

# Environmental Mechanism for Assessing Point Sources Pollution in Wadi Gaza, Palestine

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## ABSTRACT

Because of the importance of the Wadi Gaza as a unique ecosystem in Gaza Governorates, it was declared a nature reserve in June 2000. Wadi Gaza Nature Reserve was established to conserve the wetland ecosystem, to stop or slow the degradation of its natural resources and biological diversity and to promote measures for their eventual rehabilitation. Wadi Gaza represents a unique habitat supporting a rich biodiversity. The Wadi is under threat from many environmental pressures, in particular from sewage generated by recent urban growth within the catchments area, and the use of the Wadi basin as a solid waste dumping site. These polluting sources are not only deteriorating the natural habitat, but also they have an increasing negative impact on the public health of the communities around Wadi Gaza. This study outlines an agenda for investigating the sources of pollution of Wadi Gaza, effects of pollution on Gaza's ecology and on the health of its inhabitants. Also, to establish an integrated approach for river reclamation management, including technical, administrative and legislative mechanisms for improvement of existing conditions and for ensuring the sustainability of clean Wadi. A capacity building component through training and educational activities are also proposed to proactively address issues of public health/awareness, as well as the protection and sustainability of the Wadi Gaza environment. All the Wadi sources of pollution and their impacts are illustrated in details, these illustrations will be helpful tools to set the suitable solution to each source of pollution and this will give a better understanding of how to solve Wadi Gaza problems. This will lead to the right steps that should be taken in order to improve the environmental situation in Wadi Gaza area.

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## KEYWORDS

*Wadi Gaza; sustainability; Wadis; hydrology; biodiversity; environment*

## آلية تقييم البيئة ومعالجة مصادر التلوث بوادي غزة في فلسطين

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## المُستخلص

نظرا لأهمية وادي غزة ونظام البيئي الفريد من نوعه بين محافظات غزة، وإعلانه محمية طبيعية في يونيو 2000. تأسست محمية وادي غزة للحفاظ على النظام الإيكولوجي للأراضي الرطبة وذلك لوقف أو إبطاء تدهور الموارد الطبيعية والتنوع البيولوجي وتعزيز التدابير لإعادة تأهيل هكذا الموارد. يمثل وادي غزة الموئل الفريد لدعم التنوع البيولوجي إلا أنه تحت التهديد من ضغوط بيئية عديدة، لا سيما من مياه الصرف الصحي الناتجة عن النمو الحضري داخل منطقة مستجمعات المياه، فضلاً عن استخدام حوض الوادي كموقع لرمي النفايات الصلبة. هذا وتتسبب هذه المصادر الملوثة في تدهور الموائل الطبيعية إلى جانب زيادة تأثيرها السلبي على صحة المجتمع المقيم حول الوادي. توضح هذه الدراسة الخطوط العريضة لجدول أعمال لتحقيق في مصادر التلوث وأثارها على البيئة في قطاع غزة وعلى صحة سكانها، كما تضع نهجاً متكاملًا لإدارة استصلاح النهر بما في ذلك الآليات التقنية والإدارية والتشريعية المستهدفة إلى تحسين الظروف القائمة وضمان استدامة نظافة الوادي. تقترح الدراسة عنصر بناء القدرات من خلال الأنشطة التدريبية والتعليمية لمعالجة قضايا الصحة العامة ورفع الوعي بشكل استباقي، إضافة إلى حماية واستدامة البيئة في وادي غزة. تستعرض الدراسة كافة مصادر التلوث وتأثيراتها مع اقتراح آليات عملية ومفيدة كحل مناسبة لكل مصدر من مصادر التلوث مما يرتقي بالوعي لمعالجة قضايا تدهور البيئة في وادي غزة، كما يؤدي إلى الخطوات الصحيحة المفترض اتخاذها من أجل تحسين الوضع البيئي في حزام الوادي.

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## الكلمات الدالة

*وادي غزة، الاستدامة، الأودية، الهيدرولوجيا ، التنوع البيولوجي، والبيئة*

## Introduction

Because of the importance of the Wadi Gaza as a unique ecosystem in Gaza Governorates, it was declared as *nature reserve* in June 2000. Wadi Gaza Nature Reserve was established to conserve the wetland ecosystem, to stop or slow the degradation of its natural resources and biological diversity and to promote measures for their eventual rehabilitation. The initial boundaries, which extended beyond the Wadi itself, were reduced after one year due to community conflicts. As partial compensation, the Environment Quality Authority EQA requested municipalities to revise their land-use plans to ensure that the Wadi bed is respected as a protected area but since then municipal plans have not changed.

Wadi Gaza represents a unique habitat supporting a rich biodiversity. The Wadi is under threat from many environmental pressures, in particular from sewage generated by recent urban growth within the catchment area and the use of the Wadi basin as a solid waste dumping site. These polluting sources are not only deteriorating the natural habitat, but also they have an increasing negative impact on the public health of the communities around Wadi Gaza.

Wadi Gaza is the Major wetland in Gaza Governorates. It is very important as a natural habitat for many species. Many archaeological sites were discovered right along the Wadi course. Wadi Gaza is also considered as a future water catchments and percolation area to replenish the ground water aquifers. On the other hand, it is being under pressure long time ago as it faces a lot of environmental problems that affect the environment and public health. The last decade shows that the Wadi has been used as a drainage canal to sewage discharge coming from the middle area refugee camps and a site for dumping solid waste and construction debris.

Wadi Gaza area is one of the important areas in the Gaza Strip, as it is a natural area and a natural habitat for many kinds of species. Wadi Gaza falls under pressure as a result of human activities against the Wadi and its habitats. Moreover; Wadi Gaza is being declared as Natural Reserved, this declaration gave the site local and regional importance and

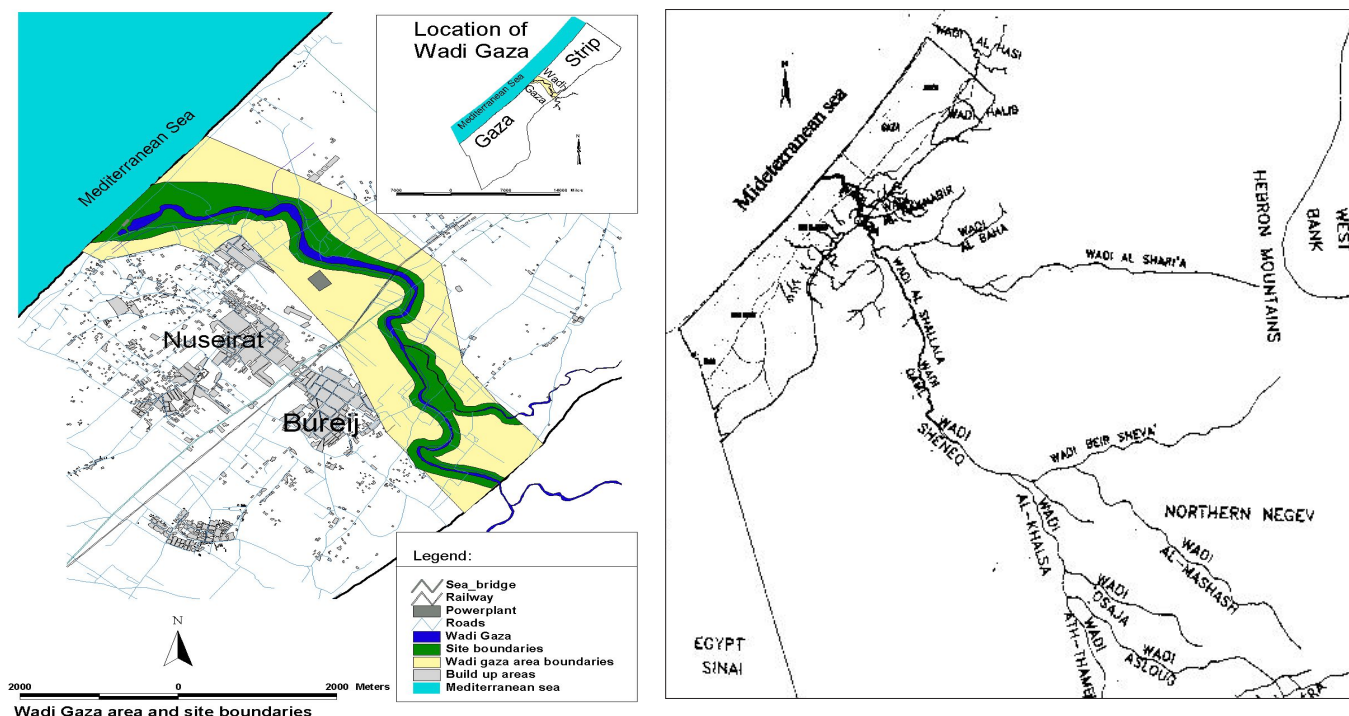
helped the Palestinian National Authority PNA to ask for funds to projects development in the Wadi area. The previous funded projects varied between case studies and physical construction projects.

This study outlines an agenda for investigating the sources of pollution of Wadi Gaza, effects of pollution on Gaza's ecology and on the health of its inhabitants. Also, to establish an integrated approach for river reclamation management, including technical, administrative and legislative mechanisms for improvement of existing conditions and for ensuring the sustainability of clean Wadi. A capacity building component through training and educational activities are also proposed to proactively address issues of public health/awareness, as well as the protection and sustainability of the Wadi Gaza environment. All the Wadi sources of pollution and their impacts are illustrated in details, these illustrations will be helpful tools to set the suitable solution to each source of pollution and this will give a better understanding of how to solve Wadi Gaza problems. This will lead to the right steps that should be taken in order to improve the environmental situation in Wadi Gaza area.

## Material and Methods

### Wadi Gaza as a Case Study

Wadi Gaza is located across the center of Gaza Strip, and is bordered in the north-west by the Mediterranean Sea, the south-east by the Bureije Camp, the south-west by Al-Nusairat Camp, and the north by Azzahra City (Figure 1). The Highest elevation of the Wadi is thirty meters Above Mean Sea Level (AMSL), dropping to sea level where it reaches the Mediterranean Sea. Its circuitous route through the Gaza Strip is around 9 km in length. The Wadi is notable for its twists and turns, especially across the Gaza Strip where it curves eight times. The Wadi width varies, with widest area of about 100 m in the far downstream where it reaches the Mediterranean Sea. Six small streams drain through upstream Wadi catchment area; the most important are Abu Qatroun Wadi and Ghalbeh Wadi. Abu Qatroun Wadi cuts through the area north and Ghalbeh Wadi south of Wadi Gaza (Figure 1).



**Figure 1: Wadi Gaza Area: Site Boundaries and Tributaries**  
(Source: Environment Quality Authority EQA; & Awadallah, (2000) )

A high percentage of the land along the Wadi lies within the municipal boundaries. The rest lies within the Gaza Strip regional areas. The Wadi is bounded in the north by land under the jurisdiction of three local authorities: Azzahra, Almoghraga, and the village council of Wadi Gaza. On its southern border, the Wadi is bounded by the Nusairat and Buraij refugee camps. The Wadi Gaza area (Table 1) is 1,313 hectares. This includes the land on the banks of the Wadi and some land within the local authority boundaries.

The land can be classified into four categories: private land (60% of the area); communal land (26.9%); dedicated land or “Waqf land” (12.1%); and government land (1%). The site boundaries as established in the year 2000 comprise the Wadi bed and the adjacent areas affecting the Wadi and affected by changes to the Wadi. However, in the year 2001, community conflicts led to boundary changes which reduced the delineated area only to the Wadi bed. Its ownership to a large extent is governmental.

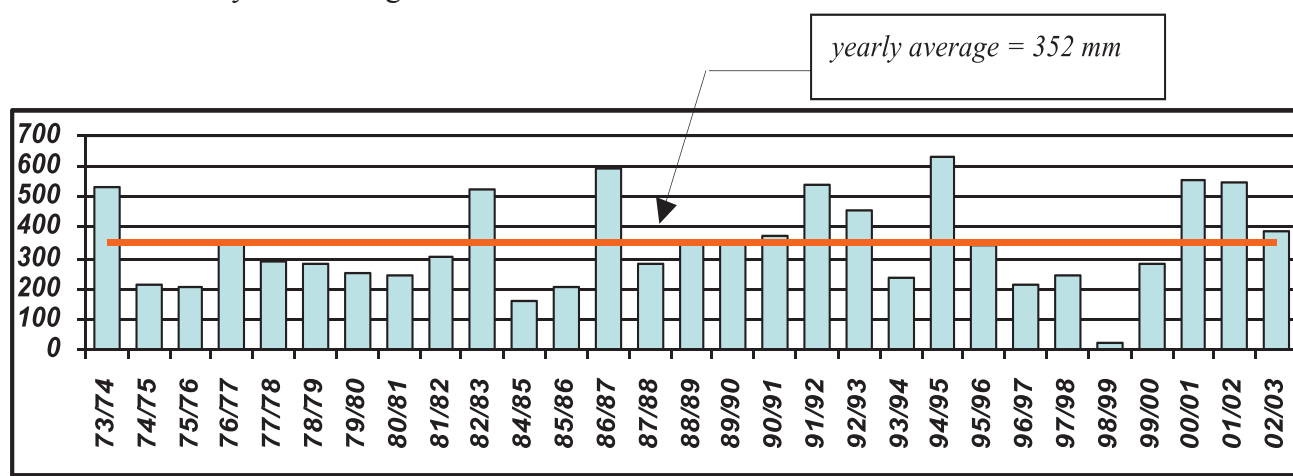
**Table 1: Summary of Wadi Gaza Morphology**

Origin source	Hebron mountains and the Northern Negev
Mouth	The Mediterranean Sea
Total length from origin	105 km
Length in Gaza strip	9 km
Width in Gaza	20-270 m with maximum width at the mouth
Topography in Gaza	30m AMSL at Gaza border gradually dropping to 0 m AMSL at the mouth
Flow direction	From east to west
Main tributaries	Wadi Ashareeaa, wadi Ashallalah

(Source: EQA (2003))

Wadi Gaza is considered as a future water catchments and percolation area to replenish the ground water aquifers. On the other hand, it is being under pressure long time ago as it faces a lot of environmental problems that affect the environment and public health. The last decade shows that the Wadi has been used as a drainage canal to sewage discharge coming from the middle area refugee camps and a site for dumping solid waste and construction debris. The development of Wadi Gaza has international, national and local concern. According to the master drainage plan done for the Ministry of Planning and international

cooperation (*MOPIC 1998*), there are 6 sub-basins in Gaza Strip which drain to Wadi Gaza. The total drainage area inside Gaza from these sub-drainage basins is only 6007 hectares or 60.07 Km<sup>2</sup>. The estimated volume of discharge from these sub-drainage basins based on 5 year return period is only about 1.0 M m<sup>3</sup>, while for example the estimated total volume discharge of Wadi Gaza for the hydrological year 1994/1995 was about 20 M m<sup>3</sup>. The average yearly rainfall for 29 years is 352 mm/year (Figure 2). This much of annual average classify the area as semi-arid area.



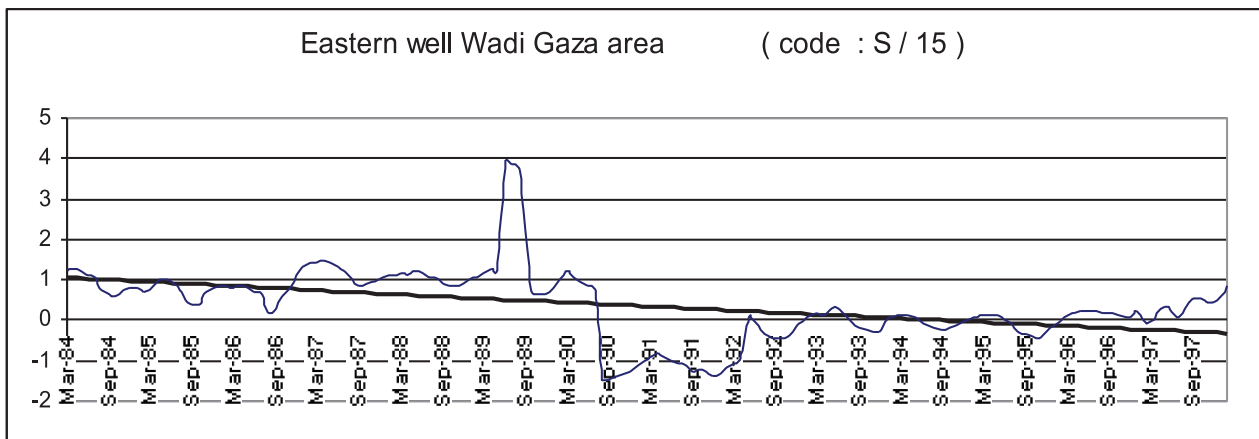
**Figure 2:** Average Rainfalls on Wadi Gaza Area

(Source: Wadi Gaza Management Plan, 2003)

Wadi Gaza groundwater aquifer is part of the Coastal Aquifer, which is the primary source of water in Gaza Strip. The regional groundwater flow is mainly westward towards the Mediterranean Sea. Most of the recharge is from dune areas near the coast overlaying the coastal aquifer itself and from the adjacent uphill area in the east zone. The maximum saturated thickness of the aquifer ranges from 120 m near the sea to a few meters near the eastern aquifer boundary located beyond the Eastern Gaza border. In the Gaza Strip, the coastal aquifer is divided into three sub-aquifers separated by impervious and clay-rich semi-pervious layers. Groundwater levels in Wadi Gaza from 7 wells (based on monthly observations) reveal fluctuations which mirror rainfall patterns: higher levels in relatively wet years and lower levels in dry years. This indicates the fast response of the aquifer to surface recharge, which in turn indicates high hydraulic conductivity values.

Despite these natural fluctuations, the overall long-term trend is that of a slowly declining groundwater level. Well S/15 (Figure 3) is a typical example of the longer term trend of a lowering water table in Wadi Gaza set against shorter term fluctuations. Over 10 years the mean groundwater level at this well has fallen more than one meter. The Gaza Strip Environmental Profile 1994, recorded that the flow of the hydrological wet year 1994/1995 occurred ten days that year, and estimated the volume of it as 20 Mm<sup>3</sup>. During the hydrological year 2000/2001 the flow was recorded for a total of 7 days with two flash floods. One flash flood started from the midnight of 24/12/2001 and continued for 3 days, with estimated discharge volume of 8.64 Mm<sup>3</sup>. The other one occurred from the early morning of 23/1/2001 for 4 days, with estimated discharge volume of 9.58 Mm<sup>3</sup>. That makes the total estimated volume of discharge for the hydrological year 2000/2001 18.22 Mm<sup>3</sup>.





**Figure 3: Well S /15 Time Series**

(Source: *Wadi Gaza Management Plan, 2003*)

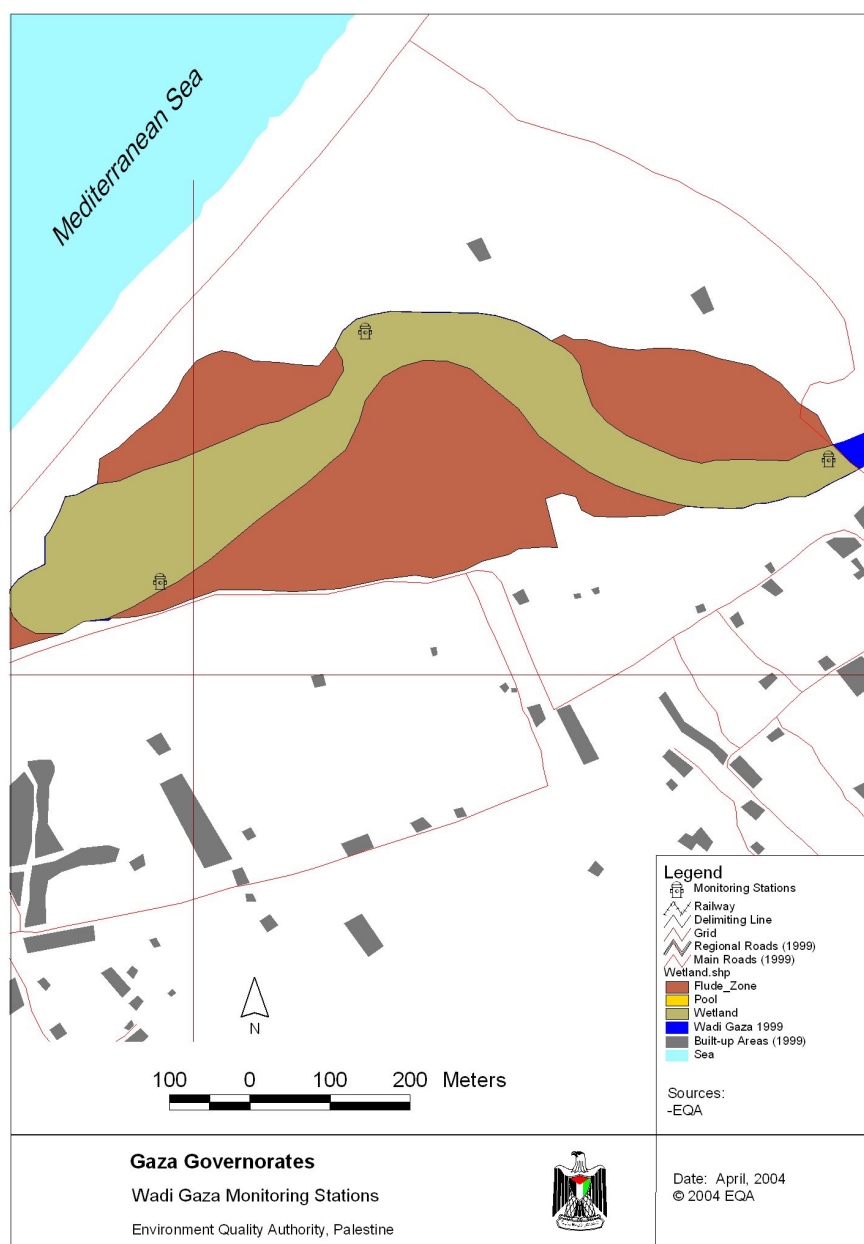
## Discussion and Results

### (1) Major Sources of Pollution

There are two types of pollutants in Wadi Gaza exist; point source and non-point source. A point source of pollution stems from a single discrete location, such as an outflow pipe. This type of source can be monitored, measured, and controlled. Wastewater, industrial and solid waste discharges are generally considered point sources pollution in the Wadi area, as they exist at a single location. The other source of pollution is the industrial hazardous waste and the domestic solid waste that concentrated in Wadi outlet. On the other hand, non-point sources deliver pollutants indirectly through environmental changes and have wide range of entries and it is difficult to measure and manage. Non point source pollution in Wadi Gaza occurs from the activities of livestock farming in the Wadi area and from using pesticides and fertilizers in agricultural practices that carried into a stream by rain, in the form of run-off which in turn affects aquatic life. The water quality monitoring stations are shown in Figure 4.

Untreated wastewater discharge into Wadi Gaza is the first major and the most destructive pollution source, which is seriously and rapidly damaging all kinds of habitats, wildlife and the unique ecosystem of Wadi Gaza. The history of wastewater discharge to Wadi Gaza starts with the construction of the grey wastewater collection system by the United Nations Refugee Work and Relief Agency (UNRWA), to serve the three refugee camps of the Middle Area: namely Al-Nusairat, Al-Bureije, and

Al-Maghazi in 1974. This open channel collection system was collecting the grey wastewater of these three residential areas and discharging it to Wadi Gaza through two outlets. After the construction of Al-Zahra City at the Northwestern edge of Wadi Gaza, it started to discharge its raw wastewater through closed pipe collection system to the Wadi. Till the year 2000, the estimated wastewater quantity that used to reach Wadi Gaza was about 2500 to 3000 m<sup>3</sup> / day. Till that time the environmental capacity of the ecosystem of Wadi Gaza was able to function and to break down and to naturally treat this quantity of pollution. At early 1999 the Danish Aid Agency (DANIDA) launched a project in the Middle Area which constructed a sewage collection network to collect wastewater from the whole of the Middle Area. The project was limited to the construction of collection network without treatment facility. The collected wastewater was planed to be treated by another project that would construct a central treatment plant at the area. Unfortunately this treatment plant is not constructed yet, and the wastewater that is being collected by this central sewage network is discharged to Wadi Gaza with a quantity exceeding 12000 m<sup>3</sup> / day. The Wadi now receives the whole quantity of wastewater collected in the middle area of Gaza Strip. Two adjacent outlets discharge daily this huge amount of wastewater to the Wadi. Other minor outlets also exist, coming from some few houses built at the edges of Wadi Gaza.



**Figure 4:** Wadi Gaza Wetland Area Showing the Water Quality Monitoring Stations

This main outlet collects raw sewage from the entire residential areas in the Middle area, including one city ( Deir Albalah), three refugee camps (Alnusairat, Albraij, and Almaghazi ) and three villages (Al Zawayda, Al Moghraga, and Al Msadar). The quantity of this raw wastewater is estimated to be about 12,000 m<sup>3</sup>/day. Al Nusirat camp: In Nusirat camp around 80% of the total population discharges all their wastewater to Wadi Gaza through the Main outlet. The generated wastewater from the sewer network discharge to the main pump of 500 m<sup>3</sup>/hr then to Al Gashash Wadi,

which finally connected to the new sewer pipe of 1000 m length to Wadi Gaza outlet. Al Bureij camp: In Bureij camp around 80% of the total population is connected to the new sewer network system, around 10% are still connected to the old sewer network, the others use septic tanks. The generated raw wastewater from the sewer discharge to the main pipe (1 meter diameter) in Salah El Deen then finally discharge to the Main outlet of Wadi Gaza through Gashash area in Al Nusirat camp using 400 mm diameter pipe. About 2000 persons live beside the Wadi are served by Bureij municipality

and discharge their wastewater to Wadi Gaza. Deir Al Balah and El Zawaida: In Deir Al Balah town around 50% of the total population is connected to the sewer network system, the others uses septic tanks. Of the total wastewater 70% reaches Wadi Gaza through a pump station that exists in the northern east part of Deir El Balah town (Al Basah Area). Also part of El Zawaida area (approximately 100 houses) are connected to Deir Al Balah sewer network, the other parts of El Zawaida discharge their wastewater to the main pipe line (Salah El Deen pipe) by gravity and finally to Wadi Gaza. Al Maghazy camp: In Al Maghazy camp around 85% of the total population is connected to the wastewater network; the other 15% uses septic tanks. All the generated wastewater discharge to main pipe (Salah El Deen pipe) then finally to Wadi Gaza. Al Msadar village: Al Msadar village around 80% of the total population are connected to the

wastewater network, the other 20% uses septic tanks. All the generated wastewater discharge to main pipe (Salah El Deen pipe) then finally to Wadi Gaza.

The new residential area (Al Zahra town) started to discharge raw wastewater to Wadi Gaza in 1999; the total quantity of wastewater discharged through this outlet is approximately 300 m<sup>3</sup>/day. Table 2 illustrates the total quantity of wastewater in the Middle Area based on number of population in 2003, assuming that the water consumption is 100 L/capita/day and the generated wastewater is 80% of water consumption. The quantity of the wastewater that reaches the Wadi depends on the percentage of households connected to the sewer network. Tables 3 present the results of tests, which were carried out recently concerning wastewater quality from the Middle Area that discharged to the Wadi Gaza.

**Table 2:** The Total Quantity of Wastewater in the Middle Area

Locality	Population (Capita)	Water consumption (m <sup>3</sup> /day)	Generated wastewater (m <sup>3</sup> /day)	% connected to sewer	Wastewater that reaches Wadi Gaza
Bureij Camp	33481	3348.1	2678.5	90	2410.6
Al Nusirat Camp	59465	5946.5	4757.2	80	3805.8
Al Maghazi Camp	22415	2241.5	1793.2	85	1524.2
Al Mughraga	4708	470.8	376.6	75	282.5
Al Zahra	5000	500	400.0	80	320.0
Johor Al Deek	2968	296.8	237.4	75	178.1
Zawaida	14291	1429.1	1143.3	75	857.5
Al Msadar	1698	169.8	135.8	80	108.7
Deir Al Balah	57003	5700.3	4560.2	70	3192.1
Total	201029	20102.9	16082.3		12679.5

(Source: Gaza Municipality (2004) *Municipalities Records*, Gaza, Palestine )

**Table 3:** Wastewater Quality from the Middle Area that Discharged to Wadi Gaza

Location	Date	TSS g/l	COD mg/l	BOD <sub>5</sub> mg/l		TKN mg/l	TP mg/l
Wadi Gaza	5/7/2003	2.6	1155	400		84	2.5
Wadi Gaza	2/8/2003	1.3	1400	1100		135	1.1
Main outlet	2/8/2003	0.2	2000	600		146	2.1
Location	Date	Imhoff cm/l	COD mg/l	BOD <sub>5</sub> mg/l	TKN mg/l	TSS mg/l	TS mg/l
Nussirat outlet Pipe	13/10/2003	10	1300	750	140	570	2.8
Al Zahra City outlet	13/10/2003	4.5	1000	410	78	260	1.6

(Source: Universal Group for Engineering and Consulting (2004) *Development of Wadi Gaza as a National Park* (The), Gaza, Palestine)

Industrial hazardous waste in Gaza is generated from print and photography shops, from the use of printer toner, chemicals, and film degrading. Mechanical workshop produce wastes from oil, grease, break fluid and batteries. The textile garment industry generates waste from dyes, chemicals, oil, grease, and auxiliary chemicals. Paper factories use bleaching chemicals, glues, and auxiliary chemicals. Other industries producing waste include construction materials, woodwork, plastics, batteries, leather tanning, metalwork, and food processing. Special wastes include hazardous waste are not directly linked with a type of industrial activity, including: pesticides in agriculture, polychlorinated biphenyls (PCBs) in electrical installations, dioxins, asbestos in building material, household waste, radioactive waste. Used Oil is used from time to time especially in summer to kill the mosquitoes in Wadi Gaza ;where it give one positive impacts on the Wadi , while it could have a very serious negative impacts on the Wadi and the Sea. On several occasions barrels of hazardous chemicals have been found near to the sea. The lab analysis of these chemicals proves that they have very negative impacts on marine life. At present, small quantities of the industrial solid waste is randomly dumped near the Wadi Gaza area due to the improvement in the solid waste management in Gaza Strip in the last few years. The direct pollution of industrial solid waste is not significant and is limited to the contaminated runoff with such solid waste that reaches Wadi Gaza in the wet season. There is no information about the quantity and the impact of these contaminants on the Wadi environment.

Approximately 95% of the population in Gaza is serviced by the collection system. There are currently three landfills in Gaza south, central and northern Gaza, respectively. All have been established through donor funded projects and have a basic infrastructure and equipments, including weighbridges to measure the weight of trucks. The landfills in southern and northern Gaza are located on impermeable lands out side the recharge area for the coastal aquifer and those do not have liners or leachate collection system. The landfills in central Gaza have a liner and leachate collection and treatment system installed. All of the locations were selected on the basis of appropriate studies.

## **(2) Point Sources Pollution Impact on Environmnet**

The significant impacts of the three major point source pollution is discussed here. Physical and human health environment in Wadi Gaza are considerably affected by these four point source pollutions. The chapter will also explain the nature of the environmental problems associated with the different pollution sources. The outcomes of this paper will also be important in stimulating the required measures and management mechanism that would be needed to rehabilitate and reclaim the natural environment of Wadi Gaza. The quantity of raw wastewater discharged daily to Wadi Gaza course is recently reaching over 20,000 m<sup>3</sup>/day. This vast quantity of heavily polluted water is well over the environmental capacity of the Wadi's natural environment. Heavy pollution load effect is eye striking, and clearly noticeable to any one visiting the site. Pollution is rapidly damaging every element of the natural environment; soil, water, and air, causing rabid degradation and even loss of habitats, fauna, flora, and aquatic life.

### **(2.1) Impact of Wastewater on Surface Water and Aquatic Wildlife**

Sewage is a threat to the marine environment because it often contains harmful chemicals, disease-causing bacteria and viruses, and dissolved material and solid matter. It enters the marine environment through direct discharges. The presence of contaminants in wastewater is a direct threat to human health. Pathogens can cause a variety of illnesses. Humans are exposed to these organisms through contaminated water and fish. Many chemicals pose risks even at very low concentrations and can remain a threat for long period of time as they bio accumulate in animal or human tissue. Sewage is one of the most significant pollutants affecting the coastal environment of the Gaza Strip. Untreated sewage discharge affects marine foodchain from phytoplankton, via zopplankton, crustaceans, macrobenthos, macro-algae to fish and mammals. An important impact of wastewater discharge to the Wadi environment is the decrease of the dissolved oxygen content of the water, due to the breakdown of organic material in the sewage water. Another impact is the eutrophication, the increase of nutrient concentration. An increase in nutrient concentrations can change the ecosystem,



high nutrient levels, high temperature and sunlight enhance the growth of phytoplankton species and may result in algal blooms that may even be toxic. Excessive bacterial growth may also occur. The increased nutrient and organic matter concentrations may favor certain species at the expense of the others. Untreated sewage contains organic and inorganic toxic substances, such as nitrates and chlorine. The quality of fish caught near the shore is not examined to identify the impacts of sewage on fish health. There is also evidence of weakened and ill looking fish near the sewage outlets at the beaches. More important is that the newly hatched fish (larvae and juveniles) grow up in the near shore zone, where the water quality is heavily affected by the raw sewage outfalls. This poses a severe threat to the fish populations of Gaza Strip where many wastewater outfalls discharge untreated sewage into the sea. Consequently, the input of raw sewage into the sea can cause a number of detrimental effects that are listed below:

- (i) Untreated sewage affects marine life, including phytoplankton, zooplankton, crustaceans, macro-algae and juvenile fish.
- (ii) Oxygen deficiency in water.
- (iii) Eutrophication (the increase of the nutrient concentration)
- (iv) Algal blooms that may be harmful.
- (v) Excessive bacterial growth
- (vi) Shift in species composition, which encourage the abundance of benthic species rather than pelagic species.
- (vii) Poisoning of species by toxic substances.
- (viii) Increase in turbidity may affect marine organisms.
- (ix) Risks in human health.

According to the Ministry of Health (Epidemiology department), in the middle area in only a four year period, there were 27839 illness

cases, with 2 deaths reported due to Diarrhea. 39 illness cases due to Hepatitis, 16 cases due to Typhoid and 7934 cases due to conjunctivitis. An epidemic of Cholera occurred in the Gaza Governorate in October and November 1994. This data recorded from 75% of all Governorate hospitals and clinics in the middle area (Table 4).

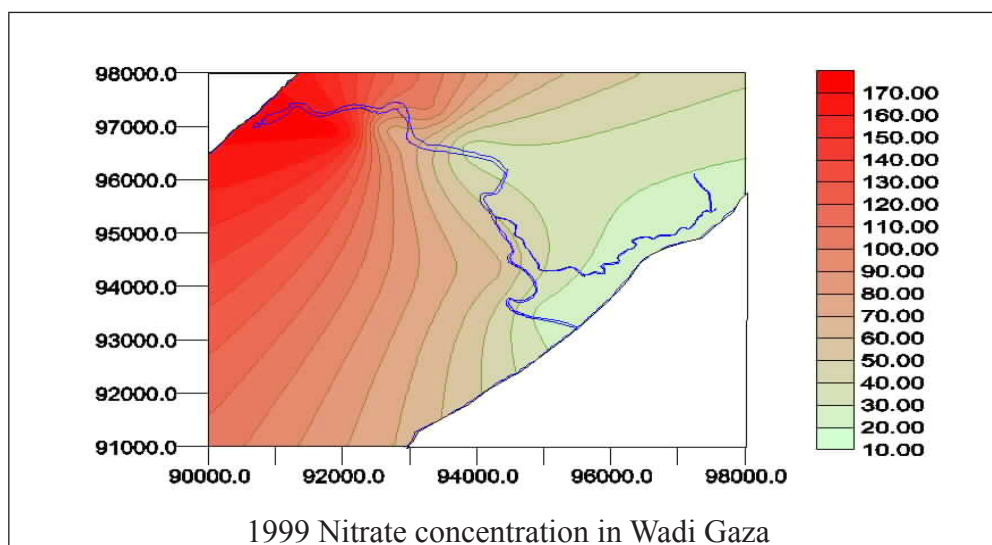
## (2.2) Impact of wastewater on Groundwater Resources

Groundwater of Wadi Gaza area was also severely affected by the discharge of raw wastewater into Wadi Gaza course. The groundwater aquifer of Wadi Gaza is part of the Coastal Aquifer, which is unconfined, shallow aquifer. That, at the mouth of the Wadi, the groundwater table intersects with the natural ground level forming the natural phenomenon of Wetlands in wadi Gaza. This fact is causing the groundwater of the area to be very vulnerable to pollution. Groundwater quality monitoring over the Wadi Gaza area is performed by Ministry of Agriculture MOA, where 12 agriculture wells are monitored twice a year. Chloride concentrations and electrical conductivity is been monitored since the seventies, while Nitrate concentration monitoring started in the Nineties (EQA, 2001). A recent study of groundwater quality in Wadi Gaza (EQA, 2001), shows high levels of Nitrate concentrations in groundwater of the area (Figure 4). As shown in the Figure the high levels of Nitrate concentrations is located at the Western part of the area. This result is matching the fact that wastewater outlet, discharges the raw wastewater at the Western part of the Wadi course where it flows from their westwards to the Mediterranean Sea. Taken into account, that at the time of study (1999), the quantity of wastewater that were discharged to the Wadi course was less than 3000 m<sup>3</sup>/day, while it is now reaching over 20000 m<sup>3</sup>/day.

**Table 4:** Annual Water Born Diseases in Gaza Middle Area.

Year	Water born Diseases in the middle area			
	Conjunctivitis	Diarrhea	Hepatitis A	Typhoid
2000	1680	4320		
2001	4071	8140	13	2
2002	2649	8204	10	1
2003	3204	7175	16	13
Total number of cases	7934	27839	39	16

(Source: Ministry of Health, Statistical Department (2001, 2002, 2003))



**Figure 4:** Nitrate Concentration over the Wadi Gaza Area in 1999 year

(Source: Environment Quality Authority EQA, 2001)

### (3) Management of Point Source Pollution

Integrated protection of resources and prevention of further deterioration is an eminent need in Wadi Gaza. Social and economic development with environmental protection and enhancement should be linked together through an integrated management approach to insure the sustainability of a clean Wadi. The management approach should incorporate the values of natural resource protection, aesthetic values, and recreational values along with consumptive uses. Future plans should focus on balancing the increasing demands on the Wadi's limited resources and incorporating the scientific knowledge available in its decisions for economic development. It also should aim at coordinating management activities concerned with the various aspects of pollution sources. An approach to the management of pollution sources in Wadi Gaza was developed to deal with the organization and strengthening of the decision-making process, including existing policies, planning and management procedures and methods that can assist in putting in place an integrated approach to prevent pollution. It does not deal with the operational aspects of management, which are more appropriately dealt with under the relevant sectoral programs, but with a broad policy direction to guide the management activities in the Wadi area.

#### (3.1) Approach

Point source pollution in Wadi Gaza affects

the environment and public health negatively, therefore, it is vital to prevent all pollution sources and manage the Wadi environment in an integrated manner. Integration should take place at two levels, considering, on the one hand all social factors (impacts of the various social sectors on the environment and natural resources) and, on the other hand, all environmental and resource components together (air, water, land, natural resources). The approach should be located based Wadi area not media or issue specific and should focus on integrating all public and private actions with public regulatory and management tools to forge effective solutions. It also should prevent all point source pollution in the site e.g. pollution by raw sewage, oil residues, garbage, and construction debris. Priority should be given to prevention of the discharge of wastewater into the Wadi through municipal pipes and canals. It is also advised to close the site completely for inappropriate activities like stone quarrying, hunting and poaching. The approach includes: administrative mechanism; legal mechanism; technical mechanism, and public awareness program.

##### (3.1.1) Administrative Mechanism

During the recent Wadi Gaza Management and planning projects, participants voiced strong support for the inclusion of all stakeholders in planning and management processes. Wadi Gaza is subject to many jurisdictions; national, regional, and local. In relation to the Wadi Gaza area

some of the institutions participate during the planning phase while others participate in the implementation, monitoring and follow up stages. A number of NGOs also contribute to the development of the Wadi area. The establishment of new municipalities and village councils around Wadi Gaza in the recent local government changes has also contributed to the already existing administrative fragmentation of Wadi Gaza, many small local councils neither have the technical capacity nor the budgets required for protection and development of the Wadi though the Wadi segments are under their jurisdictions. Solutions to the complex and interconnected issues of point sources pollution in Wadi Gaza extends to regional and local planning and management levels. Opportunities should be created throughout the Wadi basin for better coordination between individual groups and processes. No single entity can guarantee the implementation of all of the components of an effective management scheme; however, better coordination, greater stakeholder involvement, integration of science into management actions, and the definition of a common Wadi vision can greatly enhance those schemes.

### **(3.1.2) Legal Mechanism**

The Palestinian environmental law provides a framework for wastewater management and provides a mandate for concern agencies to draft further legislation and guidelines for wastewater management and setting standards for waste water discharge. While the main legislation controlling planning and construction processes in Gaza Strip is the British Law no. 28 of 1936. Additional legislation followed after the creation of the Palestinian Ministry of Environment in 1998 in the form of the Palestinian environmental Law no. 7 of 1999. Other planning initiatives had fixed the boundaries for land development and promoted the protection of natural areas and areas rich in biodiversity. However, there is a weakness of enforcement of regulations in relation to protection of natural areas and implementation of guidelines for wastewater discharge in deferent areas. Another major legal issue in the Wadi Gaza area is the land ownership. Available information estimates are that about 60% is of the land is private land, 26.9% Beer Saba'a (unregistered land), and 12/1% Waqf

land and 1% government land. Apart from a small area, located just close to the mouth of the Wadi, government land is restricted to the Wadi bed.

The Palestinian Water Authority (PWA) is involved in the domains of water resources and wastewater management. PWA drafted and the Water law with mandate over exploitation and distribution. It considered the wastewater as an important source of water among other sources. This policy puts an important objective to treat and harvest wastewater for various uses to achieve the desired water balance. In addition to infiltration to groundwater aquifers and use in agriculture, the recreational and natural uses in Wadi Gaza basin should be incorporated. Environment Quality Authority EQA and the local authorities, with the support of regional organizations, should ensure that legal policies and their instruments support the best possible control of pollution sources and Wadi reclamation management. Particular attention should be given to the wastewater and solid waste problem in the Wadi which should include:

- (i) Review the existing regulatory framework, including laws, regulations, enforcement procedures, property rights, nature protection, water and wetlands, wastewater management, urban planning, coastal planning, tourism, waste disposal, and other relevant issues in order to identify gaps and improvements needed to support sustainable pollution control and prevention of waste;
- (ii) Develop guidelines, bylaws, enforcement mechanisms, measures, and procedures that help in implementation of plans and application of relevant standards and address the shortcomings in the existing legal setup and provide the basis required for the legal protection of nature at Wadi Gaza.
- (iii) Develop policies that encourage the control of pollution and take the interests of the local population into account as a first priority and reinforce the legal basis required for effective implementation of the protection plans.
- (iv) Encourage the principle of delegating policy-making to a lower level of public authority consistent with effective action and a locally driven approach.
- (v) Develop regulations which exclude activities

that have a detrimental impact on Wadi habitat, biodiversity, and water quality.

- (vi) Provide a clear legal and administrative mandates for various stakeholders in order to prevent the overlapping of authority.

### **(3.1.3) Technical Mechanism**

The Environment Quality Authority (EQA) with the support of local and regional institutions should review and, if appropriate, revise planning and management systems to facilitate an integrated management approach. Further more; EQA should promote the improvement and further development of planning and management tools that facilitate an integrated and sustainable approach to control pollution. They should follow the policy guidelines below:

- (i) Adopt planning and management systems that facilitate the integration of environmental components such as air, water, land and other natural resources.
- (ii) Adopt strategic frameworks that allow the integration of both developmental and environmental goals.
- (iii) Establish a general framework for pollution control within which more detailed sectoral plans can be developed.
- (iv) Strengthen management systems for pollution control by including appropriate traditional and indigenous methods.
- (v) Examine and, if necessary, establish innovative and flexible approaches to program funding;
- (vii) Adopt improved systems for integrated analysis of data on land use and land resources;
- (viii) Apply procedures for assessing the environmental, social and economic impacts of specific actions.
- (ix) Analyze and test methods to include land and ecosystem functions and land resources values in national accounts.

The technical mechanism will focus on recommending a set of technical solutions as integrated mechanism for each of the previously described three major point source pollutions. Nevertheless, problems threatening Wadi Gaza natural environment are still more than dealing with point source pollutions. Threats such as, urban sprawl, surface water natural flow regime disturbance, groundwater table lowering,

overgrazing, absence of law enforcement, low environmental awareness among both public and officials, and not finally the conflict of interests over Wadi Gaza among different parties, are also, severely harming Wadi Gaza environment.

The overall objective here is to set a practical and realistic technical mechanism that would guide responsible parties on how to eliminate point source pollutions and further to mitigate the adverse impact caused by these point source pollutions on Wadi Gaza environment. It is essential for all responsible parties to act immediately, effectively, and firmly as well; to stop the fast deterioration of Wadi Gaza environment and to reverse the current trend. There are three main objectives to be attained in order to achieve the goal of Wadi reclamation and to ensure the sustainability of clean Wadi, they are:

- \* Eliminating the discharge of raw sewage into Wadi Gaza course way.
- \* Stopping the uncontrolled dumping of domestic, industrial wastes and construction debris in the Wadi Gaza site.
- \* Reducing the adverse impact of the Gaza Power Plant.

In the contexts of this division, each of these three main objectives shall be dealt with separately, followed by a collective scheme of actions for the full problem of point source pollution in Wadi Gaza.

The quantity of raw sewage now being discharged to Wadi Gaza is vast; it is reaching more than 20,000 m<sup>3</sup>/day. This quantity is much over the environmental capacity of the Wadi's wetlands and the Wadi's ecological system. The problem has been caused by centralizing the collection of the complete Middle Area Governorate sewage and discharging it through one outlet into Wadi Gaza. At the original plan, this quantity of raw sewage was intended to be pumped out to a central treatment plant of the area. The treatment plant was to be constructed south of Wadi Gaza, just outside the Wadi Gaza area and east of Al Buraij camp. It was planned to become operational by 2007. Meanwhile, it was planned to pump the centralized collected sewage of the Middle Area Governorate to Gaza City treatment



plant temporarily, till the Middle Area treatment plant is operational. Unfortunately, the donors whom pledged to this temporarily solution have retreated. At the same time the operational date of the proposed central treatment plant has also been delayed to 2008. This situation held the Wadi in miserable environmental conditions. In parallel to these wastewater infrastructure planed projects, UNDP in cooperation with EQA was implementing a large developmental and rehabilitation project in Wadi Gaza, at the assumption that the sewage will be removed from the site based on the previous plans. In view of the fact that the sewage infrastructure plans have been stopped or delayed, UNDP and EQA thought of another temporarily low cost solution. The temporarily solution was to make a constructed wetlands system using reed beds to have the raw sewage partially treated, over an area of 22 dunums separated into two ponds, at the Western end of the Wadi and before the natural wetlands area. From this brief on the final status of the sewage problem, the following points can be concluded:

- (i) The sewage problem in Wadi Gaza is a mass problem and can not be eliminated with simple technical solutions.
- (ii) The needed solution is composed of two parts. One is a short term temporary solution and the other is the long term permanent solution.
- (iii) Concerned parties of the issue must work immediately on both solutions in parallel. Firstly, to activate the implementation of the short term temporarily solution and secondly to speed up the implementation of the permanent Middle Area Central Treatment Plant (MACTP) solution.
- (iv) Unless continues and effective pressure is been put on these two solutions stakeholders to act without delays, the Wadi environment will be severely damaged to the point of non-reversible. Therefore it is suggested to form a motivated committee to carry on the following tasks:
  - (a) Follow up the implementation of both the temporarily and the permanent solutions with donors and concerned parties.
  - (b) Rise up awareness among concerned authorities, officials and local community groups of the importance of saving the environment of Wadi Gaza.
- (c) Set final dates to be respected, in agreement with donor agencies, Middle Area municipalities, Ministry of local governments MoLG, and the Palestinian Water Authority PWA for the permitting period of discharging the raw sewage to Wadi Gaza.
- (d) Bring into light and attention, the likely eternal loss of Wadi Gaza to the public view, and the mass media to mobilize the Palestinian civil and official society to save Wadi Gaza.
- (e) This committee should consist of motivated, hardworking and dedicated persons from official authorities, NGO's and local community members.
- (i) Stopping the Uncontrolled Dumping of Domestic, Industrial Wastes and Construction Debris in the Wadi Gaza Site

The solution for the problem of dumping domestic, industrial and construction debris is very much linked to the solution of the sewage problem. Since, there is no logic in cleaning the Wadi course and sides from solid wastes, while it is heavily polluted with huge quantities of sewage. This was the lesson learned from the cleaning element of the lately UNDP implemented large project in Wadi Gaza. One of the main elements of that project was to clean the Wadi course and sides from all domestic, industrial, and construction wastes. This element of the project was implemented successfully, but sadly, and not long after, dumping of these wastes started again. Even, it is been done infrequently by neighboring municipalities. Therefore, cleaning the Wadi from raw sewage comes first. With this most significant measure, a set of other technical measures should be taken:

- (a) Rising up awareness of the local community in Wadi Gaza of the importance of keeping clean neighborhood and the importance of saving the natural environment of Wadi Gaza. In this context it will be important to illustrate to local community members, the health, economic, and social benefits of keeping clean Wadi Gaza.
- (b) Equipping neighborhoods at both sides of Wadi Gaza with sufficient garbage containers for their domestic wastes.
- (c) Improving solid waste collection systems within

municipalities around Wadi Gaza, especially in collecting wastes on regular basis.

- (d) Recruiting environmental guards to prevent, monitor, and report solid waste and construction debris dumping.
- (e) Enforcing the environmental law and the Wadi Gaza natural reserve declaration law.
- (f) Stopping those who violates the law and dump wastes into Wadi Gaza by fines and or jails.
- (ii) Reducing the Adverse Impact of the Gaza Power Plant

One of the requirements of granting the approval for the construction and operation of the Gaza Power Plant (GPP) in Wadi Gaza was the submission of a full environmental impact assessment EIA including an environmental management plan EMP to EQA. This EMP was a comprehensive tool to eliminate or reduce the adverse impacts of the construction and operation of the GPP on the site's natural and human environment. It appears that, this EMP was only a paper work and is not followed nor implemented. It is the rule of EQA to monitor over the GPP operating company in order to follow the implantation of the EMP and to abide to the company's operation approval conditions.

#### **(3.1.4) Public Awareness Program**

The project put on its agenda educational and training activities to address issues of public health and awareness. One of its objectives is to provide capacity building through training and education. Awareness program will increase environmental awareness and the conflicts of the community surrounding the Wadi. It will also show environmental risks caused by different pollution source. The program will cover three main categories (groups) of the community, women, school children and decision makers. Each group has its own specific vision, so the program will treat the differences among those groups. Special attention will be given to school students as they represent the large portion of the community. Some of the activities which will cover school program:

- (a) Leaflets, procure and pictures will be distributed,
- (b) Field visit to the Wadi area, (see different activities in the Wadi),
- (c) Cleaning campaign for students in part of the Wadi,
- (d) Establish environmental club in the Wadi area.

The awareness program has been developed and implemented in Wadi Gaza Area through the directorate of environmental awareness in EQA with coordination with the local institutions and main stakeholders. This program is going to be continued as one of the main priorities and activities in order to control further pollution in the wadi area.

## **Conclusions**

Because of the importance of the Wadi Gaza as a unique ecosystem in Gaza Governorates, it was declared as *nature reserve* in June 2000. Wadi Gaza Nature Reserve was established to conserve the wetland ecosystem, to stop or slow the degradation of its natural resources and biological diversity and to promote measures for their eventual rehabilitation. This study outlines an agenda for investigating the sources of pollution of Wadi Gaza, effects of pollution on Gaza's ecology and on the health of its inhabitants. Also, to establish an integrated approach for river reclamation management, including technical, administrative and legislative mechanisms for improvement of existing conditions and for ensuring the sustainability of clean Wadi. A capacity building component through training and educational activities are also proposed to proactively address issues of public health/awareness, as well as the protection and sustainability of the Wadi Gaza environment.

There are two types of pollutants in Wadi Gaza exist; point source and non-point source. Point source pollution in Wadi Gaza affects the environment and public health negatively, therefore, it is vital to prevent all pollution sources and manage the Wadi environment in an integrated manner. Integration should take place at two levels, considering, on the one hand all social factors (impacts of the various social sectors on the environment and natural resources) and, on the other hand, all environmental and resource components together (air, water, land, natural resources). The approach should be located based Wadi area not media or issue specific and should focus on integrating all public and private actions with public regulatory and management tools to forge effective solutions. It also should prevent all

point source pollution in the site e.g. pollution by raw sewage, oil residues, garbage, and construction debris. Priority should be given to prevention of the discharge of wastewater into the Wadi through municipal pipes and canals. It is also advised to close the site completely for inappropriate activities like stone quarrying, hunting and poaching. The quantity of raw wastewater discharged daily to Wadi Gaza course is recently reaching over 20000 m<sup>3</sup>/day. This vast quantity of heavily polluted water is well over the environmental capacity of the Wadi's natural environment. Heavy pollution load effect is eye striking, and clearly noticeable to any one visiting the site. Pollution is rapidly damaging every element of the natural environment; soil, water, and air, causing rabid degradation and even loss of habitats, fauna, flora, and aquatic life. The high levels of Nitrate concentrations is located at the Western part of the area. This result is matching the fact that wastewater outlet, discharges the raw wastewater at the Western part of the Wadi course where it flows from their westwards to the Mediterranean Sea. Taken into account, that at the date of study in 1999, the quantity of wastewater that were discharged to the Wadi course was less than 3000 m<sup>3</sup>/day, while it is now reaching over 20000 m<sup>3</sup> /day. All the Wadi sources of pollution and their impacts are illustrated in details, these illustrations were helpful tools to set the suitable solution to each source of pollution and this gave a better understanding of how to solve Wadi Gaza problems. This led to the right steps that should be taken in order to improve the environmental situation in Wadi Gaza area.

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