

Environmental Impacts Associated with the Beit Lahia Wastewater Treatment Plant, North Gaza Strip, Palestine

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Abstract: The Beit Lahia wastewater treatment plant (BLWWTP) represents the hottest environmental spot in North Gaza. The current study comes to highlight the environmental impacts associated with this catastrophic anthropogenic ecosystem. The study relied heavily on field and literature surveys. The study pointed out that the whole system is seriously threatening to neighboring environs and inhabitants. The environmental impacts encountered throughout the study period include: (1) deadfall accidents in the sewage pools, (2) painful floods with particular emphasis on the flood disaster of March 2007, (3) outbreak of environmental pests, (4) the depletion of sand dunes, (5) mosquito proliferation and nuisance, (6) prevalence of intestinal parasitic infections, (7) emission of offensive odors and (8) groundwater pollution by both nitrates and bacteriological parameters. The current establishment of a new WWTP in the eastern part of North Gaza is promising in the sense that most of the problems encountered here will diminish in a gradual fashion. Finally, the role of different institutions and organizations should be strengthened towards investigating and improving the environmental health aspects of the targeted populations in the Gaza Strip.

Key words: Wastewater • Wastewater Treatment Plant • Environmental Impacts • Gaza Strip • Palestine

INTRODUCTION

The Occupied Palestinian Territories (OPTs), which include the West Bank and the Gaza Strip, represent a most environmentally suffering hot spot in the region, where long-term environmental degradation and deterioration have occurred over the last six decades of the Israeli occupation. Al-Agha [1, 2] documented the main environmental issues prevailing since decades in the Gaza Strip and he pointed out that the most serious environmental problems are the shortage and contamination of the groundwater resources. The United Nations Environment Program (UNEP) highlighted the main environmental issues of the OPTs to include the crisis of ground and surface water resources, wastewater mismanagement, solid and hazardous waste mismanagement and biodiversity depletion [3]. However, the severity and complexity of these environmental issues and the many others increase with the Israeli blockade or siege imposed on the Gaza Strip since 2006 [4] and with the Israeli war imposed on the Gaza Strip in December 2008 [5, 6].

With regard to groundwater resources in the OPTs, they are suffering due to infiltration of untreated

wastewater from leakages, overloaded wastewater treatment plants (WWTPs) and effluent discharged directly into the open environment [7]. Currently, about 40 million cubic meters (MCM) of wastewater are produced annually in the Gaza Strip alone according to current estimates declared in the different parties by the Palestinian Water Authority (PWA). It is estimated that 60% of the population is connected to a sewerage network [3]. Cesspits, open drains, boreholes and vaults are the other wastewater disposal system in the Gaza Strip [8]. Most of the wastewater produced in the Gaza Strip is discharged into the Mediterranean Sea via tens of pipelines or through Wadi Gaza; thus constituting an actual threat that pollutes the marine environment and deteriorates its biodiversity and fisheries resources [9]. The sewage composition is usually affected by the low per-capita water consumption within the Palestinian households, where there is an increase in organic constituents and influent salinity [3].

The raw sewage generally contains high levels of organic material, numerous pathogens (viruses, bacteria, fungi; protozoa and helminthes), as well as nutrients and toxic compounds. Hence, it imposes environmental and health hazards and, consequently, must immediately be

treated appropriately before its final disposal. The ultimate goal of waste-water management is the protection of the environment in a manner commensurate with public health and socio-economic concerns.

Treatment of wastewater occurs via three WWTPs (Beit Lahia, Gaza and Rafah) in the Gaza Strip. The efficiencies of these treatment plants are very low. The effluent from the Gaza and Rafah treatment plants is discharged into the Mediterranean, while the situation is totally different concerning the Beit Lahia wastewater treatment plant (BLWWTP), where connection with the Mediterranean is not found [3, 10]. The ever increasing volume of influent wastewater and the insufficient capacity has led to effluence overflowing from the BLWWTP into the surrounding sand dunes, creating a lake which covers over 45 hectares. Substantial quantities of wastewater from this lake and the other lagoon systems of the BLWWTP infiltrate into the ground, polluting soil and groundwater and imposing public health risks to neighboring inhabitants [11].

In spite of the current attention made by the different parties to the BLWWTP, the environmental health aspects are deteriorating day by day in an alarming rate and fashion in the environs surrounding the BLWWTP; especially the Bedouin Um-Unnasser Village. The present study comes to highlight the environmental impacts associated with the BLWWTP. This may enhance the knowledge of the Palestinians towards such impacts drawn by the plant and this, in turn, may represent a good base and tool enhancing such suitable interventions.

Literature Review: Work on wastewater and its allied environmental and public health issues is increasing day by day in the Gaza Strip. The scientific handling of the BLWWTP in terms of design, treatment and impacts seems to be good, where many master dissertations and scientific reports and publications are available. The PWA [12, 13] conducted environmental assessments to the BLWWTP in terms of improvement and emergency projects. Aish [14] worked on nitrate pollution sources in Beit Lahia and investigated the pollutant transport from the BLWWTP to groundwater resources by means of a groundwater model. Keshta [15] evaluated the treatment process of the BLWWTP and focused on the alternative treatment options. The 2003 UNEP report [3] highlighted the problem of wastewater management in the OPTs and introduced brief description on the BLWWTP in North Gaza. Sharif [11] and Melad [16] studied the impact of the BLWWTP on the microbiological characteristics of the neighboring wells.

Kendlbacher [17] outlined the history of the BLWWTP and highlighted many of its environmental and health impacts on the neighboring residential masses especially the Bedouin Um-Unnasser Village. Al-Khalidi [18] evaluated the performance of the BLWWTP and he revealed that the over hydraulic and organic loadings, limitation of oxygen supply and the poor design for treatment basins are the main factors standing behind the inadequate treatment performance. Finally, Al-Zain [19] conducted a cross-sectional study to examine the impact of socioeconomic conditions and intestinal parasitic infestation on hemoglobin level among children in the Bedouin Um-Unnasser Village that lies close to the BLWWTP. He revealed that 25% of the population surveyed was anemic and the prevalence of intestinal parasitic infections among them was 46.9%.

Existing Conditions of BLWWTP: The following general description of the BLWWTP is based on a number of references [3, 17, 18]. The BLWWTP (Figure 1) is located some 1.5 km east of the town center of Beit Lahia in the northern part of the Gaza Strip. The construction of the plant over the best aquifer in the area started in 1976 by military orders of the Israeli Administration to serve more than 50,000 inhabitants in North Gaza. No records showed that environmental impact assessments or statements were done before establishing the BLWWTP construction. Nowadays, the plant serves the town of Jabalia as well as nearby Jabalia refugee camp and the communities of Beit Lahia and Beit Hanoun in North Gaza. The area's total population amounts to more than 270,000 and continues to rise. About 75% of this population is connected to sewerage network. The plant was expanded in 1991 to increase its peak flow capacity of raw sewage to 5,000 m³ per day. At present, more than 19,000 m³ per day passes through it. The main goal of the plant was to produce an effluent with a high enough quality that it would be suitable for direct use in irrigation and this dream was not satisfied due to the poor quality of the treated wastewater produced.

According to PWA [12], the BLWWTP was built in sand dunes overlying a clay layer of variable thickness. The high levels of nitrates and detergents in the surrounding wells ensure that this impermeable clay layer is not continuous. The BLWWTP was constructed in stages and modification and rehabilitation activities were performed in order to increase the functioning capacity of the plant. The original design of the BLWWTP as dictated by the Israeli Civil Administration in 1976 included four primary aerated lagoons.

BIET LAHIA WASTEWATER TREATMENT PLANT (BLWWTP)

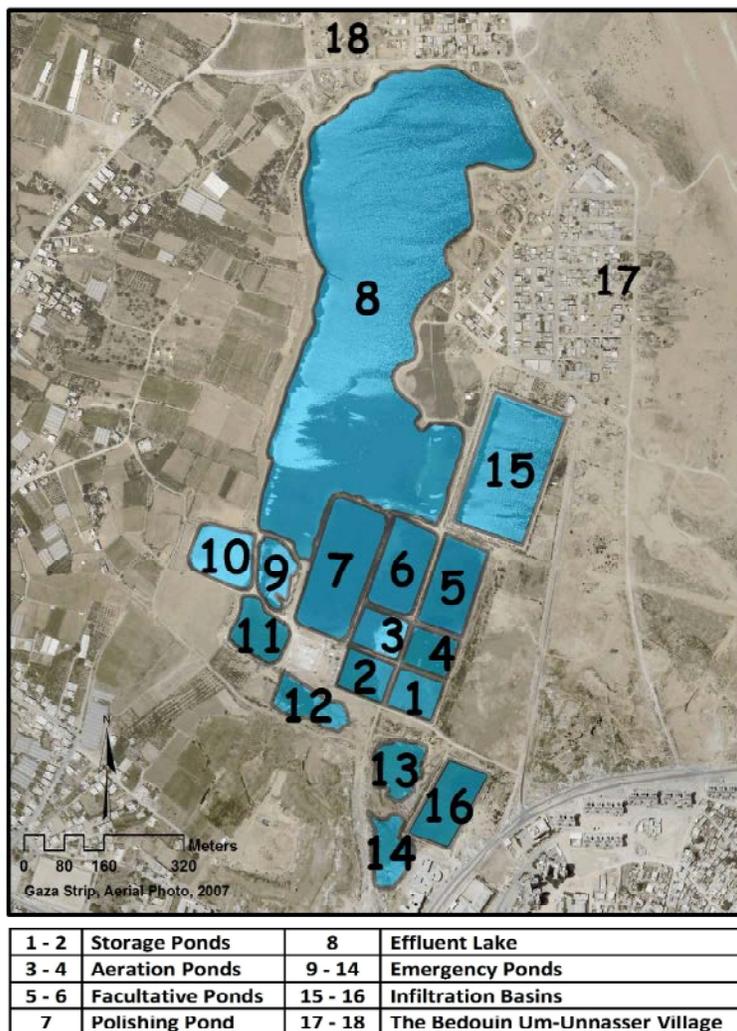


Fig. 1: The existing situation of the BLWWTP, North Gaza Strip (Aerial photo, 2007)

Currently, the existing plant has seven lagoons and it differs from the original design in the number of ponds as well as on the function of the ponds [18]. In 1999, screen, grit removal and two infiltration basins were added to the plant. The function of the screen and the grit removal unit comes from the fact that they avoid silting of the ponds and damaging of the aerators of the aerated lagoons. Figure 1 displays the serial lagoon system of the BLWWTP. These are two anaerobic lagoons, two aerated lagoons, two facultative lagoons and finally one polishing pond or lagoon. Wastewater usually passes from one lagoon to another in a serial rhythm and it finally accumulates in the effluent lake which covers more than 45 hectares.

Three new WWTP projects were proposed to be constructed near the eastern border of the Gaza Strip

in order to replace the existing ones by the year of 2020 and to conserve the deteriorating water resources by using the produced treated wastewater as unconventional water resource. One of these new WWTPs was designed to be established in the North Governorate of the Gaza Strip in order to serve the increasing population there and at the same time to produce good-quality treated effluent and sludge. The treated effluent is proposed to be recharged into the aquifer through infiltration basins and/or to be used in agricultural irrigation. In parallel, the treated sludge is proposed to be used as a fertilizer or a soil conditioner [20]. Although the final engineering design of the new plant was completely undertaken, the implementation of the project was suspended due to the deteriorating political situation of the Gaza Strip that

started in 2000. The last few years witnessed some progress in the implementation of the new plant in east Jabalia, North Gaza and a transfer of the effluent wastewater from the existing BLWWTP to the new plant. As a result, the effluent lake was dried and its threatening damage to the environment and public health is now progressively diminishing.

Study Design: This study was carried out over a period of two years extending from March, 2007 to February, 2009. The study depended largely on field and literature surveys concerning the environmental aspects of the BLWWTP in North Gaza. The field work was translated into local observations, interviews and discussions with both local people and many stakeholders. Frequent visits have been conducted to the site to satisfy the purpose of the study. Meanwhile, a considerable number of photos was taken on the site in order to highlight the environmental impacts of the BLWWTP and its allied environs.

Environmental Impacts Associated with the BLWWTP:

The existing conditions of the BLWWTP and its effluent lake are seriously threatening both the environmental and health aspects of neighboring environs. The environmental and health impacts of the plant are listed and discussed as follows:

Deadfall Accidents: The continual and amoebic enlargement of the effluent lake imposes serious threats to people living in the vicinity of the BLWWTP. Meetings and discussions with local people and municipalities revealed that about 6 children have died a terrible and painful death in the sewage pools since the construction of the plant. The main factors promoting such falling accidents were:

- The lack of awareness campaigns that may introduce the possible hazards of the BLWWTP pools to the public.
- The absence of fences or any safety measures in the BLWWTP area due to the continual rising of the wastewater level in the pools especially the effluent lake which has a depth reaching to about 15 meters.
- The continual playing of children near the pools accompanied by a total absence of yards and parks in the area. It is worth mentioning that the author recorded such playing activities in the area surrounding the pools. In many times, children were noticed climbing the sandy barriers to reach the edge of the pools where the risk of falling is present.

Table 1: The main targeted aquatic bird species hunted in the effluent lake

Family	Scientific Name	Common Name
Threskiornithidae	<i>Plegadis falcinellus</i>	Glossy Ibis
Ardeidae	<i>Nycticorax nycticorax</i>	Night Heron
	<i>Ardeola ralloides</i>	Squacco Heron
	<i>Egretta garzetta</i>	Little Egret
	<i>Bubulcus ibis</i>	Cattle Egret
Anatidae	<i>Ardea purpurea</i>	Purple Heron
	<i>Alopochen aegyptiacus</i>	Egyptian Goose
	<i>Anas strepera</i>	Gadwall
	<i>Anas platyrhynchos</i>	Mallard
	<i>Anas querquedula</i>	Garganey
Rallidae	<i>Anas clypeata</i>	Shoveler
	<i>Gallinula chloropus</i>	Moorhen
	<i>Fulica atra</i>	Coot
Recurvirostridae	<i>Himantopus himantopus</i>	Black-winged Stilt
Charadriidae	<i>Vanellus spinosus</i>	Spur-winged Plover

- The tendency of many children to hunt aquatic birds (waders and waterfowls) that usually prevail in the effluent lake and the other treatment lagoons of the BLWWTP for different purposes including food, game and the feeding of the trapped raptors. It is worth mentioning that the effluent lake provides breeding, nesting, resting, roosting and feeding habitats for tens of bird species. Table (1) shows the main targeted aquatic bird species hunted or trapped using different means by both children and adults in the ecosystem.

Kendlbacker [17] mentioned that two children cases, each of about eight years old, were drowned and died in the BLWWTP pools in 1992 and 1994. The sandy barriers of the effluent lake were raised by the water authorities tens of times in order to prevent the flooding of the surrounding areas. Additionally, wire fences have been established around the BLWWTP pools and the lake in the last years to prevent such deadfall accidents (Figure 2).

Floods: The BLWWTP and its effluent lake represent a significant real threat to the neighboring areas and human communities; particularly the Bedouin Um-Unnasser Village and Beit Lahia due to their close attachment and latitude considerations. Although many floods associated with sewage lagoons were recorded in the area, the report of Kendlbacker [17] mentioned two occasions of flood occurring in 1989 and 1992, where the sand barriers of sewage lagoon collapsed under the pressure overflow resulting in drowning of houses and agricultural lands in



Fig. 2: Wire fences have been established around the pools of the BLWWTP to prevent such falling accidents (The photo was taken by the author in 2007)

Beit Lahia, thus causing severe environmental, economic, psychological and health problems. Besides the destruction of houses and furniture, domestic animals and livestock were known to be lost during heavy floods. Many agricultural crops were completely destroyed and what was not destroyed by flood was destroyed by the agricultural authorities who prohibit the sale of pathogen-contaminated crops to the public [17].

The fear from the repetition of floods at any time during the year was the worse for neighboring people especially children and aged persons who usually complain from different psychological symptoms. This was logic because the semi-treated wastewater level of the effluent lake is rising day by day in spite of the arrangements made by the municipalities and the water authorities to raise the sand barriers of the lake and as a result, the risk of repeated floods is increasing constantly and the dilemma of being flooded by sewage made people living in a constant fear.

At times of flood, the populations of the area were found to suffer from the prevalence of intestinal parasites and other infectious diseases in addition to the bad smell omitted from the sewage remains. Mosquitoes, flies and other insects may be more abundant than usual, posing potential health problems. Debris left by the flooded wastewater usually create excellent breeding conditions for house flies, mosquitoes, cockroaches and other insects that may be capable of spreading many different disease including typhoid, dysentery and encephalitis [21].



Fig. 3: Navigation in wastewater was a common practice during floods targeting the Bedouin Um-Unnasser Village in North Gaza (The photo was taken by the author during the flood disaster in 2007)

Flood Disaster of March 2007: On March 27, 2007, effluent from an emergency filtration basin at the BLWWTP flooded the nearby Bedouin Um-Unnasser Village (Figure 3) killing five people and injuring 25 others in addition to the displacement of more than 2000 residents into temporary camps established by the different humanitarian agencies responded to the calls of the victims and the nearby communities. The whole situation regarding this painful disaster was best described by the author himself who photographically documented the serial events of the scene.

The cause of this tragedy comes from the fact that an emergency filtration basin was created in a hilly area lying east to the BLWWTP in September, 2006 by PWA. The excavation of this basin was seen as a response to the growing concerns regarding the increasing wastewater influent to the plant and as a temporary measure to prevent further overflow from the plant. The collapse of the barrier of this basin permitted the effluent to flood the nearby Bedouin Um-Unnasser Village. The strength and severity of the event made many parties to describe it as a "Tsunami".

Following the painful flood disaster, many mitigation steps were undertaken by the responsible parties to prevent further similar or repeated floods as follows [22]:

- The reinforcement and consolidation of the sandy embankments surrounding the huge effluent lake.
- The construction of two new lagoons, each of a capacity of 250,000 cubic meters, northwest of the Bedouin Um-Unnasser Village and a two 900 meter-

long pressure lines with mobile pumps to carry wastewater from the effluent lake to the newly created lagoons. This reduced the wastewater level of the effluent lake and enabled the BLWWTP and its sewage network to resume functions.

- The establishment of temporary camps owing tents, latrines and showers by the relief agencies to shelter the displaced people. Food and non-food items in addition to medications and psychological support services were made available to the sheltered populations.

Outbreak of Vertebrate Pests: Aquatic ecosystems including wetlands are good habitats to wildlife of both vertebrate and invertebrate species. They provide wildlife with all necessary requirements such as shelter, protection, food and breeding, resting and roosting places ...etc [23, 24]. Frequent ecological visits to the BLWWTP by the author showed that the system is very rich in biodiversity species including some annoying and poisonous vertebrate species that are collectively regarded as pests.

During such meetings, people from the Bedouin Um-Unnasser Village and Beit Lahia were afraid from the dangers that might be imposed by commensal rodents and venomous snakes that attack their buildings and animal husbandries and become more abundant than usual due to the present location and continual amoebic enlargement of the effluent lake. Yassin *et al.* [25] pointed out that rats, snakes, crows, barn owls and other wild species were and still common vertebrate pests in North Gaza particularly the BLWWTP area. These animals were found to pose a variety of damage to the people's cultivated and stored crops, possessions and other properties.

It is worth mentioning that the Palestine Viper (*Vipera palaestinae*), which known locally as the *Hayya Za'ara* is the only endemic snake species in Palestine (Figure 4) and most snakebites in Palestine and the Gaza Strip were attributed to this venomous and dangerous species [24-27].

The three cosmopolitan nocturnal commensal rodent species were known to occur in Palestine and the Gaza Strip and they are notably the House Mouse (*Mus musculus*), House or Black Rat (*Rattus rattus*) and Norway or Brown Rat (*Rattus norvegicus*) [24, 28]. They are actual vertebrate pests causing damage to humans, domestic animals, agricultural products and other human properties as reported by inhabitants in the



Fig. 4: The Palestine Viper *Vipera palaestinae*, is an endemic venomous snake in the vicinity of BLWWTP (The photo was taken by the author in 2005)

vicinity of the BLWWTP. The whole situation usually encourages people to apply various toxic materials including rodenticides as a control means and this in turn causes serious morbidities and mortalities among non-target species including children.

As far as the previously mentioned 2007 flood disaster in the area is concerned, many vertebrate pests are usually displaced from their habitat and left homeless. As a result, these pests seek areas which provide food and shelter. Unfortunately, many of the new havens occupied by these animals are in houses, sheds and other structures damaged by the flood. The unwelcome vertebrate pests can cause property damage and may pose potential health problems.

Depletion of Sand Dunes and Landscape: Sand dunes are a characteristic feature of the western belt of the Gaza Strip. They are a vital resource, providing various environmental and ecological values. They protect the coastal areas against the Mediterranean Sea, have a natural water cleaning and filtering capacities thus replenishing the Gaza Strip coastal aquifer and have certain natural landscape character. Moreover, they promote ecotourism and recreational activities for the Palestinians in the Gaza Strip (Figure 5). Ecological investigations carried out in the neighboring sand dunes revealed that these ecosystems harbor many common wildlife species concerning fauna and flora (Tables 2, 3). The shrubs of Acacia (*Acacia cyanophylla*) cover most of the sand dune landscape in the Gaza Strip (Figure 5).

Table 2: Common floristic species recorded in the sand dunes of the Gaza Strip

Scientific Name	Common Name
<i>Cupressus sempervrens</i>	Evergreen Cypress
<i>Pancratium maritimum</i>	Sea Daffodil
<i>Phoenix dactylifera</i>	Date Palm
<i>Opuntia ficus-indica</i>	Tuna Cactus
<i>Salsola kali</i>	Russian Thistle
<i>Artemisia monosperma</i>	Sagebrush
<i>Silybum marianum</i>	Blessed Milk-thistle
<i>Ricinus communis</i>	Castor Oil Plant
<i>Acacia cyanophylla</i>	Acacia
<i>Acacia arabica</i>	Gum Arabic Tree
<i>Alhagi maurorum</i>	Camel-thorn
<i>Ficus sycamorus</i>	Sycamore Fig
<i>Eucalyptus camaldulensis</i>	River Red-gum Tree
<i>Ziziphus spina-christi</i>	Christ's Thorn
<i>Nicotina glauca</i>	Tree Tobacco
<i>Tamarix nilotica</i>	Nile Tamarisk

Table 3: Common faunistic species recorded in the sand dunes of the Gaza Strip

Scientific Name	Common Name
Mammals	
<i>Felis silvestris</i>	Wild Cat
<i>Herpestes ichneumon</i>	Egyptian Mongoose
<i>Spalax leucodon ehrenbergi</i>	Palestine Mole-rat
<i>Jaculus jaculus</i>	Lesser Egyptian Jerboa
<i>Gerbillus pyramidum</i>	Greater Egyptian Gerbil
<i>Lepus capensis</i>	Cape Hare
Birds	
<i>Bubulcus ibis</i>	Cattle Egret
<i>Milvus migrans</i>	Black Kite
<i>Falco naummani</i>	Lesser Kestrel
<i>Falco tinnunculus</i>	Common Kestrel
<i>Alectoris chukar</i>	Chukar
<i>Coturnix coturnix</i>	Common Quail
<i>Burhinus oedicnemus</i>	Stone Curlew
<i>Vanellus spinosus</i>	Spur-winged Plover
<i>Columba livia</i>	Rock Dove
<i>Streptopelia turtur</i>	Turtle Dove
<i>Streptopelia senegalensis</i>	Laughing Dove
<i>Tyto alba</i>	Barn Owl
<i>Caprimulgus europaeus</i>	European Nightjar
<i>Upupa apops</i>	Hoopoe
<i>Galerida cristata</i>	Crested Lark
<i>Hirunda rustica</i>	Barn Swallow
<i>Pycnonotus xanthopygos</i>	Yellow-vented Bulbul
<i>Nectarinia osea</i>	Palestine Sunbird
<i>Corvus corone</i>	Hooded Crow
<i>Sturnus vulgaris</i>	European Starling
<i>Passer domesticus</i>	House Sparrow
<i>Carduelis carduelis</i>	Goldfinch
<i>Carduelis cannabina</i>	Linnet
Reptiles	
<i>Testudo graeca</i>	Spur-thighed Turtle
<i>Varanus griseus</i>	Desert Monitor
<i>Chamaeleo chamaeleon</i>	Mediterranean Chameleon
<i>Acanthodactylus boskianus</i>	Bosc's Lizard
<i>Agama stellio</i>	Agama
<i>Chalcides ocellatus</i>	Ocellated Skink
<i>Eryx jaculus</i>	Sand Boa
<i>Coluber jugularis asianus</i>	Syrian Black Snake (Arbeed)
<i>Vipera palaestinae</i>	Palestine Viper



Fig. 5: Sand dunes provide various environmental, ecological and recreational values to the Palestinians in the Gaza Strip (The photo was taken by the author in 2009)

Effluent usually overflows from the BLWWTP into the surrounding sand dunes and as a result an effluent lake was created there. The high biological oxygen demand (BOD) and suspended solids (SS) content of the effluent results in sludge production. Pore spaces of the infected sand dunes were filled with sludge and other colloidal materials resulting in clogging and low infiltration through the dunes. This scene made the effluent lake to increase in its total area from year to year and as a result more sand dunes and lands were engulfed. It is worth mentioning that land resources of North Gaza should be kept unpolluted for future developmental projects which may promote recreation and sustainable tourism aspects.

Moreover, The sandy areas lying south to the BLWWTP have been extensively used as a site for the disposal of sludge, grit and other waste materials. The hills and stocks of untreated sludge represent a focus for the spread of infective diseases in the adjacent area as was claimed by the neighboring populations.

Mosquito Proliferation: Wastewater-laden and wetland ecosystems have the capacity to harbor disease-infecting agents and annoying insects especially the families of higher Diptera e.g. mosquitoes which are considered by far the most important of the blood sucking arthropods worldwide [29]. The aquatic nature of these ecosystems provides good microhabitats for larval growth and production. With regard to the BLWWTP and its effluent



Fig. 6: Mosquito control in the BLWWTP using the Bacterium Bti (The photo was taken by the author in 2009)

lake, mosquito proliferation especially in the summer seasons constitutes a major public health to the neighboring inhabitants. This was clear from the magnitude of complains issued by the inhabitants of the Bedouin Um-Unnasser Village, Al-Awda and Al-Nada residential towers and the other residential masses of Beit Lahia and Beit Hanoun.

Complains of the inhabitants were very painful as the inhabitants claimed that mosquitoes eat them up every night. They usually make associations between mosquito proliferation and a number of health problems prevailing among them such as skin infections, rashes, itching, ulcers and allergies. To avoid such mosquito biting, the inhabitants were found to apply different personal protection measures such as burning mats, light tarps, mosquito bed nets (called locally *Namosiah*), indoor insecticides, mosquito repellents or creams and finally the window and/or door wire screens as indicated by Abd Rabou *et al.* [30]. People of similar deteriorating environments in the Gaza Strip, such as Wadi Gaza and the wastewater lagoons in Khanyounis, were found to usually ask the responsible parties to find urgent control solutions for the escalating problem of mosquito proliferation [24, 30-32]. From this point of view, different means have been used for mosquito control in the vicinity of BLWWTP as were stated by the neighboring inhabitants and the official parties. These means included vegetation burning and/or removal, petrol derivatives, chemical pesticides and biocontrol using the Bacterium *Bacillus thuringiensis israelensis* (Bti) (Figure 6).

Table 4: Intestinal parasites prevailing in the Gaza Strip and the study area

Intestinal parasite	Taxon
Protozoal intestinal parasites	
<i>Entamoeba histolytica</i>	Amoeba
<i>Giardia lamblia</i>	Flagellates
<i>Cryptosporidium parvum</i>	Coccidia
Helminthic intestinal parasites	
<i>Ascaris lumbricoides</i>	Nematodes
<i>Enterobius vermicularis</i>	Nematodes
<i>Trichuris trichuria</i>	Nematodes
<i>Strongyloides stercoralis</i>	Nematodes
<i>Hymenolepis nana</i>	Cestodes
<i>Taenia saginata</i>	Cestodes
<i>Echinococcus granulosus</i>	Cestodes

The use Bti for mosquito larval control was applied in different localities of the Gaza Strip and recorded good results [30]. Although the other methods of control stated here were found to have negative environmental, ecological and health impacts, further scientific studies are needed in this regard to determine such harmful impacts in the study area and probably the other areas of the Gaza Strip.

Intestinal Parasitic Infections: Intestinal parasitic infections are widely distributed throughout the world and especially prominent in developing countries and rural communities. The low socioeconomic status and the poor standards of public and personal hygiene promote intestinal parasitic infections in such a geographic location. In the Gaza Strip, the prevailing water shortage and pollution, wastewater crisis and solid waste accumulation and mismanagement promote intestinal parasitic infections. Poor environmental and health awareness especially in the rural areas further complicates and increases the extent of the problem. Depending on a number of studies concerning intestinal parasitic infections in the Gaza Strip, the prevalence rate was found to range between 27.6% and 32.4% [33, 34]. At least, ten intestinal parasites (3 protozoans and 7 helminthes) have been stated by the primary health care officials and the local inhabitants to infect the Palestinians in the study area, with the *Entamoeba histolytica*, *Giardia lamblia* and *Ascaris lumbricoides* being the most common ones (Table 4). According to Sallon *et al.* [35, 36], *Cryptosporidium parvum* was found along with other pathogens to be associated with diarrhea among children in the Gaza Strip.

According to Al-Zain [19], the overall prevalence rate of intestinal parasites at the Bedouin Um-Unnasser Village, which surrounds the BLWWTP, was higher than other localities in the Gaza Strip and it accounted for 46.9%. This high prevalence rate could be attributed to many factors such as the presence of domestic animals (sheep, goats, cows, camels, dogs and cats) that may play as a possible reservoir for intestinal parasites and the contamination of the children's drinking water, home environment, objects and toys they play with. The blowing dust of the local sewage environment may contain parasite eggs, cysts and mature forms [19].

During many visits, the author noticed that children of the Bedouin Um-Unnasser Village and Beit Lahia playing with sands and/or agricultural soils that are often contaminated with wastewater and primary sludge which usually contain pathogenic microorganisms such as bacteria, protozoa, viruses and helminthes. It is well known that wastewater treatment processes do not remove or inactivate all pathogenic microorganisms. Many of the microorganisms are trapped in, or adsorbed to, particulates and are concentrated in the sludge, such as *Cryptosporidium* oocysts and *Giardia* cysts [37].

The importance of intestinal parasitic infections comes from the fact that pathogenic intestinal parasites have long been considered as an important health problem for their relationship with childhood malnutrition, iron-deficiency anemia, reduced physical fitness, cognitive performance and mental development [33, 38].

Emission of Offensive Odors: Offensive odors or foul smelling gases are usually produced from WWTPs and the other sewage pools in the Gaza Strip; such as that of Wadi Gaza [32, 39] due to the anaerobic bacterial decomposition of the organic content of sewage that generates hydrogen sulfide (H_2S) and other gases. These gases are not only a permanent nuisance to nearby living people, but also the cause for various threatening health and respiratory diseases.

H_2S is regarded as the dominant odor constituent in sewage air [40]. It is a colorless and extremely hazardous gas and people can smell the "rotten egg" odor of the gas at low concentration in air. H_2S is heavier than air and may travel along the ground and it is rapidly absorbed by the lungs [41]. As far as the health impacts of H_2S are concerned, the nearby people usually suffer from irritation of the eyes, nose, throat and the whole respiratory system. The problem becomes complicated with people suffering from asthma who may experience breathing difficulties. People of Al-Nada and Al-Awda towers who

are living east to the plant are the most vulnerable to the hazards of H_2S , because of their repeated and prolonged exposure to the air currents coming from the BLWWTP area. During meetings carried out with local people, the majority claimed that the foul smelling gases of the plant are standing behind many health problems prevailing among residents in the area. These include eye inflammation, headache, fatigue, insomnia, dizziness, nausea, vomiting, digestive disturbances, staggering and excitability [42].

Nitrate and Bacterial Pollution of Groundwater: Nitrate represents one of the major pollutants of groundwater resources in the Gaza Strip [43, 44]. Many studies pointed out that the majority of the tested agricultural and drinking wells in the Gaza Strip had nitrate concentrations far beyond the allowed values (50 mg/l) set by the World Health Organization (WHO) [8, 44-46]. As far as the BLWWTP is concerned, the concentration of nitrate from the adjacent wells ranges from 50 to 200 mg/l [14]. This could be attributed to the overloading state of the plant and the amoebic movement of the effluent lake that engulfs the sandy cover in North Gaza, thus polluting and damaging both the soil and groundwater.

Nitrate pollution of groundwater in the Gaza Strip is usually attributed to anthropogenic sources that include the leakage of wastewater from cesspools and septic tanks and the probable leaching of the pollutant from solid waste landfills and dumping sites. Furthermore, the extensive and intensive application of agrochemicals and organic fertilizers including the animal manure is considered as a vital source of pollution with nitrates.

The high levels of nitrate in groundwater pose a serious threat to the public health especially infants. Methemoglobinemia is the most immediate life-threatening effect of nitrate exposure. A high positive correlation was found between nitrate concentrations in groundwater and the occurrence of methemoglobinemia among babies in the Gaza Strip [47, 48]. Al-Absi [49] analyzed blood samples from children below 6 months of age who attending the pediatric hospitals in the Gaza Strip for methemoglobin concentration and he pointed out that about 75% of the infants were suffering from methemoglobinemia. Scientifically, the primary health hazard observed in infants exposed to drinking waters having high nitrate concentration comes from the fact that nitrate (NO_3) is transformed into nitrite (NO_2) in the digestive system. The nitrite oxidizes iron in the hemoglobin of the red blood corpuscles to form methemoglobin, which lacks the oxygen-carrying ability

of hemoglobin. This creates methemoglobinemia, where the infants' hemoglobin is less than normal, which has serious effects on their development. This condition is also referred to as "blue baby syndrome", due to the bluish appearance of babies' veins and skin that comes from the lack of oxygen [17].

Finally, most people of North Gaza work in the agricultural sector and many of those people were found to live in their farms thus, consuming wells water that are not far a way from the BLWWTP for both drinking and irrigation purposes. Sharif [11] pointed out that most wells located in the western and southwestern regions to the BLWWTP showed the highest values of contamination with the bacteriological parameters (heterotrophic plate count, Total Coliform, Fecal Coliform, Fecal Streptococci) and he attributed these findings to the fact that the natural flow of groundwater in the area goes from east to west. Besides, the results showed that the closer the wells to the BLWWTP, the higher is the level of bacteriological contamination.

Concluding Remarks: The current study depended largely on field and literature surveys concerning the environmental impacts of the BLWWTP, North Gaza Strip, Palestine. It is well known that the whole ecosystem of the BLWWTP plays a major role in attracting, supporting and harboring hundreds of vertebrate fauna species; particularly aquatic birds. This could be regarded as a positive value of the system. In contrast, this anthropogenic ecosystem constitutes an actual real threat to both the environment and people in the area due to the scope and magnitude of the consequent environmental health problems it produces. In the light of the present impacts pointed out in the study, special consideration should be paid by the principal authorities to improve the whole situation of the BLWWTP and its effluent lake. With the beginning of 2010, a positive consideration recorded in North Gaza concerning the BLWWTP was the total drying out of the effluent lake that covered more than 45 hectares and constituted a temporary bomb for the neighboring people as well as the responsible authorities. This was possible after the establishment of a new WWTP in the eastern part of the North Gaza Governorate. All effluent wastewater produced by the BLWWTP was piped to the new plant and hence, most of the problems encountered in the current study are diminishing in a gradual fashion. People inhabiting the Bedouin Um-Unnasser Village that lies close to the BLWWTP were very pleased with this event and they wish that a new era with a safe environmental

health fashion will begin after the eradication of the effluent lake and the probable removal of the BLWWTP in the next future. In conclusion, the role of universities and other scientific institutions in parallel with the governmental and non-governmental organizations should be strengthened towards investigating and improving the environmental health aspects of the targeted populations in the Gaza Strip.

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