

WASTEWATER OF GAZA, CHEMISTRY AND MANAGEMENT APPROACH

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ABSTRACT

The severe shortage of water resources in Gaza has led to the need of wastewater reuse. For this purpose, wastewater quality should be identified. Wastewater and sludge chemical characteristics were investigated in a 3-year monitoring program. Twelve elements (Ag, Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) were analyzed in 120 composite samples of influent and effluent wastewater. Thirty parameters were determined in 35 sludge samples; P, AOX, C, S, CaCO₃, Mg, Ca, Na, K, Li, Cu, Zn, Ni, Pb, Mn, Fe, Cr, Co, Cd, As, Hg, Ti, Se, Br, Rb, Th, Sr, Y, U, and Zr. The results revealed that domestic wastewater influent contains considerable amounts of heavy metals and the partially functional treatment plants of Gaza are able to remove 40-70% of most metals during the treatment process. Moreover, the plants are capable to absorb the industrial effluents with no significant impact on treatment bioprocesses. Zinc and AOX only showed anomalous concentrations; more than 85% of sludge samples showed that averages of zinc and AOX are 2000 mg/kg and 550 mg Cl/kg, respectively.

Consequently, the wastewater effluent of Gaza could be used in agriculture within the frame work of integrated cooperation approach of all relevant Palestinian institutions.

KEYWORDS: Institutional arrangement; Sludge; Trace metals; Wastewater reuse

INTRODUCTION

Lack of wastewater management has a direct impact on problems related to public health, marine and coastal pollution, deterioration of nature and biodiversity, as well as landscape and aesthetic distortion in the Gaza Strip (MEnA, 2000). Currently, about 60-80% of the

domestic wastewater is discharged into the environment without treatment, either directly at the source, after collection from cesspits or through the effluent of the sewer system or the overloaded treatment plants. Gaza produces about 13 MCM annually (CAMP, 2000). About 40% (50,000 cubic meters per day) of the wastewater that is generated in Gaza is currently discharged into the Mediterranean Sea; a minor part infiltrates into the soil and contaminates the groundwater.

Compared to the neighboring countries, the industrial sector in Palestine is presently rather underdeveloped. The majority of industries is concentrated in the city of Gaza and in the northern areas, grouped in two main industrial estates, Gaza Industrial Estate (GIE) and smaller Beit Hanoun Industrial Estate (BIE). Several industries are scattered among residential areas. Up to now there has been very little production of sludge as all existing wastewater treatment plants are deficient and operating with old technologies. Although the use of sludge on agricultural land is largely dictated by nutrient content (N and P), the accumulation of potentially toxic elements is an important aspect of sludge quality, which should be considered in terms of long-term sustainable use of sludge on land (Burica *et al.*, 1996). Adsorbable organic halogens (AOX) are used as an indicator for the priority substances (Planquart *et al.*, 1999).

The main objective of this study is to introduce the concentration of trace metals and some major parameters in domestic, industrial wastewater and sludge for the first time. Moreover, it tries to highlight the various options that aim to reuse the treated wastewater and sludge in the Gaza Strip in a manner that will insure agricultural-sustainable development.

MATERIALS AND METHODS

The study area

The main two operating treatment plants in the Gaza Strip are Beit Lahia (Northern) Wastewater Treatment Plant in the northern area, and Gaza Wastewater Treatment Plant in the region of Gaza City (Fig. 1). The plants consist of several ponds for aeration and sedimentation and they have no pretreatment facilities. The former, located some 1.5 km east of the town of Beit Lahia in the northern

part of the Gaza Strip, was erected in stages, commencing in 1976. The population in the area amounts to about 200,000 people today. The plant was designed for a peak flow of 2,600 m³/h. The effluent merely overflows from the last pond of the works, spreading in a large sand dune area in the immediate vicinity of the plant, where it infiltrates to groundwater. Gaza Wastewater Treatment Plant was originally constructed in 1977 and in 1999 the plant was expanded to a capacity of 32,000 m³/day. The current flow to the plant is about 42,000 m³/day. Among 31 industries, 20 were located in the two major industrial estates; Gaza, and Beit Hanoun. The other 11 industries were scattered among residential areas especially in Gaza, Jabalia and few in Khan Yunis.

The sampling and analysis

Three sampling campaigns have been conducted in three years (20 influent and 20 effluent samples each year) in the periods 20 November-12 December 2000, 26 June-17 July 2001 and 25 April -17 May 2002. A series of grab samples (8-10) were taken over a day (one liter per two hours), starting from 6:00 am, and combined in a container to form a composite sample. Finally, one liter of the mixture was taken in an acid-washed bottle and transferred to the laboratory, then it was filtered in acid-washed filter holder and through 0.45 µm (Sartorius filter); the first few milliliters were used for rinsing, then they were discarded, and the filtrate was transferred to clean acid-washed polyethylene bottles and acidified by concentrated nitric acid (Ultrapur, Merck, v/v), and stored at 4 °C until analyses by the ICP/MS (Perkin Elmer-Sciex, Elan 6000) were performed; the other part of wastewater was filtered with no additives and stored at 4 °C for anion analyses by Ion Chromatography (IC DIONEX DX-120). Several parameters were measured during the fieldwork: temperature, electric conductivity and pH, other parameters (SS, TSS, TDS, COD and BOD₅) were measured a few hours later according to the American standard methods (APHA, 1995).

Thirty one composite samples of industrial wastewater were collected; the same 10 industries were selected in 2000 and 2001 and different 11 industries in 2002. The samples had the same treatment and analysis as the domestic wastewater samples.

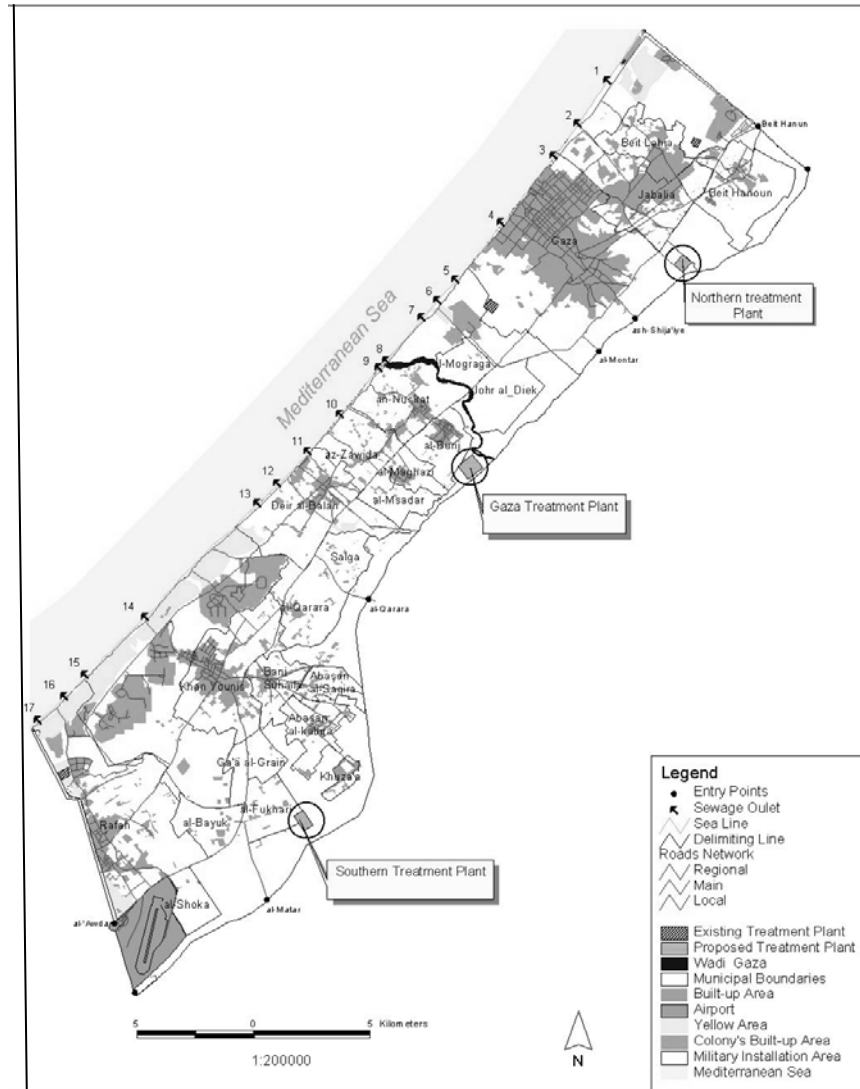


Figure (1) Existing and proposed wastewater treatment plants in the Gaza Strip.

Thirty-five sewage sludge samples were collected during the campaigns, 5, 20 and 10 in the three years. Samples were collected in polyethylene containers from the different drying lagoons of the two treatment plants and from the accumulated piles in the surrounding areas. After collection, samples were freeze-dried until complete dryness; then they were ground and homogenized in an agate mortar and sieved through a mesh of 63-mm pore size.

About 0.5 to 1.0 grams of the homogenized sample were dissolved in 10.5 ml of concentrated hydrochloric acid (37%) and 3.5 ml of concentrated nitric acid (65%) in 50 ml retorts. The samples were allowed to degas (12 hours). Then all samples were heated to 160 °C on a sand bath until a complete extraction had taken place (3 hours). After cooling, the solutions were diluted with distilled water in 50 ml volumetric flasks and kept in 100 ml polyethylene bottles for analysis. Heavy metals were analyzed by two different techniques; the Flame Atomic Absorption Spectrometry (AAS vario 6- analytikjena) was used for determination of Mg, Li, Ca, K, Na, Cu, Zn, Ni, Pb, Mn, Fe, Cr, Co, Cd and As; the Energy-dispersive Miniprobe Multielement Analyzer (EMMA) for direct analysis was used for K, Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Rb, Sr, Y, Zr, Pb, Th and U (Cheburkin and Shotyck, 1996). The distribution of total phosphorus represented as (PO₄) was measured for all sampling stations (APHA, 1995). Mercury was determined using an Advanced Mercury Analyzer (AMA) 254 solid phase Hg-Analyzer (LECO). The total carbon and sulfur were determined directly in dried samples by using a Carbon-Sulfur Determinator (Leco CS-225). Carbonates were measured directly via a carbonate bomb (Müller & Gastner, 1971). The TOC can be calculated by the subtraction of inorganic carbon from total carbon. AOX was determined by Euroglas Organic Halogen Analyzery- Netherlands.

For quality control, analytical blanks and two samples with known concentrations of heavy metals were prepared and analyzed using the same procedures and reagents. Standard Reference Materials were used for determination of trace elements in wastewater and sludge. As an independent check on the trace element measurements of the sludge, EMMA-XRF (REF) was used.

RESULTS AND DISCUSSION

Domestic Wastewater

The performance of the two treatment plants is shown in [table 1](#) and [table 2](#). Major ions of Cl, F, NO₃, SO₄, Na, Ca, Mg and K in wastewater were similar to their values in the groundwater of the area of each treatment plant. Major indicating parameters (BOD₅, COD and TSS) were removed to the maximum and all tested heavy metals in the effluent complied with different standards. The wastewater effluent had good characteristics close to the guidelines and standards

of many developed countries, and in general the results revealed that there was no significant difference between the performances of the two treatment plants in terms of heavy metal removal (Fig. 2).

Table (1) Performance of wastewater treatment plants in the Gaza Strip (4-19 July 2001).

| Parameter* | German standards | Beit Lahia WWTP** Influent | Beit Lahia WWTP Effluent | Removal (%) | Gaza WWTP Influent | Gaza WWTP Effluent | Removal (%) |
|---|------------------|----------------------------|--------------------------|-------------|--------------------|--------------------|-------------|
| pH | | 7.04 | 7.43 | -6 | 7.5 | 7.7 | -3 |
| Temperature (°C) | | 22.3 | 22.3 | 0 | 25.5 | 26 | -2 |
| Settleable Solids SS (Ml/l) | | 6 | 0.1 | 98 | 9 | 0.1 | 99 |
| Total Dissolved Solids (TDS) mg/l | | 895 | 1007 | -13 | 1470 | 1536 | -4 |
| Total Suspended Solids (TSS) mg/l | | 1288 | 1024 | 20 | 440 | 20 | 95 |
| Chloride (mg/l) | | 270 | 250 | | 555 | 480 | |
| Fluoride (mg/l) | | 0.6 | 0.6 | | 1.2 | 1.4 | |
| Sulfate (mg/l) | | 242 | 250 | | 314 | 320 | |
| Total P (mg/l) | 2 | 15 | 6 | 60 | 23 | 9 | 61 |
| Total N (mg/l) | 18 | 17 | 6 | 65 | 19 | 7 | 63 |
| NO ₂ (mg/l) | | 63 | 16 | 75 | 71 | 20 | 72 |
| NH ₄ -N (mg/l) | 10 | 64.4 | 61.4 | 5 | 62 | 60 | 3 |
| COD (mg O ₂ /l) | 110 | 884 | 108 | 88 | 940 | 89 | 91 |
| BOD ₅ (mg O ₂ /l) | 25 | 420 | 35 | 92 | 520 | 25 | 95 |

* Average value of each parameter.

** WWTP: Wastewater Treatment Plant

Table (2) Average concentrations of heavy metals in influent and effluent wastewater

| | LD* | Beit Lahia Wastewater Treatment Plant | | | | | |
|---------------------------------|-----|---------------------------------------|----------|----------|----------|----------|----------|
| | | Inf 2000 | Eff 2000 | Inf 2001 | Eff 2001 | Inf 2002 | Eff 2002 |
| Ag µg/l | 0.5 | 0.7 | 0.6 | NM | NM | 7.3 | 1.3 |
| Al µg/l | 25 | 73 | 39 | NM | NM | 138 | 44 |
| As µg/l | 5 | 5.6 | 5.1 | 0.7 | 0.6 | 5.5 | 5.4 |
| Cd µg/l | 0.5 | < 0.5 | 0.8 | 0.1 | < 0.5 | < 0.5 | 1.3 |
| Co µg/l | 0.3 | 0.3 | 0.8 | NM | NM | 0.6 | 0.8 |
| Cr µg/l | 2.5 | 38.9 | 7.6 | 25.3 | 2.9 | 25.2 | 8.4 |
| Cu µg/l | 1 | 6.0 | 6.7 | 2.5 | 2.7 | 8.5 | 5.1 |
| Fe µg/l | 15 | 373 | 114 | 344 | 76 | 356 | 347 |
| Mn µg/l | 1 | 120 | 96 | 116 | 47 | 142 | 139 |
| Ni µg/l | 0.5 | 21.9 | 11.8 | NM | NM | 13.1 | 12.1 |
| Pb µg/l | 2.5 | 2.6 | < 2.5 | 2.9 | < 2.5 | 2.7 | < 2.5 |
| Zn µg/l | 10 | 120 | 35 | 105 | 29 | 87 | 59 |
| Gaza Wastewater Treatment Plant | | | | | | | |
| Ag µg/l | 0.5 | 0.8 | 0.8 | NM | NM | 0.7 | 1.0 |
| Al µg/l | 25 | 71 | 61 | NM | NM | 89 | 278 |
| As µg/l | 5 | 6.6 | 7.0 | 0.4 | 1.1 | 7.8 | 8.4 |
| Cd µg/l | 0.5 | 0.5 | < 0.5 | 0.1 | 0.1 | 0.5 | < 0.5 |
| Co µg/l | 0.3 | 0.4 | 0.7 | NM | NM | 0.5 | 0.9 |
| Cr µg/l | 2.5 | 11.3 | 4.8 | 7.0 | 2.6 | 11.3 | 5.9 |
| Cu µg/l | 1 | 7.0 | 7.0 | 4.3 | 3.2 | 6.9 | 7.5 |

| | | | | | | | |
|--------------------|-----|-----|-----|-----|-------|-----|-------|
| Fe $\mu\text{g/l}$ | 15 | 137 | 132 | 163 | 121 | 198 | 202 |
| Mn $\mu\text{g/l}$ | 1 | 76 | 68 | 303 | 103 | 70 | 52 |
| Ni $\mu\text{g/l}$ | 0.5 | 5.5 | 6.8 | NM | NM | 5.4 | 7.1 |
| Pb $\mu\text{g/l}$ | 2.5 | 2.6 | 2.6 | 2.5 | < 2.5 | 3.3 | < 2.5 |
| Zn $\mu\text{g/l}$ | 10 | 75 | 54 | 61 | 41 | 92 | 56 |

NM: not measured

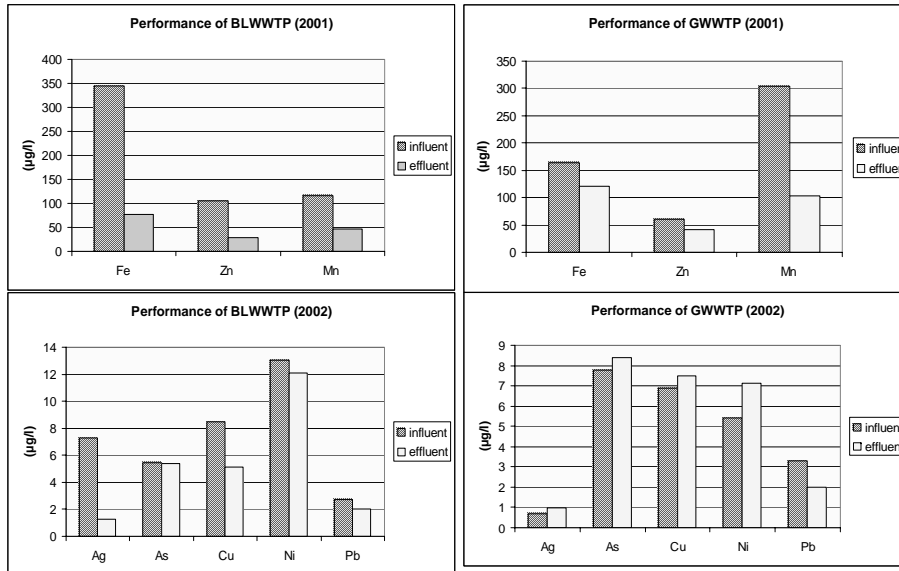


Figure 2: Performance of Beit Lahia wastewater treatment plant (BLWWTP) and Gaza wastewater treatment plant (GWWTTP), heavy metals in influent and effluent wastewater.

Industrial Wastewater

From the field surveys, it was found that the industrial wastewater was disposed to the municipal sewage system when the latter was present, or to septic tanks constructed for each industry, or directly to the surrounding areas which are in some cases Wadies. Treatment processes were almost absent, and in the best case they were very simple, represented in sediment tanks. There was no periodic inspection, and if present there were no scientific rules regarding the discharge standards or quality control. Tables 4a, and 4b showed the heavy metals in the effluent of 31 industries. The results of 2001 for the same industries were similar to the results of 2000. The treatment plants are able to absorb all amounts of pollutants and the final effluent is considered clean for agriculture and other reuse applications.

Table (3a) Heavy metals in the effluents of 10 industries in the Gaza Strip ($\mu\text{g/l}$), year 2000.

| Industry | Fe | Zn | Cu | Mn | As | Pb | Cr | Cd |
|-------------------------|------|-------|-------|-----|------|------|-------|-------|
| Pharmaceutical Industry | 97 | 259 | 2.68 | 40 | 0.92 | <2.5 | <2.5 | <0.5 |
| Cosmetics Industry | 127 | 109 | 4.262 | 45 | 0.36 | 4.1 | 5.52 | <0.5 |
| Jeans washing | 775 | 1369 | 500 | 124 | 1.2 | 6.61 | 16.43 | <0.5 |
| Electroplating Factory | 5450 | 29500 | 4000 | 219 | 3.58 | 102 | 15859 | 70.15 |
| Galvanic Factory | 2900 | 3096 | 14.95 | 26 | 2.36 | 10.3 | 797 | 9.40 |
| Detergent Factory | 1619 | 1730 | 1 | 71 | 7.77 | 110 | 1073 | 8.65 |
| Cloth Washing Factory | 277 | 503 | 500 | 57 | 1.9 | 6.52 | 50.65 | <0.5 |
| Ice Cream Factory | 222 | 251 | 100 | 26 | 1.44 | <2.5 | 50.95 | 0.86 |

| | | | | | | | | |
|---------------------|------|-----|-----|----|------|------|-------|------|
| Soft Drinks Factory | 825 | 143 | 400 | 64 | 1.34 | 4.25 | 22.32 | <0.5 |
| Car Washing Machine | 1308 | 212 | 100 | 75 | 2.12 | 27.3 | 23.13 | <0.5 |

Table (3b) Heavy metals in the effluents of 11 industries in the Gaza Strip ($\mu\text{g/l}$), year 2002.

| Industry | Ag | Al | As | Cd | Co | Cr | Cu | Fe | Mn | Ni | Pb | Zn |
|-------------------------------|-------|------|-----|-------|-----|-------|------|------|-----|----|-------|-------|
| Industry of Detergents (1) | 2.79 | 925 | 31 | 0.7 | 2.2 | 103.5 | 174 | 645 | 12 | 27 | 10.7 | 269 |
| Industry of Detergents (2) | 35.05 | 1010 | 29 | 2.3 | 2.3 | 281.0 | 48 | 375 | 16 | 5 | 7.9 | 174 |
| Metal coating – Galvanization | 21.55 | 104 | 8 | < 0.5 | 3.4 | 71.5 | 385 | 565 | 3 | 5 | < 2,5 | 10200 |
| Jeans-Washing Industry | 8.9 | 59 | 5 | 0.6 | 0.8 | 7.6 | 39 | 380 | 111 | 5 | < 2,5 | 940 |
| Pharmaceuticals | 1 | 313 | 14 | 0.8 | 3.5 | 102.5 | 54 | 3200 | 221 | 22 | 53.0 | 605 |
| Cosmetics and perfumes | 0.5 | 33 | 8 | < 0.5 | 0.5 | 11.4 | 11 | 379 | 42 | 5 | < 2,5 | 426 |
| Jeans-Washing Industry | 1.755 | 38 | 10 | < 0.5 | 0.5 | 34.1 | 25 | 281 | 32 | 13 | < 2,5 | 102 |
| Paintings | < 0.5 | 1440 | 15 | 0.5 | 2.2 | 8.7 | 51 | 585 | 45 | 6 | 453.0 | 173 |
| Soft Drinks | 2.05 | 466 | 14 | 0.8 | 1.0 | 27.3 | 32 | 1330 | 21 | 14 | 84.5 | 63 |
| Industry for Plastics | < 0.5 | 920 | 5 | < 0.5 | 0.3 | 6.9 | 10 | 395 | 22 | 2 | 17.2 | 53 |
| Metal Electroplating | 0.94 | 143 | < 5 | 0.7 | 3.6 | 48050 | 1585 | 1270 | 80 | 74 | 7.0 | 1085 |

Sludge

Beside the common heavy metals analyzed (Table 4), extra 9 elements were determined (Table 5) and, despite that these elements have lower importance, 7 of them have low concentrations and titanium (Ti) and strontium (Sr) only showed considerable amounts in the tested samples. Zinc exceeded all standards of developed and industrial countries. The effluent wastewater showed low contents of Zn and the average of Zn removal in the treatment

process was 55%; this ratio finds its way to the sludge. Based on the field surveys, the Zn sources are expected to be domestic and commercial origins. Both AAS and EMMA showed high amounts of Zn.

Table (4) Averages of trace metals and major parameters in sludge of three years.

| Parameter | Gaza WWTP 2000 | BLWWTP 2001 | Gaza WWTP 2001 | BLWWTP 2002 | Gaza WWTP 2002 |
|---------------------------|----------------------|----------------|----------------------|----------------|----------------------|
| | Mean | Mean | Mean | Mean | Mean |
| PO ₄ (g/Kg) | 10 | 10 | 21 | 13 | 25 |
| AOX [mg/kg] | 490 | 467 | 523 | 480 | 495 |
| C[%] | 15 | 31 | 31 | 34 | 24 |
| S[%] | 0.5 | 2.0 | 2.0 | 3.8 | 2.6 |
| CaCO ₃ [%] | 23 | 17 | 23 | 17 | 22 |
| Mg [%] | 0.9 | 1.2 | 1.3 | 1.0 | 1.0 |
| Ca [%] | 7 | 4 | 4 | 8 | 11 |
| Na mg/Kg | 2230 | 1257 | 3076 | 4145 | 7095 |
| K mg/Kg | 2425 | 1158 | 1447 | 1890 | 1746 |
| Li mg/kg | 3.3 | 3 | 3 | 3.1 | 2.9 |
| Cu mg/Kg | 110 | 200 | 251 | 257 | 276 |
| Zn mg/Kg | 897 | 1646 | 1909 | 2000 | 2281 |
| Ni mg/Kg | 24 | 60 | 25 | 46 | 25 |

| | | | | | |
|----------|------|------|------|-----|-----|
| Pb mg/Kg | 49 | 77 | 121 | 92 | 140 |
| Mn mg/Kg | 206 | 148 | 235 | 158 | 244 |
| Fe [%] | 1.1 | 1.7 | 1.2 | 1.4 | 1.4 |
| Cr mg/Kg | 50 | 120 | 82 | 98 | 93 |
| Co mg/Kg | 4.1 | 6.5 | 5.3 | 2.8 | 2.5 |
| Cd mg/Kg | 0.9 | 2.4 | 1.3 | 2.0 | 1.8 |
| As mg/Kg | 18.2 | 35.0 | 21.2 | 6.4 | 4.1 |
| Hg mg/Kg | 3.1 | 2.0 | 2.6 | 2.4 | 3.3 |

Table (5) Other elements in sludge produced from Gaza (mg/kg), by using EMMA

| Parameter | LD* | Sludge quality of Beit Lahia WWTP, April 2002 | | | | | Sludge quality of Gaza WWTP, April 2002 | | | | |
|-----------|-----|---|------|------|--------|----------|---|------|------|--------|----------|
| | | max | min | mean | median | σ | max | min | mean | median | σ |
| Ti | | 3336 | 2457 | 2835 | 2846 | 328 | 3213 | 2276 | 2719 | 2854 | 416 |
| Se | 0.6 | 2 | 1 | 1.2 | 1.0 | 0.5 | 5 | 3 | 3 | 3 | 1.0 |
| Br | 0.7 | 20 | 18 | 19.2 | 19 | 0.7 | 27 | 17 | 23 | 23 | 3.9 |
| Rb | 0.7 | 13 | 8 | 10.5 | 11 | 2.1 | 12 | 8 | 10 | 10 | 1 |
| Sr | 0.8 | 363 | 335 | 349 | 352 | 11.5 | 984 | 540 | 709 | 651 | 168 |
| Y | 1.0 | 9 | 6 | 8.0 | 9 | 1.2 | 8 | 6 | 7 | 7 | 1.0 |
| Zr | 0.5 | 86 | 59 | 71.0 | 69 | 10.5 | 185 | 96 | 129 | 103 | 42 |
| Zn | 1.0 | 1597 | 1383 | 1495 | 1472 | 98 | 1642 | 1107 | 1341 | 1261 | 239 |

| | | | | | | | | | | | |
|----|-----|---|---|---|-----|-----|----|---|---|---|-----|
| Th | 2.5 | 9 | 5 | 7 | 7 | 1.8 | 3 | 0 | 2 | 2 | 1.4 |
| U | 2.5 | 5 | 3 | 4 | 4.3 | 0.8 | 11 | 6 | 9 | 9 | 2.0 |

*) Limit of Detection

Mg, Ca, Li, Cu, Zn, Fe, Cr, and Co had similar concentrations and no significant changes occurred during the three years of monitoring of the two plants; however the results of As and Zn were 2-3 times higher in the years 2001 and 2002, respectively. Nickel was 2-3 times higher in Beit Lahia WWTP while Mn and Pb were 2 times higher in the sludge of Gaza WWTP. Na was (2-3 times) higher in the sludge of Gaza because it is higher with the same ratio in Gaza's groundwater. The averages of calculated total organic carbon TOC for sludge are 17-22 % for Beit Lahai and Gaza, respectively, while the results of nitrogen for the two plants showed averages that are less than 2% (the American standards); nitrogen in Beit Lahia WWTP was 1.35% while it was 1.6 in Gaza WWTP. This range puts the sludge of Gaza in an acceptable ranking for land application. Phosphorus was 0.7% and 0.4 % in Gaza and Beit Lahia respectively and both values are less than the standards of the USA (1%) and other developed countries. AOX was in the range of 200-600 mg Cl/kg, while the German and EU standard is 500 mg Cl/kg. The main source of AOX in sludge was the 26 paper industries distributed in Gaza and the northern area. These industries were using old technologies and they represented the largest consumer of chlorine and the greatest source of toxic organochlorine discharges directly into waterways.

The fluctuation of heavy metal contents in wastewater and sludge was due to the irregular production of industrial wastewater arrived to the plants; the irregular inputs of domestic wastewater arrived to the plants through the evacuating tankers of septic tanks; the seasonal variation (rainy and dry weathers); and the major operation problems of the existing treatment plants.

Recommended Institutional Arrangements

Figure 2 proposes an integrated approach for wastewater sector in Palestine.

1. The Ministry of Health (MOH) is to be responsible for the regulation of the hygienic quality of wastewater reused for irrigation of marketed crops. At the regional level, the different hygienic departments are in charge of periodical monitoring in their laboratories, health education and prevention campaigns.
2. The Ministry of Agriculture (MOAg) is responsible for the implementation of the reuse projects, i.e. supply and development of irrigation schemes (pumping stations, reservoirs pipes, canals, etc.).
3. The Palestinian Water Authority (PWA) is the leading institution and it is to be responsible for wastewater collection, treatment, and disposal. This includes detailed planning, construction, rehabilitation, operation and maintenance of the entire water and wastewater infrastructure. It is expected that these activities would be implemented through the emerging private water utility, which will work under the direct supervision of PWA.
4. The Ministry of Environmental Affairs (MEnA) will be responsible for the preparation of environmental standards, guidelines, policies and EIA legislation and enforcement. In addition, MEnA will be responsible for surveying and monitoring the environmental impact of collection systems, treatment and the reuse of wastewater.
5. Master planning at the regional/national levels would be a shared responsibility between PWA in consultation with MOPIC and MEnA.

6. Master planning of local areas would be at the local (municipality) levels would be a shared responsibility between local municipalities/Ministry of Local Government and PWA in consultation with MOPIC and MEnA.

7. Ministry of Finance (MOF): Financial Projects counterpart cosigner, project financing, and following up the financial issues.

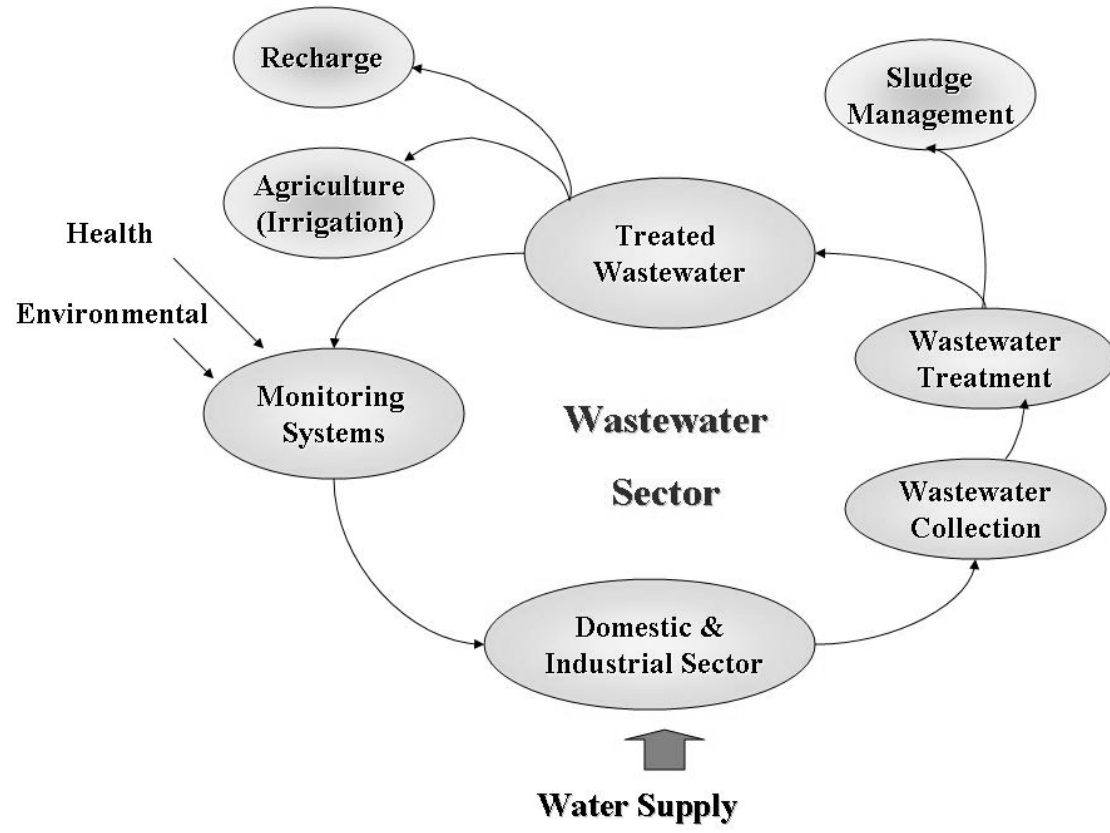


Figure 2. Recommended Institutional Arrangement on Wastewater Sector in Palestine.

Conclusions

1. The existing wastewater treatment plants in Gaza showed a similar performance, and although they are partially functional, the heavy metal contents of the effluent are less than that of the standards of neighboring countries, and the treated wastewater could be used in agriculture with respect to heavy metals.
2. The industries in Gaza are light and they have no treatment facilities. Some individual industries produce high amounts of heavy metals in their effluents but the wastewater treatment plants have the capability to absorb the industrial effluents with no significant impact on the treatment bioprocesses.
3. The existing plants produce small amounts of sludge with low contents of all tested heavy metals except Zn, which exceeds the standards of all industrial countries this is additional to the AOX which is found to be more than 500mg Cl/kg in some sludge samples of Gaza treatment plant while more than 85% of the samples have less than 500mg Cl/kg.
4. In addition to total metal concentrations the determination of specific chemical forms of heavy metals and their mode of binding in soil is very important in order to estimate their mobility, bioavailability and related ecotoxicity. Education, information, and training of farmers also play an important role in promoting sensible reuse practices.

5. Gaza Strip is a good example for similar studies in all neighboring countries which have similar conditions of metrology and climate, environment and natural resources, population growth, water scarcity, wastewater management problems and finally socio-economic situations. The findings and conclusions of wastewater reuse and sludge application could be imitated in these similar areas not only in the region but also in many developing countries.
6. By the reuse of treated wastewater, Gaza can not only reduce the pollution load of the Mediterranean Sea by wastewater contaminants but also consider wastewater as a precious source of water which could be used in agriculture.

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