CHARACTERIZATION OF THE WASTEWATER PRODUCED FROM ALEXANDRIA (PRESENT – FUTURE) AND THE IMPROVEMENT OF THE MEDITERRANEAN SEA

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INTRODUCTION

The major objectives for the Alexandria Wastewater Project are to protect public health and environmental quality [1]. The current discharge of primary treated effluents from East and West treatment plants to Lake Maryout and the Mediterranean Sea pose potential health risks through exposure to pathogens in the water and fish used for human consumption.

In the Mediterranean Sea, effluent discharged to Lake Maryout from the East treatment plant (ETP) and the West treatment plant (WTP) eventually goes in reduced concentrations to El Mex Bay from El Mex Pump Station, and untreated wastewater was discharged directly to the area of Kait Bey in the Western Harbor through the Kait Bey and Silsila outfalls.

These discharges affect water quality in these areas, leading to threats to human health and ecological concerns.

Numerous comments were received from government, ministries, local government agencies and the public requesting that the treated effluent water be made available for irrigation. The government has established criteria for the reuse of treated wastewater in agriculture.

I- THE EXISTING WASTEWATER TREATMENT AND DISPOSAL SYSTEM

I.1 East Treatment Plant

The East treatment plant (ETP) began treating the wastewater primarily in 1993, servicing the East Zone of the Alexandria Wastewater Project (AWP) area, (Fig. 1) [3]. The ETP has a capacity of 410 million L/day (MLD). Unit processes and operations at ETP include coarse screening, grit removal, primary clarification, scum removal, and sludge pumping. ETP is operating with an average daily flow of 391 MLD. Coarse screening and grit removal are done at the headwork. This structure includes a distribution channel for distributing flow to three mechanically – screened bar screens, where screening solid removed from the wastewater are transported to Sludge / Solids Disposal site (site 9 N) and transported by vacuum trucks to site 9N.

Solids produced from the primary treatment are collected and pumped out of the units to the West Zone Collector for treatment at the Mechanical Dewatering Facility (MDF).

The primary treated effluent discharges to the Hydrodrome Drain which connects to the Kalaa Drain, which is pumped (through the Kalaa Pump Station) to a drain which terminates at the Main Basin of Lake Maryout.

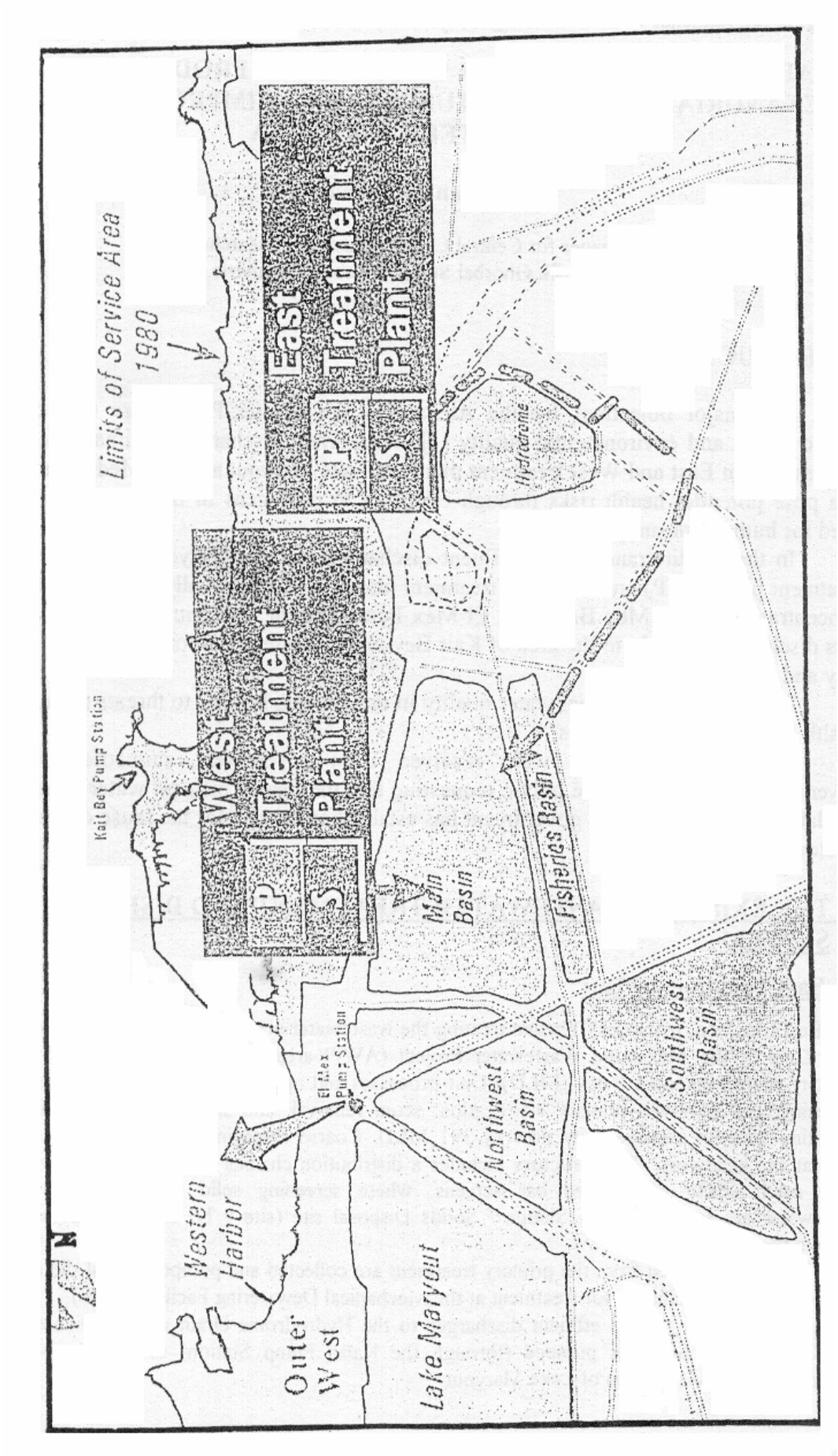


Figure 1. East and west treatment plants of Alexandria city

I.2 West Treatment Plant

The WTP also began operation in 1993. It has a design capacity of 186 million L / day and servicing the West Zone of the city with wastewater flowing to the plant through the West Zone Tunnel. This plant is expanded now to include the wastewater of the Central Zone. Unit processes and operations at the WTP include coarse screening, influent pumping, grit chamber, intermediate screening, primary clarification, scum removal, and sludge pumping. The treatment processes take place as follow [3]:

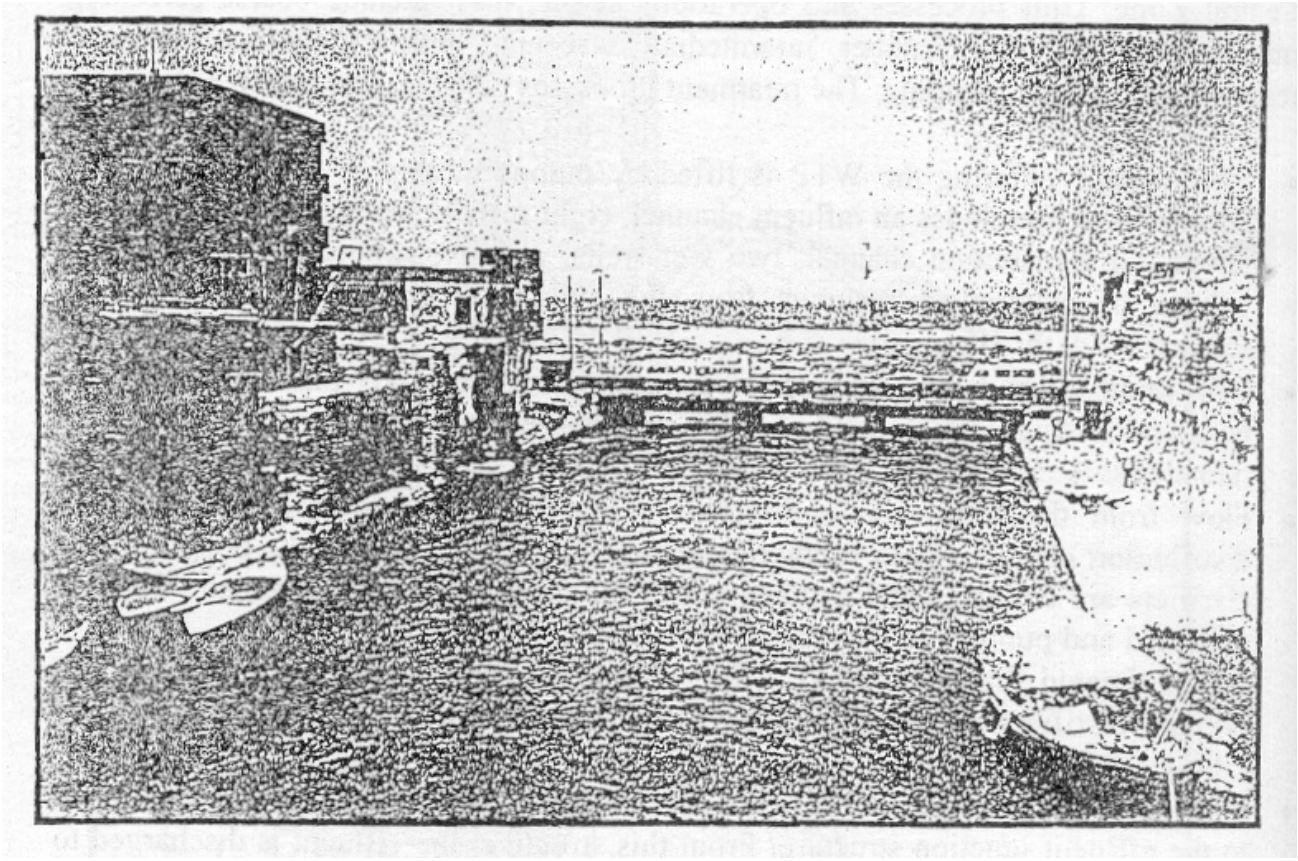
- Raw sewage entering the WTP is lifted by pumps located in the Influent Pump Station, which includes an influent channel, eight screen channels, four mechanical screens, a distribution channel, two wet wells, and five raw sewage pumps. The volume of materials screenings from the coarse screens and the intermediate screens is 2.9 m^3 / day.
- Grit removal and intermediate screening operations take place at the plant headworks. Approximately 14m^3 / day of grit are removed daily. Later the grit is reloaded into dump trucks for transport to site 9N.
- Flow from the headwork is directed to eight rectangular clarifiers through a distribution channels with submerged gates. Solids that settle to the bottom of the clarifiers are collected and pumped out of the unit to MDF for treatment. Scum is collected and pumped to tank trucks for transport to site 9N.
  It is estimated that 163,700 kg / day of total suspended solid is removed in the primary clarifiers. The biological oxygen demand removals also appear to be high, (30%).
- Flow from the primary clarifiers is collected in an effluent channel which is piped to the effluent junction structure. From this structure, the effluent is discharged to the Main Basin of Lake Maryout through an open channel.
- The MDF processes primary sludge from the WTP and also sludge from the ETP. The combined primary sludge are dewatered at the MDF, using 12 belt filter presses, and loading into trucks for transport to site 9N for disposal on land.
  The average daily MDF sludge flow is 2.64 million L / day, with solids content of 103,533 kg / day. The resulting sludge cake solids content about 29.3%.

I.3 Final Disposal Points of the Wastewater

El Mex Station pumps the flow of a large agricultural collection system called the Omoum Drain, and those flows which enter the Omoum, to the sea. Both the discharges of the East and West Treatment Plants of Alexandria enter the Omoum Drain via Lake Maryout [3].

The ETP discharge flow enters the Hydrodrome Drain then the Kalaa Drain and finally the south of the Main Basin of Lake Maryout, while the WTP discharges its flow directly to northwest of the same basin. The flow of the Main Basin enters the Omoum Drain to the sea via El Mex pump station, (Panel 1).

El Mex station can be characterized as a dam, holding back the sea from entering the lowlands of the interior of Alexandria. At this dammed site are located 12 pumps which are used to lift the Omoum Drain water up and out to sea, maintaining a healthy flow in the Omoum.



Panel 1. El Mex discharge channel entering Mex Bay

The average station discharge flow is approximately 6 million m^3 / day. The discharge from the pumps at the station is directed down a series of canals which combine into a single canal approximately 500 meters north of the station. The total distance from the station to the confluence with Mex Bay is approximately 1 km.

The El Mex discharge flow enters Mex Bay 1.5 km southwest of the entrance to the Western Harbor, (Fig. 2). The flow is generally directed towards the southwest, parallel to shore, due to the presence of a natural reef / rock structure approximately 150 metres offshore of the mouth of the discharge canal. A man made jetty, located 750 m of the discharge canal (750 metres west of the discharge), and affects the flow by directing the El Mex plume out into the bay proper, or perpendicular to the shoreline.

The transport and mixing of the El Mex discharge plume is predominantly controlled by the physical alignment and features of the shore line adjacent to the mouth of the discharge and the large density difference between the discharge and the receiving waters. There is 1 to 2 meter thick layer representing a fresh brackish water lens lying on top of a lower seawater layer. The presence of this freshwater lens is visually observable.

The El Mex discharge is very turbulent and carries a significant suspended solids load as it enters the Mex Bay system. The suspended sediments and turbidity form an opaque layer (which it mixes and dilutes), forms differing colors of water, from dark brown to a translucent green. These colors are easily distinguished from the color of the Mediterranean Sea which is a deep blue.

II- PHYSICAL CHARACTERISTICS OF MEDITERRANEAN SEA

The Mediterranean Sea is a relatively small, oligotrophic (nutrient poor) sea almost entirely enclosed by the continents of Africa, Asia and Europe. It has a maximum length of 3800 km, a width of 800 km and a maximum depth 5000 m. It has a total surface area of 2.5 million km^2 and water renewal time of 80 years [3].
The Mediterranean coastline, including its islands, is about 45000 km long and is shared by 18 countries.

A sill between Sicily and Tunisia divides the Mediterranean Sea into eastern and western basins. The eastern portion of the eastern basin forms the northern border of Egypt.

The Mediterranean currents are characterized by: 1) They are generally parallel to the shore. 2) Surface current speeds are generally higher than subsurface currents. 3) Current speeds during summer are higher than in the fall. 4) The current direction is northeast during summer and northeast during April. 5) Several short-term current reversals happen in September and October. 6) Occasionally, there are very low current speeds (May and August) which might result in lower dilution of the wastewater plume.

Ocean tides play a significant role in moderating magnitude and direction of coastal currents and therefore strongly influence the shoreward transport of effluents discharged from deep sea. Generally, the tides in the water of Alexandria are semi-diurnal with a range of about 34 cm (CDM 1978).

The wave field generally approaches Alexandria's coastline from a westerly to northwesterly direction with mean significant wave heights of 0.7 m and zero crossing period of 4.6 second.

The wind speeds are generally low between 4-8 knots. Highest wind speed (28 knots) was recorded during December and January and lowest speed (4 knots) in June and September.

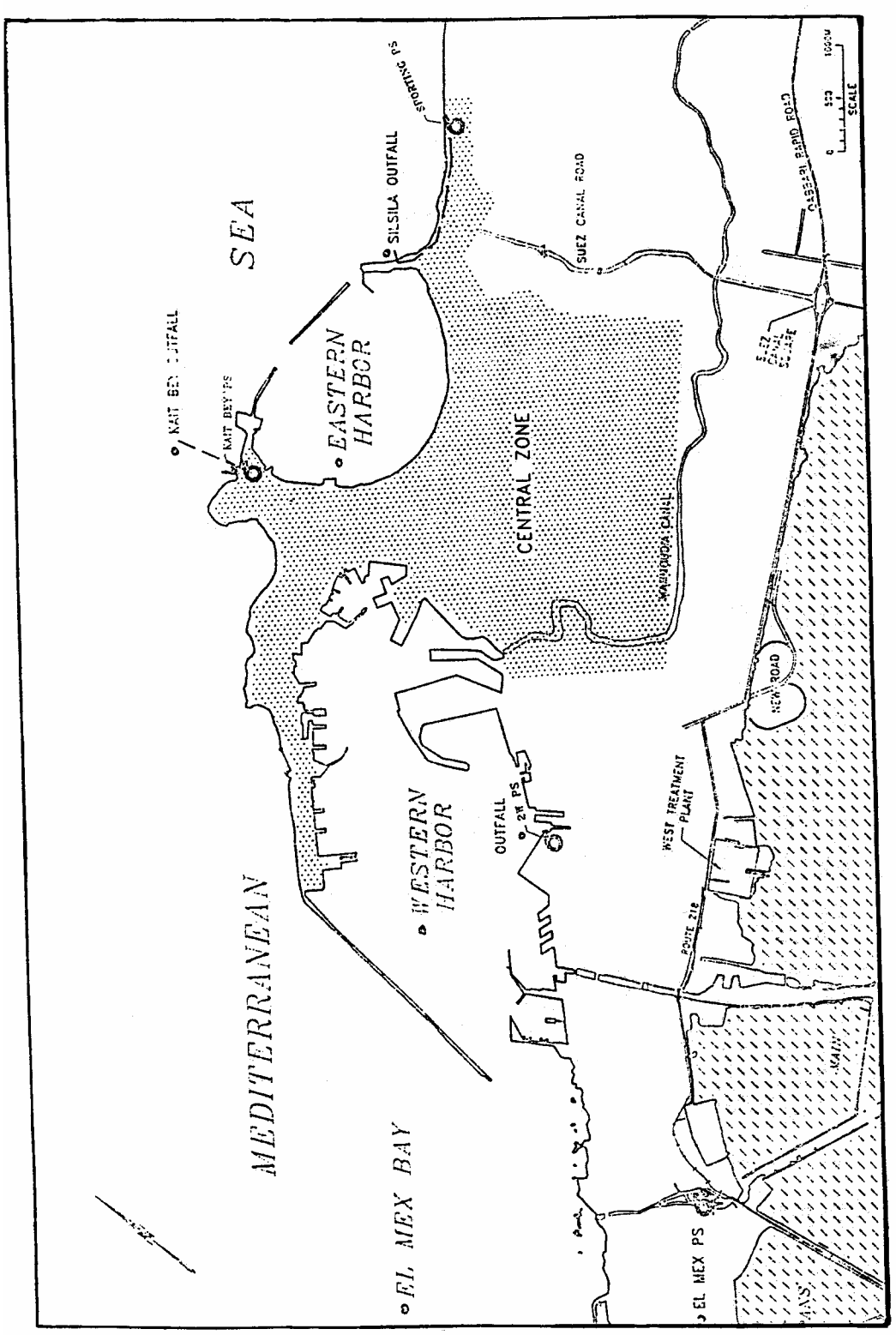

SEA
MEDITERRANEAN
EASTERN HARBOR
WESTERN HARBOR
CENTRAL ZONE
SILSILA OUTFALL
SPORTING PS
SUEZ CANAL ROAD
MAHMOUDA CANAL
NEW ROAD
WEST TREATMENT PLANT
OUTFALL
2ND PS
ROUTE 218
EL MEX PS
EL MEX BAY
SCALE

Figure 2

Water Quality before the Cessation of Kait Bey and Silsila Outfalls

* Water quality assessments in the Eastern Harbor indicate (except coliforms level) that there were very few differences between the shoreline water and water farther away from shore. The harbor was shown to be eutrophic (Table 1).

* Near shore in the Kait Bey areas showed high coliform level, and the water near the break in the outfall pipe and at the mouth of the outfall were characterized by high wastewater – related parameters (BOD – nutrient – coliforms). Priority pollutant concentrations in the water of Kait Bey were very low.

* El-Mex Bay water was showed higher levels of ammonia, nitrate, and orthophosphate and coliform and lower dissolved and total solids. Also high mercury, nickel, lead and 1.2 – dichloroethane (organic priority pollutant) were predicted.

* Water quality at the offshore (8-12 km from shore-line) was generally low in nutrient, biological oxygen demand (BOD) and coliform levels and higher in dissolved oxygen and salinity.

* Sediment quality in offshore & Kait Bey and El-Mex Bay were generally the same. Silver was delected in the Offshore, metal and pesticide in Kait Bey and mercury in El-Mex Bay (western part). While sediment quality in the Eastern Harbor was marked by high nitrogen and phosphate (Table 2).

* The salinity and the density of surface water mass is 20000 to 25000 mg / l this loss saline water extends on the top of Mediterranean Sea water as a layer of average thickness 1 to 2 meters. It is the product of the El-Mex pump station discharge.

*** How are the pollutants spreading in the sea**

After the discharge of the flow into EL-Mex Bay through EL-Mex Pump Station, the discharge takes a long trip:

- Exiting the canal, it will be directed towards the southwest (along the shoreline) into the central portion of the bay.

- The transport of the flow has been towards the southwest to Dekhila Harbor and towards northeast to the entrance of the Eastern Harbor.

- A very dilute portion of the flow is wrapping around the eastern and the western break-water of EL-Mex Bay.

- Vertically the discharge flow is limited to the upper 1 to 2 meters of the water column.

Table (1) **Specifications of Alexandria Coastal Wastewaters [3]

Analyte* in mg/L	Offshore (Blank)	East Harbor	Kait Bey	El-Mex Bay
Nitrate	0.00	0.01	0.01	0.02
Nitrate+Nitrite	0.08	0.10	0.07	0.12
Ammonia	0.04	0.18	0.14	0.38
Organ Nitrogen	0.95	0.80	1.40	0.47
Total Phosphate	0.02	0.06	0.07	0.12
Orthophosphate	0.01	0.03	0.03	0.07
Dissolved solids	54,000.00	48,000.00	52,000.00	45,000.00
Total solids	54,000.00	54,000.00	53,000.00	45,000.00
Suspended solids	15.00	19.00	19.00	18.00
Total volatile solids	190.00	200.00	210.00	170.00
Volatile suspended solids	8.10	9.90	9.00	11.00
Total coliform MPN/100ml	670.00	810.00	940.00	1,300.00
Fecal coliform MPN/100ml	73.00	220.00	360.00	490.00
Dissolved oxygen	6.90	6.60	6.30	6.90
Hardness	7,100.00	7,000.00	7,300.00	6,600.00
Oil & grease	2.50	6.20	4.00	2.70
Sulphate	2,900.00	3,000.00	3,300.00	2,800.00
Sulfides	0.16	0.13	0.21	0.17
BOD	1.80	4.50	3.60	4.20
COD	65.00	88.00	95.00	94.00
Total Alkalinity	130.00	130.00	130.00	150.00
Chloride	29,000.00	28,000.00	28,000.00	25,000.00

* Mean concentrations.

** Before the cessation of the Kait Bey and Silsila outfalls

Table (2) Concentrations* of Nutrients and Heavy Metals in the Mediterranean Coastal Sediments [3]

Analyte	Offshore	Eastern Harbor	Kait Bey	El-Mex Bay
Nutrients				
Nitrate + Nitrite	0.28	0.33	0.64	0.76
Ammonia	14.63	18.29	10.76	11.92
Total Phosphate	0.30	1.53	0.97	0.60
Heavy Metals (P.P.)				
Antimony	0.57	1.30	0.42	0.72
Arsenic	8.90	5.70	11.20	5.10
Beryllium	ND	ND	ND	ND
Cadmium	0.18	ND	ND	ND
Chromium	6.33	7.60	3.68	8.20
Copper	5.50	6.80	7.21	7.60
Lead	5.96	34.00	10.70	5.40
Mercury	ND	0.27	0.15	4.70
Nickel	3.48	0.37	1.68	ND
Selenium	0.42	ND	0.40	0.33
Silver	6.85	ND	5.02	4.60
Thallium	1.24	ND	0.62	0.21
Zinc	10.40	32.50	16.70	10.20

* In mg / Kg, wet weight
ND = Not Detected.

III- FUTURE WASTEWATER DISPOSAL SYSTEM

III-1. First phase

This phase consists of two stages:

III-1.1 Rerouting of the Kait Bey Discharge

This stage was completed in 2002 where about 200000 m^3 / day of sewage flow was discharged untreated to the sea off the Anfoushi through the Kait Bey and Silsila pump stations, waters of Anfoushi and closest to Kait Bey outfall have been subjected to impact by the wastewater discharge. Complete cessation of the discharge from Kait Bey and Silsila pump stations leads to 1) signification improvement in water quality of the Anfoushi and 2) positively influence both inshore and offshore (3-5 km) environments.

III-1.2 Upgrading the Wastewater Treatment plants

This stage began in 1999 and is expected to be completed in 2004. The following major changes in Alex. Wastewater disposal system is shown below:

- ETP primary treatment would continue with an increased capacity allowing for the population growth to 2010. Winter flows would increase from 369 to 533 MLD while summer flows from 426 to 604 MLD. The effluent would be discharged to the same disposal point (Main Basin of Lake Maryout).
- WTP-primary treatment would continue allowing for the population growth to 2010. Central zone tunnel (carrying the discharges of Silsila and Kait Bey outfalls) was connected to the WTP. Flow discharged from WTP increase from 251 to 461 MLD and is discharged to Main Basin of Lake Maryout to El-Mex Bay (through El-Mex channel).

Sea Water & Sediment Quality under first phase

- In El-Mex Bay, the BOD would increase from 0.9 to 1.7%, resulting in reduction of D.O. Ammonia loading % will be twice during summer than winter (3.7 mg / l) which is higher than the specific chronic toxicity guild line of 2 mg / l (EA, 1996n) this may adversely impact oxygen and increase eutrophication.
- Fecal coliform loads in El-Mex Bay would decline during summer because of the higher temperature; the coliform die off rate in the summer is approximately twice that in the winter.
- Sediments nutrient load in El-Mex Bay will be increased.
- Priority pollutant metal and organics would not be expected to change in the water and sediments.

Table (3) represents the expected wastewater and sediment quality of Alexandria City after phase nº. (I)

Table (3) Expected Wastewater Quality Produced [3] from Alexandria City after Phase (I)

Average Monthly Concentrations of Constituents			
Parameters	After the Expansion of ETP and WTP		Sea Discharge
	ETP	WTP	ETP + WTP
Temperature ºC	22.00	22.00	22.00
pH S.U.	7.40	7.30	7.40
BOD_5 (mg / L)	143.00	184 - 236	161 – 184
COD (mg / L) (Dichromate)	N / A	548.00	
COD (mg / L)			431.00
DO (mg / L)	2.20	4.40	0.00
Oil and Grease (mg / L)	15.00	20.30	17.40
TDS (mg / L)	1,105.00	1,365.00	1,221.00
TSS (mg / L)	337.00	166 – 252	143 – 181
Colored substances	NA	Present	Present
Sulphide (mg / L)	<0.12	2.00	2.10
Cyanide (µg / L)	ND	ND	ND
Phosphate (mg / L)	4.90	5.40	5.10
Nitrate (mg / L)	0.10	0.40	0.20
Ammonia–N (mg / L)	NA	NA	25.60
Fluoride (mg / L)	0.67	0.80	0.70
Phenol (mg / L)	0.05	0.07	0.06
Total Heavy Metal (µg / L)	<0.18	<0.16	

III-2. Second Phase

Secondary Treatment with Water Reuse

Secondary treated and chemically disinfected final effluent would be discharged from ETP and WTP to Omoum Drain through a series of open channels (bypass Lake Maryout), where it would be available for diversion to a reuse project.

The Ministry of Public Works and Water Resource (MPWWR) has targeted an area of 80000 feddans in the Alex. Governorate for agricultural development as irrigation water becomes available.

It is located west of Nubaria, beginning approximately 45 km west of the city and extending west-southwest 20 km inland. The primary-treated effluent from ETP and WTP is not used for irrigation (except for wood-producing trees).

MPWWR have indicated that they plan to use effluent from ETP and WTP for irrigation in the future.

Water and Sediment Quality under Second Phase

Under lake bypass alternatives and the diversion to a reuse project, El Mex Bay and Western Harbor would highly improve environments. So, El Mex Bay would be protected after phase nº. II.

Table (4) represents the expected wastewater quality of Alexandria after phase nº. (II).

Table (4) Expected Wastewater Quality Produced [3] from Alexandria City after Phase (II)

Average Monthly Concentrations		
Parameters	Lake Discharge Lake Bypass	
	ETP	WTP
Temperature ºC	22.00	22.00
pH S.U.	7.40	7.60
BOD_5 (mg / L)	30.00 – 50.00	30.00 – 50.00
COD (mg / L) (Dichromate)	110.00-160.00	130.00-180.00
DO (mg / L)	2.20	4.00
Oil and Grease (mg / L)	15.00	11.00
TDS (mg / L)	1,105.00	1,365.00
TSS (mg / L)	124.00	30.00 – 50.00
Colored substances	NA	NA
Sulphide (mg / L)	<0.12	0.64
Cyanide (µg / L)	ND	NA
Phosphate (mg / L)	4.90	4.70
Nitrate (mg / L)	0.10	0.60
Fluoride (mg / L)	0.67	NA
Phenol (mg / L)	0.05	NA
Total Heavy Metal (µg / L)	<0.18	<0.08
Total Coliform (MPN / 100mL)	5,000	5,000

CONCLUSIONS

1- The discharge flow into El Mex Bay is directed along the shore line and westward into the bay, then to the West Harbor and out to Anfoushi and finally to the entrance of Eastern Harbor.

2- The discharge of untreated sewage through Kait Bey and Silsila outfalls was completely ceased in 2002.

3- The complete cessation of the discharge from Kait Bey and Silsila outfalls (phase I) lead to significant improvement in water quality off Anfoushi and Western Harbor.

4- The diversion to a reuse project (phase II) will lead to highly improve the water quality of the Main Basin of Lake Maryout, the Western Harbor and El Mex Bay environments.

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