsible for many nuisances such as evolution of heavy clouds of smoke, fly ash, malodors, irritating and noxious gases, and spread of fire and pollution to adjacent areas.(5)

Following the exacerbation of the solid waste management problem in Alexandria, the Governorate contracted a company to carry out the solid waste management and this agreement started from October 2001.

As a part of the contract, the company composted about 25% of the generated solid wastes. Since the end of 2002, the remaining 75% of the solid wastes are transferred to the newly constructed sanitary lanfill.(1)

Alexandria sanitary landfill is located at Borg AL-Arab, kilo-54, along Alexandria Matrouh Highway. The length and width of the site are 3 km and 250 m, respectively. The average annual precipitation in the area is 14 mm. The area has no surface water bodies and very limited resources of useable groundwater. The site includes 7 landfill cells. Each cell was expected to be filled in two years operation. The site received a daily average of 1910 tons of solid wastes during the period from 10/2001 to 4/2003, and it will accomodate Alexandria solid wastes for 15 years.(1)

The soil at landfill site is characterized by being of saline stony nature. The landfilling is performed by trench method in the form of cells. The bed of the landfill cells consists of: bottom layer of compacted clay, PVC layer, leachate collection system, and Geotex layer to protect the underneath layers from the mechanical effect of landfilling equipment.[1]

Solid wastes delivered to the landfill site are weighed, recorded, and dumped into the cell. The solid wastes are spread and compacted up to 50 cm. Earth is spread over the solid wastes and compacted.[1] The lined lagoons are designed to receive the leachate resulting from the biodegradation of the landfilled solid waste. The biogas formed from biodegradation of landfilled solid wastes is burned and the produced heat is used for drying the lagoons leachate. The remaining residues are re-landfilled.

One of the most significant impacts of a landfill on the surrounding environment has been consistently identified as arising from leachate. The leachate takes up organic and inorganic constituents by means of physical, hydrolytic, and fermentative processes. Environmental monitoring programmes for landfills were set-up, therefore, to focus on the detection of leachate impacts, particularly any contamination of ground and surface waters. Conventional monitoring programmes involve periodic sampling of ground and surface waters surrounding a landfill for chemical indicators of contamination.[6]

The study aims at assessment of the solid waste sanitary landfill leachate characterization and its impacts on the groundwater.

MATERIAL AND METHODS

Leachate from the lined aerated lagoons has been collected to assess its characterization and stabilization. In an effort to study the extent of groundwater contamination, five monitoring wells have been drilled around the site. They have been drilled to monitor the impacts of the leachate on the groundwater. Sampling has been done three times for each location during the period from January to August 2002.

All the collected samples were analyzed for the physical, chemical, and heavy metals analyses according to internationally accepted procedures in the Standard Methods for the Examination of Water and Wastewater.(7)

RESULTS AND DISCUSSION

1. Characteristics of Leachate and its Stability

The results of physical, chemical, and heavy metals analysis are shown in tables (1 and 2). The analysis of data confirms that leachates from the landfill are severely contaminated with organics, salts, and heavy metals.

It is noted from the chemical characteristics of the leachate that fluctuations in concentration level occur and were attributed to aging and thickness of waste layers, stage of decomposition, and relandfilling of the concentrated residues from the drying lagoons.

1.1. Assessment of pH

The pH of the leachate samples ranged between 6.7-7. Fortunately, these pH values are suitable for the methanogenic bacteria as suggested by Bolzonella *et al.*(8) They declared that acidic pH (5.30) caused an extension of the time required for the organic fraction of the waste to be stabilized since methane forming anaerobes are known to be very sensitive to low pH. High pH of 7.25 is suitable for growth of methanogenic bacteria.

The pH values (6.7-7.4) are almost within the range found by Al-Yaqout and Hamoda(9) who declared that the pH values were high in the operated landfill (6.9-8.2) due to the high alkalinity concentrations. On the other hand, they were less than what has been found by the same authors in a closed landfill (7.82-8.06). They attributed the increase in pH in the closed landfill to the high alkalinity concentrations in the samples and to the decomposition in the readily biodegradable organics and the production of gases. However, the poorly biodegradable organics remain with little change. Biodegradation of organic carbon is coupled to microbial growth. Thus, some of the degraded carbohydrates are used for synthesis of cell mass.[10]

1.2. Assessment of Conductivity and Salts

The very high values of conductivity (33,840 – 53,000 μs/cm) with a mean value of 41,637 μs/cm) indicate the presence of dissolved inorganic materials (24,500-36,480 mg/l with a mean value of 30,083 mg/l). They were higher than those found by Al-Yaqout and Hamoda[9] who found that the conductivity and TDS in operated and closed landfill were (1.2–16.9 ms/cm) and (744-7316 mg/l), and (6.21–21.90 ms/cm) and (1100-9910 mg/l), respectively. They noted that conductivity is sensitive to variations in dissolved solids, with which it has almost direct relationship. Conductivity and mineralization are elevated in leachate due to contact with solid wastes.

Chloride show high concentrations (8,250 - 17,500 mg/l with a mean value of 12,750 mg/l). They are very high compared with that recorded by North *et al.*[11], (340-927 mg/l). They were also higher than that found by Monje-Ramirez and Orta de Velásquez (7000 mg/l)[12] and by Mikac *et al.* (100-5000 mg/l), [6] who attributed the high values to the incorporation of saline water into the sanitary landfill.

Sulphates values (275 and 680 mg/l with a mean value of 535 mg/l) were lower than that found by Al-Yaqout and Hamoda[9] in borehole (1600 - 3650 mg/l) of operated landfill. On the other hand, they were within the range found by the same authors [9] in another borehole (300 - 600 mg/l). They pointed that high values in boreholes indicated that the plume may be moving due to hydraulic gradient.

The values of Mg (704 - 1380 mg/l with a mean value of 1058 mg/l) were very high compared with the results found by Al-Yaqout and Hamoda[9] in the operated landfill (5.2-20.8 mg/l) and closed landfill (86-268 mg/l). The reason of the high Mg concentrations was due to the disposed off industrial wastes.

1.3. Assessment of Nitrogen Forms and Phosphate-P Results

NH_4–N concentrations have shown high values with a mean value of 600 mg/l. The high results of NH_4–N concentrations are in accordance with Sponza and Agdag[13] who found that the concentration of NH_4–N of the compacted wastes after 8 days of anaerobic biodegradation was 600 mg/l and with Mikac *et al.*,[6] (could exceed 300 mg/l). They were also within the range found by North *et al.*,[11] (86-716 mg/l). These high values in the current study mean that the process of stabilization is still in the initial stages. On the other hand, the NH_4-N concentrations of the present study were lower than that have been found by Mikac *et al.*,[6] (740 mg/l).

The highest concentrations of NH_4-N in the current study can be attributed to the compaction of the wastes that presses and degrades the solid wastes resulting in high decomposition of proteins. It is expected that with time, compaction will increase the saturation of the waste by moisture resulting in more favorable conditions for biological degradation of proteins and amino acids. This has been found by Sponza and Agdag[13] who found that NH_4–N concentrations at 40 and 57 days of anaerobic biodegradation were 300-400 mg/l and 400–

450 mg/l, respectively. The results at 40 days show that partial degradation of nitrogenous compounds occur. The results at 57 days show that partial degradation of proteins could cause 50% reduction in the NH_4–N concentrations due to the non-acclimatization of methanogenic bacteria to high ammonia concentrations. Therefore, the accumulation of ammonia could have an inhibitory effect. A lag phase was dependent on NH_3–N level and was more sensitive factor than the NH_4–N level for unacclimated bacterial system.(14)

As reported by Marttinen *et al.*(15), the landfill leachate treatment was normally focused on the removal of organic nitrogenous, carbonaceous matters, and ammonia nitrogen, since the three parameters are quite important for possible inhibition of methane production under anaerobic conditions. It is important to note that most of the nitrogen in the solid waste landfills is in the ammonia form following the degradations of proteins and amino acids.(16) Leachate toxicity significantly correlated with the COD and ammonia in untreated and treated leachate.(15) Ammonium concentrations as high as 400 mg/l may inhibit the growth of anaerobic methanogenic bacteria in all reactors.(17) The concentration of NH_4-N of the present study will consequently affect the growth of anaerobic methanogenic bacteria.

Nitrate-N concentrations have shown low values (0 to 2.5 mg/l with a mean value of 1 mg/l). The high concentrations of NH_4-N and low concentrations of Nitrate of the current study are in agreement with North *et al.*,(11). They found that the leachate had higher NH_4^+ and lower NO_3^- values than background stream sites. Although landfills are generally considered anaerobic environments, the heterogeneous mixture of wastes can create air pockets, and rainwater also provides an oxygen input. Oxidising conditions in the landfill may cause two reactions: volatilization and nitrification. The former reaction leaves enriched NH_4^+, whereas in the latter reaction, ammonium is converted to nitrate typically via nitrite, which results in an increase in NO_3^- values.[18] The more prevalent reducing conditions in a landfill may cause reduction of nitrate to ammonium, and consequently lead to higher NH_4^+ values and lower NO_3^- values.

The results of total nitrogen, total phosphate, and NH_4–N concentrations (mean values of 973, 0.33, and 600 mg/l) were expected to decrease during the process of stabilization where methanogenic microorganisms consumed nitrogen and phosphorus through the degradation of carbonaceous compounds as suggested by Sponza and Agdag[13].

1.4. Assessment of BOD and COD Results, and BOD_5/COD Ratios

It is clear from table (1) that the BOD_5 values ranged from 21,000 to 40,000 mg/l with a mean value of 28,833 mg/l. These high values indicate that the process of stabilization is in the initial stages and are very slow. This is explained by the fact that stabilization of the readily available organics start first followed by the more resistant substances as mentioned by Reinhart *et al.*[19] These values are very high compared with the BOD_5 values of control, compacted, and shredded wastes at the initial and 57 days of anaerobic biodegradation (16,661, 27,152, and 24,804 mg/l; and 4251, 5330, 2145 mg/l, respectively).

The COD results ranged between 35,000 and 60,720 mg/l with a mean value of 45,240 mg/l. These values are very high compared with the values reported by Sponza and Agdag[13] who found that COD values of the initial and after 57 days of anerobic incubation of the leachate samples collected from the control, compacted, and shredded wastes were 14,000, 25,500 and 23,500 mg/l; and 6400, 7750, and 2300 mg/l, respectively. This can be attributed to the fact that the wastes of the present study were compacted in the landfill and compaction increases the COD levels of the leachate, and retards the degradation of the solid wastes. Increasing the compaction generate significantly lower moisture for microbial growth and the degradation process via microorganisms occurred slowly with a lag phase. All of these results agreed with that of other studies.[13,19]

The BOD and COD values (mean values of 28.833 and 45.240 mg/l) indicate clearly severe contamination and are very high compared with their corresponding values recorded by Al-Yaqout and Hamoda[9] in both operated and closed landfiils (30-600 mg/l) and (157.9-9440 mg/l), and (210-345 mg/l) and (6400-8800 mg/l), respectively. They attributed their results to the decomposition of organic waste.

In order to study in greater detail the proportion of biodegradable organic carbon in the leachate, it was considered to determine the BOD_5/COD ratio. The BOD_5/COD ratio indicates the changes in the amount of biodegradable compounds in the leachate. High BOD_5/COD ratios such as 0.97 indicate the low biodegradability of leachate.[20] Sponza and Agdag[13] found that after 57 days of anaerobic biodegradation, BOD_5/COD ratio of 0.97 had decreased approximately to 0.5. This ratio implies a highly biodegradable leachate. In other words, this level shows that the increasing biodegradability of organics was due to solubilization through methanogenesis. As the organic content biodegradation of MSW occurs, the BOD_5/COD ratio decreased. This decreases indicated that the organic wastes were degraded through fermentation phase which was showing a decreasing biodegradability due to methane formation. Sponza and Agdag[13] found that the

BOD_5/COD ratio of the shredded wastes was the lowest compared with controlled and compacted wastes. This indicated that the organic waste in shredded wastes was converted rapidly to methane via methanogenesis.

If the BOD_5/COD ratio is between 0.02 and 0.13, this implies that the leachate has a low biodegradability through anaerobic phase. When this ratio is between 0.4 and 0.8, this implies the high biodegradability of the leachate.[21] The BOD_5/COD ratio measured in the current study (0.6-0.66 with a mean value of 0.64) was similar with the findings of Otieno[21]. This indicates that the leachate of the present study is biodegradable and requires time and favourable conditions for anaerobic biodegradation as has been found by Ledakowicz and Kaczorek[22]. In their study, BOD_5/COD ratio dropped from an initial 0.55 to 0.2 on the 80^{th} day of the biodegradation.

Table (1): Results of Physical and Chemical Analyses of Alexandria Solid Waste Wastes Landfill Leachate Collected during the Period from January to August, 2002.

Parameter	January	May	August	Mean
PH	7	6.7	7.4	
Conductivity (μS/cm)	38,070	33,840	53,000	41,637
TDS (mg/l)	29,270	24,500	36,480	30,083
Chlorides (mg/l)	12,500	8,250	17,500	12,750
Suspended solids (mg/l)	17,460	13,222	2600	11,094
COD (mg/l)	40,000	60,720	35,000	45,240
BOD (mg/l)	25,500	40,000	21,000	28,833
Total Nitrogen (mg/l)	950	1150	820	973
Ammonia-N (mg/l)	600	600	600	600
Nitrate-N (mg/l)	2.5	ND	0.5	1
Sulphtes (mg/l)	680	650	275	535
Phosphates (mg/l)	0.39	0.21	0.4	0.33
Calcium (mg/l)	4880	03,720	400	3000
Magnesium (mg/l)	1380	704	1090	1058
Oil and Grease (mg/l)	139	115	40	98
BOD/COD	0.64	0.66	0.6	0.64

1.5. Assessment of Heavy Metals

Heavy metals were found at high concentrations indicating the toxic nature of leachate in the studied landfill. The presence of high concentrations of heavy metals in leachate is a cause of concern since their seepage into the groundwater will pose great risks to human health. Heavy metals such as lead will interfere with essential nutrients of similar appearance such as calcium (Ca^{2+}) and zinc (Zn^{2+}). The maximum limits for human consumption of Cu, Ni, Pb, and Zn are 10.0, 632, 50, and 5.0µg/l, respectively.[23]

The heavy metals concentrations of Alexandria Sanitary Landfill Leachate have been compared with those reported for Kuwait, USA, Germany and Italy [9,24] as presented in table (3). It is quite clear that the concentrations of heavy metals observed in other countries is generally higher than that measured in Alexandria.

Zinc (Zn) concentrations (0.352 - 0.928 mg/l with a mean value of 0.724 mg/l) were very high compared with the results obtained by AL-Yaqout and Hamoda[9] in active landfill (0.1–0.2 mg/l). However, they were lower than what have been obtained by the same authors in old landfills (0.2-4.8 mg/l). They attributed their high results to the industrial wastes. Rowe *et al.*,[24] noted that Zn is a cause of concern with regards to plant and aquatic life.

Copper (Cu) concentrations (0.002-0.032 mg/l with a mean value of 0.021 mg/l) were higher than those found by AL-Yaqout and Hamoda[9] in active landfill (zero). On the other hand, they were lower than what have been obtained by the same authors in old landfills (0-0.2 mg/l).

They attributed their lower results to the copper non-mobile nature in soil.

On the other hand, lead (Pb) concentrations (0.007 - 0.032 mg/l with a mean value of 0.023 mg/l) were lower than what has been recorded by AL-Yaqout and Hamoda[9] (0.1 mg/l) in some boreholes of active landfill. They attributed the concentrations of Pb to the disposed off industrial wastes, which were toxic to all forms of life at this level. Acidity in leachate causes lead to be released from solid wastes landfill.[24]

Nickel (Ni) concentrations (0.073 - 0.081 mg/l with a mean value of 0.078 mg/l) were lower than what has been recorded by AL-Yaqout and Hamoda[9] (0.4-0.6 mg/l) in old landfill.

The other toxic measured metals (Cr, Cd, and Mn) have recorded mean values of 0.006, 0.003, and 0.730 mg/l, respectively.

1.6. Assessment of Leachate Stabilization

The stabilized leachates from sanitary landfills are characterized by high concentrations of recalcitrant organic matter ($BOD_5/COD<0.1$). A significant proportion of recalcitrant material (>60% of TOC) comprises humic substances.[25] A further proportion is made up of synthetic compounds.[26] The computed (BOD_5/COD ratios of the leachate of the current study ranged between 0.6 and 0.66 with a mean value of 0.64 which indicate that the leachate of the current study is unstabilized. These results agreed also with Monje-Ramirez and Orta de Velásquez[12] who found that leachates obtained from the Bordo Poniente sanitary landfill were well-stabilized ($BOD_5/COD <0.01$).

The concentration of ammonia of the present study (600 mg/l) indicated also the unstability of the leachates. Therefore, a recommended treatment is a must before the process of drying. These can include coagulation and ozonation as recommended by Monje-Ramirez and Orta de Velásquez[12]. They indicated that coagulation–ozonation coupling processes can be considered as an excellent alternative for removing and transforming recalcitrant organic matter found in stabilized saline landfill leachates. In their study, the overall results of leachate treatment were 100% removal of leachate color, 78% removal of COD, and an increase in the BOD_5/COD ratio from 0.006 to 0.015.

1.7. Comparison with Other Leachates

The chemical characteristics of the Alexandria sanitary landfill leachate have been compared with those reported for USA, Germany, Italy, and Kuwait as presented in Table 3.[24,9] It is quite clear that pH of Alexandria leachate is in cocordance with the leachates of the other countries except that of USA. The organic strength of Alexandria leachate as represented by BOD and COD, agreed with that of Germany while they were higher than those of other countries. The other parameters concentrations fluctutated with their corresponding concentrations in the leachate of other countries. The low strength of leachate generated in the landfill of Kuwait may be attributed to the rising water table (dilutional effects) and mixing of leachate with subsurface water.[9] The high strength of most of the parameters concentrations of the leachate of the present study may be attributed to that re-landfilling of the residue after drying the leachate in lagoons increasing the concentrations of the pollutants in addition to the short time in the landfills which was not enough for the microorganisms to biodegrade the organic fractions of the wastes.

Table (2): Results of Heavy Metals Analysis of Alexandria Solid Waste Landfill Leachate Collected during the Period from January to August, 2002.

Parameter	January	May	August	Mean
Pb (mg/l)	0.029	0.032	0.007	0.023
Cu (mg/l)	0.029	0.032	0.002	0.021
Zn (mg/l)	0.928	0.892	0.352	0.724
Ni (mg/l)	0.079	0.081	0.073	0.078
Mn (mg/l)	0.911	1.1	0.180	0.730
Cd (mg/l)	0.003	0.004	0.0005	0.003
Cr (mg/l)	0.004	0.004	0.009	0.006

Table (3): Comparison of Leachate Quality of Alexandria Sanitary Landfill Leachate with Other Leachates.

Parameter (mg/l)	Alexandria	Kuwait[9,24]	USA[9,24]	Italy[9,24]	Germany[9,24]
pH	6.7-7.4	6.9-8.2	5.1-6.9	6-8.5	5.7-8.1
BOD	25,500-40,000	30-600	13,400	2125-10,400	400-45,900
COD	40,000-60,720	157.9-9440	1340-18.100	7750-38,520	1630-63,700
Sulphate	275-680	55-3650	0.01-1280	219-1860	1-121
Zn	0.352-0.928	0-4.8	18.8-67	5.7	-
Pb	0.007-0.032	0-0.2	0-4.46	-	-
Cu	0.002-0.032	0-0.2	0-0.1	-	-
Ca	400-4880	5.6-122	254.1-2300	0-175	70-290
Mg	704-1380	5.2-268	233-410	827-1469	100-270

2. Groundwater Contamination at Alexandria Sanitary Landfill

The results of the physical, chemical, and heavy metal analyses of the samples collected from the monitoring wells are presented in tables (4 and 5).

In order to study the contamination of the surrounding groundwater by the landfill leachate, the important chemical indicators have been selected. These indicators will be chosen based on their concentrations in the leachate and their effects. They include ammonia, chloride, BOD, COD, and heavy metals.(6)

The BOD and COD concentrations of the 5 monitoring wells ranged between 15-39 mg/l and 25-65 mg/l, respectively. NH_4-N ranged between 0.12-0.90 mg/l. Oil and grease were nil in all the wells. The heavy metals show very low concentrations. All of these results are very low compared with their corresponding mean values in the leachate values. This indicated that there is no contamination from the leachate to the groundwater surrounding the site. On the other hand, the high chloride concentration (1350-21,250 mg/l) in the monitoring wells may be attributed to the location of the site which is near to the sea.

CONCLUSION AND RECOMMENDATIONS

Based on the obtained results the following is concluded:

- The analysis of data confirms that leachates from the landfill are severely contaminated with organics, salts, and heavy metals.
- The fluctuations in concentration levels of the different parameters may be attributed to aging and thickness of waste layers, stage of decomposition, and re-landfilling of the concentrated residues from the drying lagoons.

Table (4): Results of Physical and Chemical Analyses of Monitoring Wells Samples at Alexandria Solid Waste Sanitary Landfill Collected during the Period from January to August, 2002.

Site	Site 1			Mean	Site 2		Mean	Site 3			Mean	Site 4	Site 5
	January	May	August		January	May		January	May	August			
pH	7.4	7.7	7.6		7.4	7.8		7.7	8.2	8.1		7.8	7.8
Conductivity (μS/cm)	43,600	46,100	50,800	46,833	45,000	42,200	43,600	6,750	7480	6580	6937	35,100	11,140
TDS (mg/l)	32,567	30,925	34,440	32,644	32,063	27,720	29,892	5,262	5022	4230	4838	23,300	5780
Chlorides (mg/l)	21,000	18,500	18,500	19,333	21,250	17,000	19,125	2,250	2250	1350	1950	12,500	2800
Suspended solids (mg/l)	4,975	4823	3055	4284	3,751	5080	4416	7,554	2780	3470	4601	4680	730
DO (mg/l)	---	---	3.6	3.6	---	---	---	---	---	6	6	5	5.8
COD (mg/l)	40	60	65	55	40	38	39	25	29	42	32	40	40
BOD (mg/l)	25	39	32	32	30	32	31	15	20	36	24	30	28
Total Nitrogen (mg/l)	1.1	1.3	1	1.13	1.3	1.1	1.2	1	1.1	1	1	1.1	0.9
Ammonia-N (mg/l)	0.36	0.32	0.12	0.27	0.52	0.64	0.58	0.24	0.9	0.72	0.62	0.16	0.16
Nitrate-N (mg/l)	0.05	0.04	0.04	0.04	0.05	0.03	0.04	0.06	0.04	0.3	0.13	0.24	0.05
Nitrite-N (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulphtes (mg/l)	1100	1500	1250	1283	1100	1500	1300	900	600	400	633	1000	700
Phosphates (mg/l)	0.02	0.1	0.15	0.09	0.02	0.05	0.04	0.02	0.075	0.25	0.115	0.15	0.15
Calcium (mg/l)	520	560	320	467	720	560	640	280	180	80	180	200	120
Magnesium (mg/l)	1552	1535	1490	1526	1580	1550	1565	345	370	172	296	1120	287
Oil and Grease (mg/l)	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero	Zero

Table (5): Results of Heavy Metals Analysis of Monitoring Wells Samples at Alexandria Solid Waste Sanitary Landfill Collected during the Period from January to August, 2002.

Site	Site 1			Mean	Site 2		Mean	Site 3			Mean	Site 4	Site 5
	January	May	August		January	May		January	May	August			
Pb (mg/l)	0.003	0.005	0.006	0.005	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.013	0.006
Cu (mg/l)	0.001	0.009	0.011	0.007	0.004	0.002	0.003	0.018	0.006	0.0002	0.008	0.004	0.002
Zn (mg/l)	0.021	0.03	0.015	0.022	0.023	0.029	0.026	0.023	0.023	0.011	0.019	0.017	0.013
Ni (mg/l)	0.003	0.005	0.005	0.004	0.001	0.006	0.004	0.001	0.009	0.001	0.004	ND	0.002
Mn (mg/l)	0.436	0.382	0.048	0.289	0.279	0.315	0.297	0.258	0.312	0.130	0.233	0.033	0.182
Cd (mg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0004	0.0001	ND	0.0004
Cr (mg/l)	0.0004	0.001	0.006	0.002	0.0004	0.0009	0.0007	0.0007	0.001	ND	0.0006	ND	ND
Hg (mg/l)	ND	ND	---	ND	ND	ND	ND	ND	ND	---	ND	---	---

- The high concentrations of NH_4–N (mean value of 600mg/l) indicated that the process of stabilization was still in the initial stages, and may be attributed to the compaction process and the growth of anaerobic methanogenic bacteria.
- The high BOD_5 results (mean value of 28,833mg/l) indicate that the process of stabilization is in the initial stages and is very slow.
- The high COD results (mean value of 45,240 mg/l) can be attributed to the compaction of the wastes in the landfill which increases the COD levels of the leachate and retards the degradation of the solid wastes.
- The BOD_5/COD ratio measured in the current study (mean value of 0.64) indicated that the leachate of the present study is biodegradable and unstabilized, and requires time and favourable conditions for anaerobic biodegradation.
- Heavy metals were found at high concentrations indicating the toxic nature of leachate. However, they were lower compared with those observed in other countries.
- Re-landfilling of the residue after drying the leachate in lagoons and the short time of biodegradation in the landfill site are some causes which effect the high strength of most of the parameters concentrations of the leachate.
- Assessment of groundwater contamination indicated that there was no contamination from the leachate into the groundwater surrounding the site.

Based on the observed conclusion, the following is recommended:

1. Shredding of Municipal Solid Wastes (MSWs) before disposal will have a positive effect on the rate of biological degradation.

2. Factors enhancing the biological degradation of the waste in the landfill should be studied and adjusted.
3. A follow-up study should be carried out to study the leachate generation rate, and the extent and nature of its interaction with the surrounding environment.
4. In combination with conventional monitored chemical parameters such as ammonium concentrations, ^{13}C and ^{15}N isotops are suggested to be used as a tool to monitor the impact of landfills on their surrounding environment.
5. Treatment of leachate before drying by coagulation–ozonation coupling processes can be considered as an excellent alternative for removing and transforming recalcitrant organic matter found in landfill leachates.
6. Continuous monitoring of the groundwater.
7. Identification of the sources of heavy metals in the solid waste transferred to landfill site is required.
8. High levels of heavy metals should be treated beforehand.

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