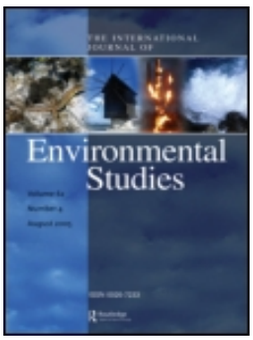

International Journal of Environmental Studies

ISSN: 0020-7233 (Print) 1029-0400 (Online) Journal homepage: http://www.tandfonline.com/loi/genv20

# Physico-chemical and microbial assessment of Ramallah municipal dump site

Orayb El-Sayrafi , Ghasan Daghra , Ratib Hussein & Khalid Swaileh

**To cite this article:** Orayb El-Sayrafi , Ghasan Daghra , Ratib Hussein & Khalid Swaileh (2011) Physico-chemical and microbial assessment of Ramallah municipal dump site, International Journal of Environmental Studies, 68:4, 509-518, DOI: 10.1080/00207233.2011.582725

**To link to this article:** http://dx.doi.org/10.1080/00207233.2011.582725

*International Journal of Environmental Studies,*
Vol. 68, No. 4, August 2011, 509–518

# Physico-chemical and microbial assessment of Ramallah municipal dump site

ORAYB EL-SAYRAFI†, GHASAN DAGHRA†, RATIB HUSSEIN‡
AND KHALID SWAILEH*‡

†Department of Chemistry, Birzeit University, PO Box 14, West Bank, Palestine; ‡Department of Biology and Biochemistry, Birzeit University, PO Box 14, West Bank, Palestine

(*Received 18 April 2011*)

Leachate samples from a main, near residential area dump site at Ramallah in the West Bank were assessed for 12 physico-chemical parameters and 12 pathogenic microbes. The results indicate that the environmental pollutants carry health risks to the general public.

*Keywords:* Leachate; Solid waste dump site; Microbial pollution

## 1. Introduction

Municipal solid waste landfills produce a highly contaminated leachate that poses serious health, as well as environmental threats [1–3]. Leachate is a dark brown liquid with strong odour and containing high levels of pollutants. The nature of its composition is highly variable depending on characteristics of the refuse, environmental factors, humidity and temperature. Leachate usually contains various organic and inorganic compounds, heavy metals and microorganisms. This necessitates continuous monitoring. Leachate quality studies can allow decision-makers to take measures to reduce health risks and environmental pollution.

The Palestinian Central Bureau of Statistics (PCBS) estimates that two million tonnes of solid wastes were produced in the Palestinian Territory during 2007. These wastes were dumped in over 133 randomly located dump sites, some of which are close to residential areas. Domestic solid wastes constitute about 53.7% of the total solid wastes generated in Palestine. Industrial and health care sectors generate about 46.3%. The typical composition of solid wastes in the West Bank is as follows: organic matter 60–70%, paper/cardboard 7–10%, plastic 5–10%, glass 3–6%, metals 2–3% and others 3–7% [4].

Ramallah is one of the main Palestinian cities. Its population size and industrial sector is rapidly growing since the establishment of the Palestinian Authority in 1995. The Ramallah dump site lies 2.4 km to the southwest of the city centre. It is situated on the top of a hill with an elevation of 850 m above sea level. The Ramallah dump site was established in the late 1960s, with an original area of about 4500 $m^2$. In the

*Corresponding author. Email: kswaileh@birzeit.edu

*International Journal of Environmental Studies*
ISSN 0020-7233 print: ISSN 1029-0400 online © 2011 Taylor & Francis
http://www.tandf.co.uk/journals
DOI: 10.1080/00207233.2011.582725

1990s, it was expanded to receive wastes from two neighbouring cities (Al-Bireh and Beitounia). The overloaded dump site started receiving 350 tonnes of refuse per day serving a total population of more than 100,000 in the year 2000. As a result, a mountain of garbage (reaching 60 m high) began to pile up endangering the surrounding residential areas especially in winter. Almost no studies have been made of this or other dump sites.

This paper reports a study characterising leachate originating from Ramallah dump site. Our team analysed relevant physico-chemical parameters, heavy metals, total and faecal coliforms and some pathogenic bacteria in leachate samples collected from different locations within the dumping site. This allows one to assess the pollution caused by this uncontrolled dumping site to groundwater, soil and population inhabiting the neighbouring residential areas.

## 2. Materials and methods

### *2.1. Sample collection*

A total of 12 leachate samples from four stations were collected in polyethylene buckets, covered with screens and embedded deep within the landfill. Sampling stations were located in different directions of the dump site. Leachate sample collection was carried out every three weeks during the wet season (January–February 2008). Samples collected were immediately transferred to the lab in polyethylene bottles that were stored in a refrigerator (4°C) for subsequent analysis.

### *2.2. Sample analysis*

#### *2.2.1. Physico-chemical parameters analysis*

Physico-chemical parameters and heavy metals were measured in all samples according to the Standard Methods [5]. Physico-chemical parameters that were examined in leachate samples included: pH, electrical conductivity (EC), alkalinity, total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), chemical oxygen demand (COD), biological oxygen demand (BOD), calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^{+}$), potassium ($K^{+}$), ammonia ($NH_4^{+}$), chloride ($Cl^{-}$), sulphate ($SO_4^{2-}$), phosphate ($PO_4^{3-}$) and heavy metals (Pb, Co, Ni, Cr, Cu, Fe, Al, Ba, Bi, Mn, Cd, Zn, Li).

Leachate samples' pH and electrical conductivity (EC) values were measured immediately after collection using Metrohm 827 pH Lab Meter (UK) and Jencons 4010 Conductivity Meter (UK), respectively. Chloride, sulphate, and nitrate concentration were measured using a Coupled Ion Analyzer (CIA) (Waters, MA). Chemical oxygen demand (COD) was measured by oxidation using $Hg_2SO_4/H_2SO_4$ and $Ag_2SO_4/H_2SO_4$. Biochemical oxygen demand ($BOD_5$) was evaluated after incubating a 330 ml sample for five days at 20°C. Alkalinity was determined by titration versus 0.02N sulphuric acid.

The TSS, TDS, and TS were determined by gravimetric method. The phosphate was determined using ascorbic acid method and $NH_4^{+}$ was determined by direct Nesslerisation. Major ions (Ca, Mg, Na, and K) and heavy metals (Pb, Co, Ni, Cr, Cu, Fe, Al, Ba, Bi, Mn, Cd, Zn, and Li) and were determined by using ICP-AES, Optima 3100.

Table 1. The specific primers used in the present study to detect microorganisms and their sequence

| Microorganisms | Sequence 5'→3' | Amplicon | Reference |
|---|---|---|---|
| *Shigella* spp. | H8: GTTCCTTGACCG CCT TTCCGAAC<br>H15: GCCGGTCAGCCACCCTC | 620-bp | [7] |
| *Legionella* spp. | LEG1: GTCATGAGGAATCTCGCTG<br>LEG2: CTGGCTTCTTCCAGCTTCA | 900 bp | |
| STEX1 | F: ATAAATCGCCATTCGTTGACTAC<br>R: AGAACG CCCACTGAGATCATC | 180 bp<br>255 bp | [8] |
| STEX2 | F: GGCACTGTCTGA AACTGCTCC<br>R: TCGCCAGTTATCTGACATTCTG | | |
| *Campylobacter* spp. | F: ATCTAATGGCTTAACCATTAAAC<br>R: GGACGGTAACTAGTTTAGTAT T | 857 bp | [9] |
| *Salmonella* spp. | 139: GTGAAATTATCGCCACGTTCGGGC AA<br>141: TCATCGCACCGTCAAAGGAACC | 284 bp | [10] |
| *Citrobacter* spp. | Crt4F: TTGGCGTCCAGCGCATTCA<br>Crt4R: AATTCCAGCCTTCGGCAAACG | 100 bp | [11] |
| *Acinetobacter* spp. | rA1: CCTGAATCTTCTGGTAAAAC<br>rA2: GTTTCTGGGCTGCCAAACATTAC | 425 bp | [12] |
| *P. aeruginosa* | F: TTCCCTCGCAGAGAAAACATC<br>R: CCTGGTTGATCAGGTCGATCT | 519 bp | [13] |
| *H. pylori* | F: CTAAGAGATCAGCCTATGTCC<br>R: GCGCAATCAGCGTCAGTAATG | 520 bp | [14] |
| *A. hydrophila* | F: GCAGTGGTTTATGACAAAGACG<br>R: TTAGAAGTTGTATTGCAGGGC | 1008 bp | [15] |

### *2.2.2. Microbial analysis*

Total and faecal coliforms were analysed by membrane filtration technique according to Standard Methods [5] using 45 μm filters (Sartorius, Germany). Samples were serially diluted to get countable numbers.

The presence of 10 pathogenic and opportunistic bacteria was examined using a molecular biology technique known as Polymerase Chain Reaction (PCR). These microorganisms were: *Salmonella* spp., *Shigella* spp., *Legionella pneumophila*, *Helicobacter pylori*, STEC, *Campylobacter* spp., *Pseudomonas aeruginosa*, *Aeromonas hydrophila*, *Citrobacter* spp., and *Acinetobacter* spp. DNA Extraction was done according to Oude Elferink *et al*. [6]. Specific primers (table 1) were used to detect the presence of these bacteria in leachate samples. The PCR reaction was conducted in a Hybaid Omni-Gene thermocycler according to Swaileh *et al*. [16]. The amplification products were separated in 1.5% agarose, stained with ethidium bromide visualised with UV transluminator and documented with Kodak Polaroid Gelcam.

## 3. Results and discussion

### *3.1. Physico-chemical analysis*

Table 2 summarises the physico-chemical parameters that were examined in leachate samples from Ramallah landfill. The pH values for samples from the four sampling stations ranged between 6.22 (S2) and 7.5 (S4). The average pH value for all samples from all stations was 6.82. The results obtained are in agreement with range values obtained by Yoshida *et al*. [17], Mor *et al*. [1] and Armstrong and Rowe [18] and are clearly less than those pH values obtained by others [3,19,20]. The pH value of leachate depends on the

Table 2. Mean values for physical and chemical characteristics of leachate samples collected from four stations (S1–S4) in Ramallah dump site between January and February 2008

| Parameter | S1 | S2 | S3 | S4 | Average |
|---|---|---|---|---|---|
| pH | 6.93 | 6.22 | 6.63 | 7.50 | 6.82 |
| EC[a] | 13110 | 10870 | 18260 | 30450 | 18172.5 |
| TDS[b] | 2206.67 | 1834.33 | 2440.00 | 3973.33 | 2613.58 |
| TSS[b] | 3219.33 | 2237.00 | 2036.67 | 778.00 | 2067.75 |
| TS[b] | 5430.67 | 4102.67 | 4482.67 | 4750.00 | 4691.5 |
| COD[b] | 3707.33 | 1791.67 | 939.77 | 2182.47 | 2155.31 |
| BOD[b] | 600.00 | 566.67 | 536.67 | 523.33 | 556.67 |
| BOD/COD | 0.16 | 0.30 | 0.58 | 0.42 | 0.36 |
| NH4-N[b] | 12.33 | 15.97 | 19.67 | 25.20 | 18.29 |
| $SO_4^{2-b}$ | 154.67 | 187.67 | 219.00 | 245.33 | 201.67 |
| $P\text{-}PO_4^{3-\dagger}$ | 4.00 | 3.63 | 5.43 | 6.13 | 4.80 |
| $Cl^{-b}$ | 599.67 | 500.67 | 502.67 | 781.00 | 596.0 |
| Alkalinity[b] | 435.33 | 389.67 | 566.33 | 816.00 | 551.83 |

[a]μs/cm.

[b]mg/L.

concentration of acids in the leachate and on the partial pressure of $CO_2$ in the landfill gas that is in contact with the leachate [21]. The low pH values indicate young-aged leachate samples where early fermentation processes increase the concentrations of volatile acids and inorganic ions accompanied by an increase in $CO_2$ production.

During the initial stage of decomposition, organic matter is oxidised under aerobic conditions. The aerobic stage is usually short and is accompanied by depletion of oxygen. It is then replaced by three major phases of anaerobic digestion: (i) acetogenic fermentation, (ii) intermediate anaerobiosis, and (iii) methanogenic fermentation. The three phases can operate simultaneously in different parts of the landfill [22]. Leachate from the first phase exhibits high values of biochemical oxygen demand (BOD, commonly > 10,000 (mg/l), high BOD/COD (chemical oxygen demand) ratios (commonly > 0.7) and low acidic pH values (typically 5–6). The intermediate anaerobiosis that follows is accompanied with a gradual increase in the methane ($CH_4$) and a decrease in $CO_2$ and volatile fatty acids. The diminishing concentration of fatty acids brings about an increase in pH values and alkalinity.

According to the US Environmental Protection Agency (EPA) [23], in typical landfill leachate, the acetogenic phase is characterised by high BOD and BOD/COD ratio (13,000 mg/L and 0.58, respectively) as compared to lower values (180 mg/L and 0.05) in the methanogenic phase (table 3). Ramallah dump site leachate showed a mean BOD value of 556.67 mg/L and a BOD/COD ratio of 0.36. Along with other parameters (table 3), this indicates a slow progress of leachate samples of Ramallah landfill site from the acetogenic phase to the methanogenic phase.

The EC values measured in leachate samples ranged between 10,870–30,450 μs/cm with an average of 18,172 μs/cm (table 2). These values are greater than values reported for leachate samples from other regions [17,20,21,25]. Nevertheless, the mean value of EC from Ramallah dump site is less than that of Mor *et al*. [1] measured for leachate samples from Gazipur landfill in India as 24,500 μs/cm. The high values of EC and TDS (2613.58 mg/L) indicate the presence of significant amounts of dissolved inorganic ions 121 that result from the mineralisation processes during the anaerobic decomposition of the waste

Table 3. EPA [23] parameters of acetogenic and methanogenic phases of leachate fermentation compared to those observed in Ramallah dump site

| Parameter[a] | Acetogenic phase (EPA [23]) | | Methanogenic phase (EPA [23]) | | Ramallah dump site | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| pH | 6.1 | 4.5–7.5 | 8 | 7.5–9 | 6.82 | 5.1–8.41 |
| $BOD_5$ | 13,000 | 4000–40,000 | 180 | 20–550 | 556.67 | 100–950 |
| COD | 22,000 | 6000–60,000 | 3000 | 500–4500 | 2155.31 | 501.7–5470 |
| BOD/COD | 0.58 | | 0.05 | | 0.36 | |
| SO4 | 500 | 70–1750 | 80 | 10–420 | 201.67 | 39–520 |
| Ca | 1200 | 10–2500 | 60 | 20–600 | 218.57 | 66.7–568 |
| Mg | 470 | 50–1150 | 180 | 40–350 | 86.88 | 29.4–114 |
| Fe | 780 | 20–2100 | 15 | 3–280 | 6.05 | 0.78–19.9 |
| Mn | 25 | 0.3–65 | 0.7 | 0.03–45 | 1.22 | 0.135–4.88 |
| Zn | 5 | 0.1–120 | 0.6 | 0.03–4 | 0.43 | 0.228–1.22 |

[a]All units are in mg/l, except for pH.

in the dump site. TDS values obtained in the present study (table 2) are much less than that obtained by Al Sabahi *et al*. [2] for leachate from a dump site in Yemen as 32,305 mg/L and that obtained by Mor *et al*. [1] for leachate from India as 27,956 mg/L. However, our values are greater than those reported by Al-Muzaini [3] for a dump site in Kuwait as 537 mg/L. The average TSS value for leachate samples from the four stations was 2067.75 mg/L. Only station 4 exhibited a low value for TSS (778 mg/L) compared to other stations. Leachate from this station exhibited highest values for pH, EC and TDS, however (table 2).

Mean COD and BOD values for leachate samples from the Ramallah dump site were 2155.31 mg/L and 556.67 mg/L, respectively (table 2). These values are clearly less than those reported by other studies [1,2,17–19,26]. However, our values are still higher than those obtained Al-Muzaini [3]. The values obtained by our study indicate low-intermediate organic strength of the leachate in Ramallah dump site caused by bio-/chemo-degradable organic matter. The BOD/COD ratio was more than 0.3 except for leachate from S1 where the ratio was 0.16. The mean ratio for all sampling stations was 0.36. This generally indicates a young-middle aged leachate (BOD/COD > 0.3) and that the landfill is in the acidogenic phase 226Older, more stabilised leachate tends to have a ratio that is less than 0.2 [2,17].

Amonia-nitogen values in leachate samples ranged between 12.33 mg/L and 25.2 mg/L with an average value of 19.29 mg/L (table 2). These values are much less than those reported by Mor *et al*. [1], Isidori *et al*. [19] and Çeçen and Gürsoy [26] as 2675, 3700 and 1493 mg/L, respectively. Ammonia-N results from the de-amination of amino acids during the decomposition of organic compounds [27].

Sulphate concentration in leachate samples from the Ramallah dump site ranged between 154.67 and 245.33 mg/L with an average value of 201.67 mg/L (table 2). These values are less than those reported by Ehrig [24] and Amina [20] but higher than those reported by Abdulatif *et al*. [28], Al-Muzaini [3] and Armstrong and Rowe [18]. Phosphate levels in leachate samples were generally low; ranging between 3.63 mg/L and 6.13 mg/L with an average of 4.8 mg/L. These concentrations are much less than those reported by Esakku *et al*. [29]. Chloride ranged from 500.67 mg/L to 781 mg/L with an average of 596 mg/L (table 2). These values are slightly higher than the common leachate concentration of 500 mg/L [30]. Alkalinity is used to indicate the rate of biological activity. High alkalinity values indicate anaerobic respiration while low alkalinity values result from aerobic respiration. Alkalinity values of the present study ranged between 389.67 mg/L and 816 mg/L with an average of 551.83 mg/L. Although high, these values are still much less than those reported by Çeçen and Gürsoy [26] to be more than 6418 mg/L.

Leachate samples were analysed for heavy metal and other elements (table 4). The Na, K, Ca, and Mg were clearly at higher levels than the other elements. Their mean levels were 754.65, 327.16, 218.57, and 86.88 ppm, respectively. The high magnesium levels in leachate show that industrial wastes like cosmetics, cement and textile are being dumped in the landfill [31]. Levels of the remaining metals were almost close to or less than 1 ppm. Cd was not detected in most samples. Generally, heavy metal levels in leachate samples were low and do not pose serious environmental threat. Results of the present study are comparable to those reported by some authors [3,17,26] and less than those reported by others [1,2,19]. The mean values for elements in the Ramallah dump site leachate are comparable to or slightly less than the EPA [23] typical values observed in landfills in the methanogenic phase (table 3).

Table 4. Mean concentrations (mg/l) of heavy metals and ions in leachate samples collected from four stations (S1–S4) in Ramallah dump site between January and February 2008. Number of samples analysed from each station = 3

| Ion | S1 | S2 | S3 | S4 | Average |
|---|---|---|---|---|---|
| Fe | 6.053 | 5.202 | 5.347 | 7.610 | 6.053 |
| Zn | 0.435 | 0.386 | 0.370 | 0.548 | 0.435 |
| Li | 0.194 | 0.167 | 0.198 | 0.219 | 0.194 |
| Cr | 0.027 | 0.025 | 0.022 | 0.035 | 0.027 |
| Co | 0.060 | 0.057 | 0.055 | 0.068 | 0.060 |
| Ni | 0.201 | 0.202 | 0.169 | 0.231 | 0.201 |
| Cu | 0.180 | 0.223 | 0.170 | 0.148 | 0.180 |
| Mn | 1.216 | 0.946 | 1.227 | 1.475 | 1.216 |
| Al | 1.222 | 0.966 | 0.879 | 1.822 | 1.222 |
| Cd | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| Ba | 0.184 | 0.159 | 0.187 | 0.207 | 0.184 |
| Pb | 0.112 | 0.109 | 0.099 | 0.128 | 0.112 |
| Bi | 1.140 | 1.140 | 1.140 | 1.140 | 1.140 |
| Ca | 218.57 | 180.60 | 201.20 | 273.90 | 218.57 |
| K | 327.16 | 358.37 | 304.78 | 318.33 | 327.16 |
| Mg | 86.88 | 89.18 | 82.69 | 88.77 | 86.88 |
| Na | 754.65 | 797.74 | 693.56 | 772.67 | 754.65 |

### *3.2. Microbial analysis*

Table 5 summarises the results of microbiological analyses of total and faecal coliforms. Total coliform values ranged between 6 and 57,600 CFU/ml with an average of 18,963.8 CFU/ml. Faecal coliform bacteria indicate the presence of sewage contamination and the possible presence of other pathogenic organisms. The number of faecal coliforms in leachate samples ranged between less than one and 24,000 CFU/ml with an average of 7602.7 CFU/ml. These constitute about 40% of the total coliforms in leachate samples. The high numbers of total and faecal coliforms pose risks to human health. This is all the more important because residential areas are near to the dump site. In addition, as the dump site lacks any leachate drainage system, rainwater washes leachate out of the dump site contaminating freshwater resources and spreading these coliforms far away from the dumpsite.

Table 5. Total and faecal coliforms (CFU[a]/ml) in leachate samples collected from Ramallah dump site between January and February 2008

| Sample no. | Station no. | Total coliforms | Faecal coliforms |
|---|---|---|---|
| 1 | S1 | 20,000 | 8000 |
| 2 | S1 | 10,000 | 1000 |
| 3 | S1 | 3800 | 1500 |
| 4 | S2 | 6 | 0.4 |
| 5 | S2 | 19,200 | 11200 |
| 6 | S2 | 57,600 | 21312 |
| 7 | S3 | 44,160 | 24000 |
| 8 | S3 | 40,800 | 17760 |
| 9 | S3 | 10,000 | 1000 |
| 10 | S4 | 6400 | 1460 |
| 11 | S4 | 9000 | 1740 |
| 12 | S4 | 6600 | 2260 |
| Average | | 18,963.8 | 7602.7 |

[a]CFU = colony forming unit.

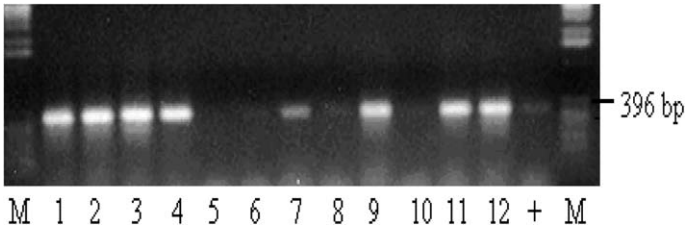


Figure 1. The PCR product of *Acinetobacter* spp. Lanes M: Roche DNA molecular weight marker X. Lanes 1–12: leachate samples. Lane (+): positive control.

Table 6. Pathogenic and opportunistic pathogenic bacteria tested by RAPD technology in 12 leachate samples collected from Ramallah dump site between January and February 2008

| Microorganism | Samples with positive results | % |
|---|---|---|
| *Citrobacter* spp. | 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12 | 91.7 |
| *Acinetobacter* spp. | 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12 | 91.7 |
| *Pseudomonas aeruginosa* | 1, 2, 3, 6, 7, 11, 12 | 58.3 |
| *Salmonella* spp. | 1, 2, 7, 8, 9, 12 | 50 |
| *Aeromonas hydrophila* | 9, 12 | 16.7 |
| *Shigella* spp. | 3 | 8.3 |
| *Legionella* spp. | – | – |
| *H. pylori* | – | – |
| *STEC* | – | – |
| *Campylobacter* spp. | – | – |

In order to investigate further the presence of pathogenic and opportunistic pathogenic bacteria, the specific PCR technique (figure 1) was applied to detect 10 microorganisms in leachate samples (table 6). Six bacterial species out of 10 were found in some leachate samples. The remaining four were negative in all samples analysed. *Citrobacter* and *Acinetobacter* were recorded in about 92% of the samples, *Pseudomonas* and *Salmonella* in 58% and 50%, respectively and *Aeromonas* and *Shigella* in 17% and 8% of the samples. The main sources of pathogens in landfills are facial tissues, pet faeces, diapers, paper towels, and food waste. Biomedical waste that ends up in municipal landfills increases the number of microorganisms.

In conclusion, our examination of the Ramallah dump site leachate indicated that key parameters like pH, BOD, COD, BOD/COD and conductivity indicate the progress of decomposition from the acetogenic phase to the methanogenic phase. Concentrations of metals and other ions in leachate samples were generally low except for Ca, K, Mg and Na. All leachate samples analysed contained considerable amounts of total and faecal coliforms that can contaminate the environment and threaten public health in the adjacent residential areas – and beyond. The specific molecular biology test (PCR) proved the presence of six pathogenic or opportunistic pathogenic bacteria in leachate samples. Most of these bacteria are commonly encountered in municipal landfills. Finally, Ramallah dump site needs careful management that takes into consideration the health and environmental threat to the neighbouring residential areas. Public health must be protected; the dump site is a threat.

### *Acknowledgement*

The authors would like to thank Birzeit University for the financial support for this project.

### *References*

[1] Mor, S., Ravindra, K., Dahiyaa, R.P. and Chandra, A., 2006, Leachate characterization and assessment of ground water pollution near municipal solid waste landfill site. *Environmental Monitoring and Assessment,* **118**, 435–456.

[2] Al-Sabahi, E., Abdul Rahim, S., Wan Zuhairi, W.Y., Al Nozaily, F. and Alshaebi, F., 2009, The characterization of leachate and groundwater pollution at municipal solid waste landfill of Ibb City, Yemen. *American Journal of Environmental Sciences,* **5**(3), 256–266.

[3] Al-Muzaini, S.M., 2009, A comparative study of the characterization of landfill leachate at the dumping sites in Kuwait. *Journal of Food Agriculture and Environment,* **7**(3 & 4), 679–683.

[4] UNEP, 2003, Desk study on the environment in the occupied Palestinian Territories, Pekka Haavisto, Chairman, Jeneva, 20 January.

[5] APHA, 1995, *Standard Methods for the Examination of Water and Wastewater* 19th edn (Washington, DC: American Public Health Association).

[6] Oude Elferink, S.J.W.H., Rinia, A.A., Bruins, M.E., de Vos, W.M. and Stams, A.J.M., 1997, Detection and quantification of *Desulforhabdus amnigenus* in anaerobic granular sludge by dot blot hybridization and PCR amplification. *Journal of Applied Microbiology,* **83**, 102–110.

[7] Theron, J., Morar, D., Du Preez, M., Brözel, V.S. and Venter, S.N., 2000, A sensitive seminested PCR method for the detection of *Shigella* in spiked environmental water samples. *Water Research,* **35**, 869–874.

[8] Paton, A.W. and Paton, J.C. Detection and characterization of shiga toxigenic *Escherichia coli* by using multiplex PCR assays for *stx*1, *stx*2, *eaeA*, Entero-hemorrhagic *E. coli hlyA*, *rfb*O111, and *rfb*O157. *Journal of Clinical Microbiology*, **36**, 598-602.

[9] Denis, M., Soumet, C., Rivoal, K., Ermel, G., Blivet, D., Salvat, S. and Colin, P., 1999, Development of a m-PCR assay for simultaneous identification of *Campylobacter jejuni* and *C. coli*. *Letters in Applied Microbiology,* **29**, 406–410.

[10] Rahn, K., De Gandis, S.A., Clarke, R.C., McEwen, S.A., Galan, J.E., Ginocchio, C., Curtiss, R.III. and Gyles, C.L., 1992, Amplification of an invA gene sequence of *Salmonella typhimurium* by polymerase chain reaction as a specific method of detection of *Salmonella. Molecular* and Cellular Probes*,* **6**, 271–279.

[11] Kaclíková, E., Krascsenicsová, K., Pangallo, D. and Kuchta, T., 2005, Detection and quantification of *Citrobacter freundii* and *C. braakii* by 5'-nuclease polymerase chain reaction. *Current Microbiology,* **51**(4), 229–232.

[12] Krawczyk, B., Lewandowski, K. and Kur, J., 2001, Comparative studies of the *Acinetobacter* genus and the species identification method based on the *recA* sequences. *Molecular and Cellular Probes,* **16**, 1–11.

[13] Khan, A.A. and Cerniglia, C.E., 1994, Detection of *Pseudomonas aeruginosa* from clinical and environmental samples by amplification of the exotoxin A gene using PCR. *Applied and Environmental Microbiology,* **60**, 3739–3745.

[14] Hoshina, S., Kahn, S.M., Jiang, W., Green, P.H., Neu, H.C., Chin, N., Morotomi, M., LoGerfo, P. and Weinstein, I.B., 1990, Direct detection and amplification of *Helicobacter pylori* ribosomal 16S gene segments from gastric endoscopic biopsies. *Diagnostic Microbiology and Infectious Disease,* **13**(6), 473–482.

[15] Khushiramani, R., Girisha, S.K. and Karunasagar, I., 2006, Cloning and expression of an outer membrane protein ompTS of *Aeromonas hydrophila* and study of immunogenicity in fish. *Protein Expression and Purification,* **51**, 303–307.

[16] Swaileh, K.M., Hussein, R. and Ezzughayyar, A., 2008, Evaluating wastewater-induced plant genotoxicity using randomly amplified polymorphic DNA (RAPD). *Environmental Toxicology,* **23**, 117–122.

[17] Yoshida, M.S., Sothom, A., Souissi, N., Bousselmi, L., Jedidi, N., Ghrabi, A. and Ferchichi, M., 2000, Characterization of leachate from Henchir El Yahoudia closed landfill. *Water Waste and Environment Research,* **1** (2), 129–142.

[18] Armstrong, M.D. and Rowe, R.K., 1999, Effect of landfill operations on the quality of municipal solid waste leachate. Proceedings of 7th International Landfill Symposium, S. Margherita di Pula, Cagliari, Sardinia, October, II, pp. 81–88.

[19] Isidori, M., Lavorgna, M., Nardelli, A. and Parrella, A., 2003, Toxicity identification evaluation of leachates from municipal solid waste landfills: a multispecies approach. *Chemosphere,* **52**, 85–94.

[20] Amina, C., Abdekader, Y., Elkbri, L., Jacky, M. and Alain, V., 2004, Environmental impact of an urban landfill on a costal aquifer (El Jadida, Morocco). *Journal of African Earth Sciences,* **39**, 509–516.

[21] Banar, M., Aysun, O. and Kürkcüoglu, M., 2006, Characterization of the leachate in an urban landfill by physicochemical analysis and solid phase microextraction-GC/MS. *Environmental Monitoring Assessment,* **121**, 439–459.

[22] Taylor, R. and Allen, A., 2006, Protecting Groundwater for Health. In: O. Schmoll, G. Howard, J. Chilton and I. Chorus (Eds) *Waste Disposal and Landfill: Potential Hazards and Information Needs, Protecting Groundwater for Health* (London: WHO, IWA Publishing), pp. 339–360.

[23] EPA, 1995, *Decision Maker's Guide to Solid Waste Management, Volume II* (Washington, DC: EPA).

[24] Ehrig, H.J., 1989, In: H.T. Christensen, A. Stegmann and R. Cossu (Eds) *Leachate Quality, Sanitary Landfilling: Process, Technology and Environmental Impact*, 2nd edn (London: Academic press), p. 78.

[25] Al-Muzaini, S., Beg, M.U. and Muslmani, K., 1995, Characterization of landfill leachates at a waste disposal site in Kuwait. *Environment International,* **21**, 399–405.

[26] Çeçen, F. and Gürsoy, G., 2000, Characterization of landfill leachates and studies on heavy metal removal. *Journal of Environmental Monitoring,* **2**, 436–442.

[27] Tatsi, A.A. and Zouboulis, A.I., 2002, Production, composition and temporal variation of pollution parameters for sanitary landfill leachates. *Advances in Environmental Research,* **6**, 207–219.

[28] Abdulatif, M.A., Sulaiman, W.N. and Osama, E.M., 2000, Groundwater quality in Khartoum State, Sudan. *Journal of Environmental Hydrology,* **8**, 16–23.

[29] Esakku, S., Karthikeyan, O.P., Joseph, K., Nagendran, R., Palanivelu, K., Pathirana, K.P.M.N., Karunarathna, A.K. and Basnayake, B.F.A., 2007, *Proceedings of the International Conference on Sustainable Solid Waste Management*, 5-7 September, Chennai, India, pp. 341–347.

[30] ADEME, 1996, *Guide méthodologique pour la remise en état des décharges d'ordures ménagerès et assimilés* (Paris, France: Agence de l'Environnement et de la Maitrise de l'Energie).

[31] Al-Yaqout, A.F. and Hamoda, M.F., 2003, Evaluation of landfill leachate in arid climate – a case study. *Environment International,* **29**, 593–600.