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The Environmental Impacts of Wastewater Discharge on the Coastal Water Quality in The Gaza Nearshore Region

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الآثار البيئية لتصريف المياه العادمة على جودة المياه الساحلية في المنطقة الشاطئية لغزة

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Abstract :

Gaza City is considered one of the most densely populated cities in the world. Several sewage outfalls are discharging about 60,000 m3/ day of untreated and partially treated wastewater into the Gaza Nearshore region. Therefore, the contamination will cause potential pathogenic infections and diseases, and also will increase environmental threats and eutrophication on coastal water. On the other hand, coastal water pollution will pose a serious risk on seawater desalination plants. Therefore, this study aimed to investigate the effect of effluent discharges on coastal water quality concerning bathing water criteria and eutrophication level. In-Situ measurements were conducted in the nearshore zone. Seawater quality parameters were tested, including Total Suspended Sediments (TSS), Secchi Disk depth (SDD), Phosphorus (P), Fecal Coliforms (FC), and Chemical Oxygen Demand (COD). The finding showed that the quality of Gaza coastal water ranges between mesotrophic to highly eutrophic class. The water clarity was very low and the average SDD less than 4.15 m. The phosphorous concentration displayed spatial variation ranging from 0.18 mg/l and 3 mg/l. The COD varied between 32 mg/l and 288 mg/l. The measurements exhibited high levels of bacterial contaminants with a concentration of 252 cfu/100 ml. In summary, the results did not coincide with the coastal water quality criteria for bathing or fishing; even more, they will pose a potential health risk to beach visitors and cause a threat to the seawater desalination process in case of direct withdrawal from seawater.

Keywords: pollution, Wastewater, Gaza Coastal Zone.

الملخص

تعتبر مدينة غزة من أكثر المدن كثافة سكانية في العالم. تقوم العديد من مصبات الصرف الصحي بتصريف حوالي 000،60 متر مكعب / يوم من مياه الصرف الصحي غير المعالجة والمعالجة جزئيًا في منطقة غزة القريبة من الشاطئ. لذلك ، سيسبب هذا التلوث عدوى وأمراضًا محتملة ، كما سيزيد من التهديدات البيئية عمليات التخثث للمياه الساحلية. من ناحية أخرى ، سيشكل تلوث المياه الساحلية خطراً جسيماً على محطات تحلية مياه البحر. لذلك ، هدفت هذه الدراسة إلى معرفة تأثير تصريف النفايات السائلة على جودة المياه الساحلية فيما يتعلق بمعايير مياه الاستحمام ومستوى التخثث. أجريت قياسات في المياه الساحلية لمدينة غزة. تم اختبار معايير جودة مياه البحر ، بما في ذلك إجمالي الرواسب العالقة (TSS) ، وعمق قرص Secchi (SDD) ، والفوسفور (P) ، والقولون البرازي (FC) ، والطلب على الأكسجين الكيميائي (COD). وأظهرت النتائج أن نوعية المياه الساحلية في غزة تتراوح بين فئة متوسطة إلى عالية التخثث. وكان نقاء المياه منخفضًا جدًا وكان متوسط SDD أقل من 4.15 م. أظهر تركيز الفسفور تباينًا مكانيًا يتراوح بين 0.18 مجم / لتر و 3 مجم / لتر. تفاوت COD بين 32 مجم / لتر و 288 مجم / لتر. كما أظهرت مستويات عالية من الملوثات البكتيرية بتركيز 252 cfu / 100 ml. باختصار ، لم تتطابق النتائج مع معايير جودة المياه الساحلية للاستحمام أو صيد الأسماك ؛ والأكثر من ذلك ، أنها ستشكل خطراً صحياً محتملاً على زوار الشاطئ وتهدد عملية تحلية مياه البحر في حالة السحب المباشر من مياه البحر.

كلمات مفتاحية: التلوث ، المياه العادمة ، المنطقة الساحلية لغزة.

Introduction

Humans have exploited coasts and shorelines in constructing residential complexes, industrial zones, economic, and tourist facilities worldwide. The pace of these events increased dramatically after the modern industrial revolution, which posed a threat to the future of these regions. On the other hand, coastal areas are vulnerable to climatic changes and global warming consequences. Therefore, continuous monitoring of these areas, whether for seawater quality or geomorphological evolution, is essential for understanding pollution and change patterns. Moreover, to maintain the environmental integrity of these areas and the rapid intervention of governments to prevent things from deteriorating. Although the integrated Coastal Zone Management (ICZM) models were adopted by coastal countries, to some extent, to overcome resource exploitation by societies, these efforts have not succeeded in reversing environmental degradation. A significant reason for this is that the economic and social changes leading to this decline operate increasingly at temporal and spatial scales more extraordinary than the scope of management regimes established through ICZM (Mee, 2012; Dias et al., 2013; Petrişor et al., 2020; Theobald et al., 2020; Surya et al., 2020).

In particular, the Gaza Strip coastal zone has witnessed extensive urban expansion induced by population growth. As a result, seawater pollution has spread in recent years due to pumping untreated or partially treated wastewater into the sea. The unpleasant smell of the seawater, the turbidity, which covers a large part of the coastal waters and the surrounding wastewater outlets, are apparent evidence of seawater pollution. In addition, artificial human interventions have provoked geomorphological changes along the entire shoreline (Assaf, 2001; Ali, 2002; Zviely & Klein, 2003; Abualhin & Niemeyer, 2009, 2018; Abualhin, 2016)

In the case of the Gaza Strip, where the siege was imposed for 14 years and almost had no natural resources, the population density exerts enormous pressure on the resources and results in a sever environmental problem. Since the ICZM paradigm is not incorporated in the corresponding local authorities and municipalities, there is a need to upgrade the monitoring and follow-up systems to interact with the community needs. One of the new approaches that recently adopted to mitigate the drinking water crisis in the Gaza strip is to build up central seawater desalination plants, which require regular monitoring of seawater quality. Seawater quality and characteristics are essential for the optimal operation of the open intake system that feeds the plant (Frenkel & Gourgi, 1995; Ismail, 2003; Al-Agha & Mortaja, 2005; Mogheir et al., 2013; Peiris et al., 2017; Matar et al., 2021b).

Wastewater effluent characteristics and Standards in the Gaza governorate

The population for the Gaza governorate has increased from 644,823 in 2017 to about 713,488 in 2021(PCBS, 2021). As the population density increase, the wastewater effluents discharged into coastal water will increase. The Gaza governorate has the largest wastewater treatment plant (GWWTP) in the Gaza Strip. The GWWTP discharges more than 60,000 m^3/day of treated wastewater directly into the sea. Palestinian Authority restricts pumping treated wastewater into the sea or using agricultural irrigation unless it complies with Palestinian standards (Shomar et al., 1999; Kramer & Post, 2004; PWA, 2012b, 2013a; Bonoli et al., 2020). The efficiency of wastewater systems in Gaza's governorates varies in terms of the quantities of wastewater and the coverage of the infrastructure of wastewater systems as well as the final destination of the wastewater effluents Table1 shows Palestinian Standards of wastewater reuse in irrigation or for seawater outfall, where Table 2 shows the disparity in the quantity of wastewater influent in the Gaza strip governorates in 2012, where most of the wastewater effluents end up at sea. During wars, often frequent, or frequent power outages, large quantities of wastewater are pumped in poor quality or without treatment to the sea, ranging from 10,000 to 30,000 m^3 / day, as raw wastewater (Ashour et al., 2009; PWA, 2012a, 2013b; Vestner et al., 2013). In addition to the frequent emergency cases, the plant works under the maximum capacity, resulting in inadequate treatment of the wastewater and discharging effluent of poor quality into the sea.

Table 1: Palestinian Standards for Wastewater Reuse (Physico-chemical parameters) (PWA, 2012b, 2013a; Vestner et al., 2013)

Quality characteristics	**Effluent characteristics mg/l**	**Average Raw Influent** (Shomar et al., 1999)	**Types of Reuse**
Fecal Coliform	No detectable FC/100 ml [3]		All types of landscape irrigation and Seawater Outfall
Turbidity	2 (6 NTU)		
Biochemical Oxygen Demand BOD_5	60	470- 800	
Chemical Oxygen Demand COD	200	600 - 1300	
Dissolved Oxygen DO	> 1		
Total Suspended Sediments TSS	60	500 - 864	
Total Phosphorus TP	5	20	
Nitrate nitrogen NO3-N	25	70	
Phosphor P	0.1 to 30	Over 30	

Table 2: General features of wastewater production and collection in Gaza Strip in 2012 (PWA, 2012a)

Governorate	Population Capita	Sewage network (%)	Sewage discharge (m^3 /day)	Final Destination
Northern	290, 000	80%	23,000	100% Infiltration basins
Gaza	550, 000	90%	60,000	100% to the sea
Middle	220, 000	75%	10, 000	
Khan Younis	280, 000	40%	10,000	
Rafah	185, 000	75%	10,000	

Understanding changes in coastal water quality and defining the source of contamination is critical for managing the marine systems and developing. Therefore, many studies and governmental and non-governmental reports investigated the wastewater effluents discharged in the Gaza strip. For example, the United Nations Country Team, in their report about the occupied Palestinian territories, reported that about 90,000 m^3 – 108,000 $m^3$of raw or partly treated sewage is released daily into the sea creating public health hazards and problems for the fishing farms (Ashour et al., 2009; UNSCO, 2012; Efron et al., 2018). Around 33 million cubic meters of untreated or partially treated wastewater are dumped every year in the Mediterranean (UN, 2015). The seawater contamination due to dumping raw sewage into the coastal water of the Gaza Strip forced the Ministry of Health to frequently shut down the beaches and restrict bathing in the sea. Nahal et al., 2021 investigated the effect of wastewater discharge on seawater properties. Seawater temperature, electrical conductivity, dissolved oxygen, pH, and total dissolved salts were evaluated at a water column ranging from 0 to 5 meters (Nahhal et al., 2021). Zaqoot et al., 2012 demonstrated that the worst marine seawater pollution is linked to the central area of the Gaza strip, and pollutants discharged through sewage (such as BOD, Nitrogen, and Phosphorus) are considered the most significant pollutant threats to the coastal waters. About 40% of the wastewater generated in Gaza is discharged into the Mediterranean sea (Zaqoot et al., 2012). Pumping treated wastewater effluent into seawater is a standard procedure by most countries if it meets safety standards. However, most of the dumped effluent in the Gaza sea does not meet the Palestinian standards, Table l, where the BOD level is higher than 50 mg/l and the turbidity above 30 mg/l (90 NTU), and the contaminated with fecal coliform, which increases eutrophication and health risk and pathogens transmission.

Seawater quality criteria for bathing, fishing, and contact water sport

The impacts of wastewater effluents spewed into marine bodies and its risks on coastal zones pollution have given rise to concern by many international and regional authorities worldwide, such as the World Health Organization (WHO), the

European Union (EU), and the United Nations Environment Programme (UNEP). As a result, these organizations and associations have issued and adopted guidelines for the water quality criteria necessary to maintain the safety of beaches, protect seafood from contamination, and ensure a safe marine environment for swimming, bathing, fishing, sports, and recreational zones (EC, 1975; UNEP/WHO, 1985, 1996b; UNEP, 1985; EU, 2002, 2020; Ministry of Environment, 2002; WHO, 2003; EPA, 2012; PWA, 2012b).

In the Mediterranean Sea, the consequences of the growing development of coastal areas have resulted in moderate to severe pollution and deterioration of seawater quality due to increased wastewater effluent discharge. In these circumstances, the counties have adopted the protocol Protection of the Mediterranean Sea against Pollution from Land-based Sources (UNEP, 1980, 1985; UNEP/WHO, 1996a; Kamizoulis & Saliba, 2004; Kress et al., 2004). Several studies and reports have attributed the diseases associated with bathing in polluted marine areas. Ingestion of contaminated water by wastewater effluents while swimming or bathing poses potential pathogenic infections in the eyes, ear, skin, and upper respiratory (Cabelli, 1983; Fattal et al., 1983; Dufour, 1984; Shuval & Fattal, 2003; WHO, 2003; Osode & Okoh, 2009).

Oligotrophic features characterize the open water of the Mediterranean with low nutrient concentration and high water clarity. The direct discharge of domestic wastewater into the coastal shelf and urbanization and touristic activities lead to decreased coastal water quality and developed local mesotrophic-eutrophic conditions in the entire shore. The main reason for water eutrophication is the abundance of nutrients, mainly Phosphorous and Nitrogen, that encourage algae growth and energize phytoplanktonic production. Therefore, measuring seawater clarity is considered one of the most essential international and local seawater quality criteria (Carlson, 1977; Caine, 1995; Ministry of Environment, 2002; Kamizoulis & Saliba, 2004; EPA, 2004, 2006, 2012, 2018; Fuller & Minnerick, 2007; Pavluk & bij de Vaate, 2008; UNEP/MAP, 2015; LCWA, 2016; Richardson et al., 2019; Tugrul et al., 2019; Chen, 2021).

As for microbiological pollutants, the United Nations Environment Programme (UNEP), in their report in 1997, adopted new criteria and standards for coastal bathing water of the Mediterranean Sea. The concentration of Faecal coliforms per 100 ml must not exceed 100 in 80% of the samples (UNEP, 1996). Table 4 shows reference values for Fecal coliform pollutants in the Mediterranean coastal areas. Thus, Fecal coliform (FC) was adopted as a pathogenic microbiological indicator for seawater quality in this study.

The potential damage from anthropogenic activities and wastewater discharge in aquatic bodies increases water column turbidity and hinders the light penetration into deeper layers, consequently impacting the photosynthesis process. However, all the natural water bodies contain a suspended matter component consisting of organic and inorganic material expressed as the Total Suspended Solids (TSS) and measured in mg/l. The TSS is one of the water quality indicators adopted by international seawater quality criteria. Therefore, TSS concentration due to wastewater discharge into the fisheries and aquatic life must not exceed a range of 10-25 mg/l or not raise the TSS concentration more than 10 % above the natural average level (Chapman & Jackson, 1996; Ministry of Environment, 2002).

Direct discharge of untreated domestic effluents into the marine ecosystem is a primary source of marine eutrophication. Most nutrient inputs in coastal water, including a significant amount of Phosphorous (P) and Nitrogen (N), are linked to wastewater discharge. Organic and inorganic fertilizer runoffs form a substantial source of phosphorus in water bodies. Soft drinks industrial and laundry detergents are expected to increase total phosphorus concentration in the raw effluent by about 6 mg/l (EPA, 1986; Litke, 1999). Serious environmental and health risks could emerge because of high phosphorus concentration, hindering sunlight penetration, reducing dissolved oxygen in the water, and increasing eutrophication. The domestic waste associated with heavy population density and low treatment efficiency contributes to raising the phosphorus load in the water bodies in coastal cities worldwide. The phosphorus (P) concentration was measured for water depth ranges for the surface layer to the depth of 2-3 meters below the seawater surface. The surface concentration of phosphorous displayed spatial variation ranges from 0.18 mg/l deeper water of nearshore zone and 3 mg/l in seawater receiving urban wastewater discharges, with an average concentration in the study area of 1.64 mg/l, Figure 6. The studied area exhibited high levels of phosphorous that exceeded the recommended seawater quality limit by EPA for marine and estuarine waters, P less than 0.1 mg/l (EPA, 1986). The phosphorus limit set by the Mediterranean Action Plan (MAP) for effluent discharge in coastal water is 1 mg/l (Ministry of Environment, 2002).

Therefore, the study aims to assess coastal water quality parameters in the coastal zone of the Gaza City and compare them with international standards. Also, the study intends to generate maps to monitor pollution impacts and spot the distribution of pollution in coastal waters, which reflects the risks of dumping effluents into the sea. Furthermore, addressing these issues will enable the decision-maker to anticipate better the solutions for problems that threaten the coastal environment and interact either by regulations or interventions.

Materials and Methods

Study Area

The study area includes the Gaza fishing port coastal area, map center 31.5 N and 31.43 E, extending 7 km along the shoreline and about 3 km seaward. Figure 1 shows the study area, including the sampling locations and the wastewater outfalls. The study area is distinguished by heavy population density and extensive economic, tourism, and anthropogenic exploitation. As a result, this area is interspersed with many wastewater outfalls, about five outlets, including medical effluents. The coastal water of the Gaza city receives wastewater effluents from 5 outfalls, and two of them are major outfalls serving around 650,000 inhibitors, as illustrated in Figure 1. The map shows the location of five wastewater effluent outlets that continuously discharge 100 % of about 60,000 m^3/day effluent into seawater, which causes a contamination plume along the shoreline of the Gaza City. Some outlets are from Al-Shati camp and others from Elshaikh Ejlieen wastewater treatment plant, which disposes of stormwater and sewage, while some outlets belong to a fishing farm. Therefore, the effluent characteristics vary from raw to poor quality. Based on the varying volume and quality of effluent coming from each sewage outfall, the seawater quality of the Gaza Sea varies temporally and spatially. According to government reports and searches, the BOD_5 ranges from 470 to 800 mg/l; COD varies between 600 -1300 mg/l, and TSS about 400- 865 (Shomar et al., 1999; Assaf, 2001; PWA, 2012b, 2013b; Zaqoot et al., 2012; Vestner et al., 2013; Abualtayef et al., 2017; Efron et al., 2018; Matar et al., 2021a; Nahhal et al., 2021). International and local standards set limits of some seawater quality criteria. If they are exceeded, the coastal water must be closed, and its entry is restricted, such as increasing BOD of 3 mg/l and increasing Fecal Coliform of 100/100 ml. Furthermore, the proper coastal outfall has to be installed to achieve the individual pollutant concentration level in seawater below their toxicity limits within a distance of 50 m from the discharge point, which is not the case in the Gaza city where the effluent is discharged directly on beach sand or at the shoreline, Figure 1.

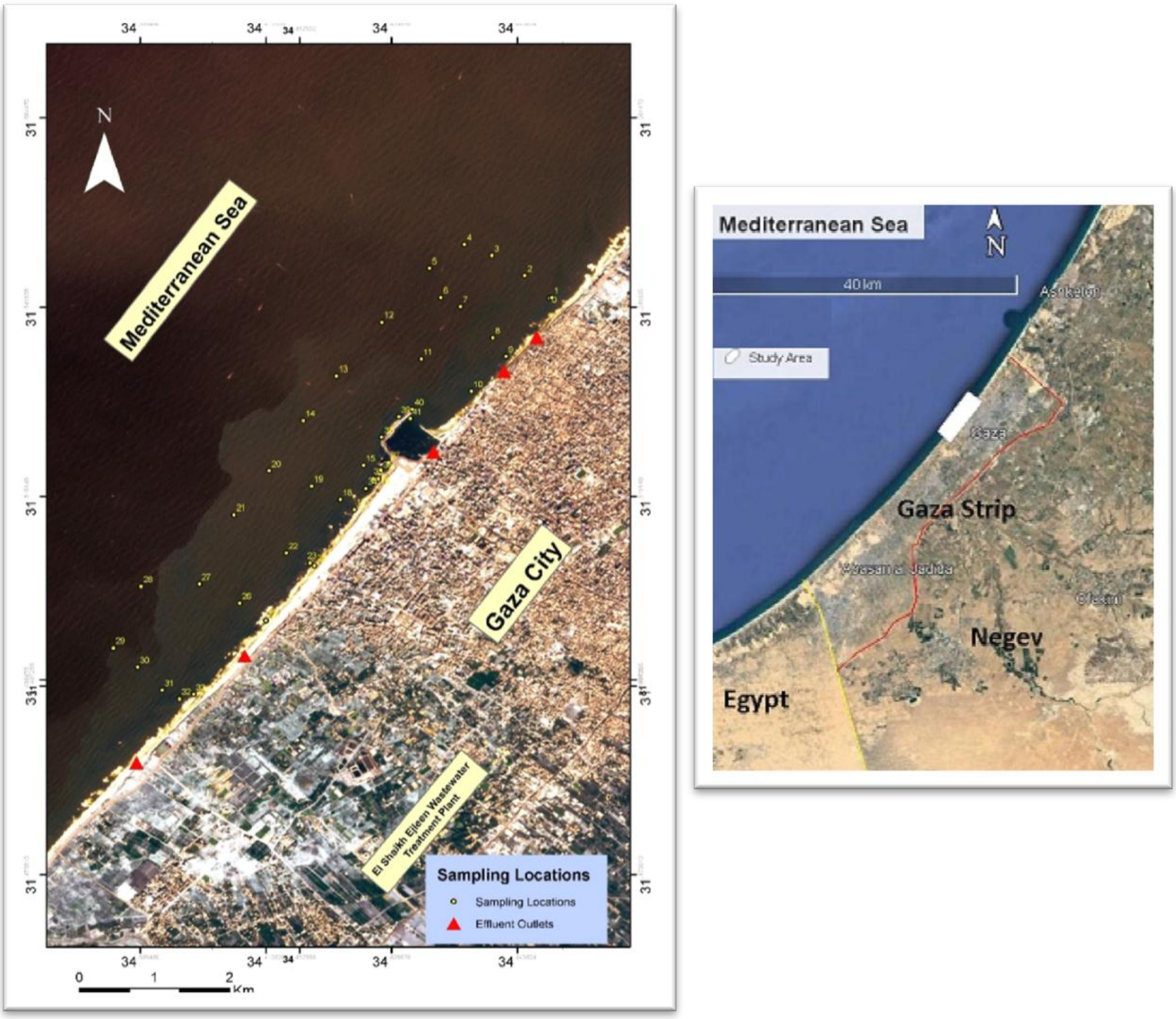

Fig (1): Study area: Sampling location map and wastewater effluent outlets

Sampling and laboratory analysis

The methodology process includes activities, in situ measurements, and laboratory analysis. In situ measurements involves surface and subsurface seawater samples that were collected from 41 locations distributed along and across the coastal area of Gaza City. The samples that were collected offshore in transects with longshore intervals of about 800 – 900 m. During the in situ measurement, coordinates of each sampling point were gathered using Garmin GPS and projected on a map, including four wastewater outlets in the entire study area. The turbidity at each site was measured using a Secchi depth method (Secchi disk black and white, 20 cm diameter). Simultaneously, seafloor depths were calculated, where the deepest measurement was at 25 m below the surface, and the shallowest was 0.54 m. Subsurface samples were collected at three depths; at the sea surface, 2 m, and 3 m below the surface using a 1000 ml bottle for physio-chemical analysis. In addition, sterilized bottles were used to collect samples for microbiological analysis.

In situ measurements of Secchi Disk Depth (SDD)

The Secchi depth method (SDD) has been adopted as an easy measuring method widely utilized for aquatic environment clarity and to evaluate the ecosystems. The Secchi disk procedure considers the depth of disappearance to measure the water clarity. Therefore, the primary function of a Secchi disk is to provide a simple visual index of water clarity (Preisendorfer, 1986). Also, it can be used in quantifying light attenuation through varying water depths dictated by water molecules, phytoplankton productivity, and dissolved matter distribution. Moreover, Secchi depth has been found as a reliable indicator of the trophic state of a waterbody provided that the amounts of inorganic turbidity (Megard & Berman, 1989; Buiteveld, 1995; Luhtala & Tolvanen, 2013). In the current study, Secchi depth was measured with a 20 cm diameter black and white quadrate disk from 40 stations to determine seawater transparency and delineate seawater turbidity. The measurements were taken at relatively calm water. (Chapman et al., 1996).

At the laboratory, the samples were tested for Fecal Coliforms (FC), Chemical Oxygen Demand (COD), Total Suspended Sediments (TSS), and Total Phosphorus (TP).

Fecal Coliform (FC)

Fecal coliform concentrations were measured using the technique recommended in Standard Methods (Miescier et al., 1978). The Samples passed through the Gellman Millipore filter under negative pressure. The plates used to isolate fecal coliform were incubated at 44^{o}C for 24 to 48 hours. The colonies that appeared on the membrane surface were counted and identified by the Gram stain, biochemical tests, and specific antisera. All the concentrations reported are in cfu per 100ml.

Chemical Oxygen Demand (COD)

A composite sample was formed by taking 10 ml from every sample using a pipette. A sample volume of 2.5 ml was transferred to the culture (digestion tube). A 0.2 mercuric sulfate was added to inhibit the Cl interferences in seawater in addition to a 1.5 ml digestion solution. After that, 3.5 ml of sulfuric acid reagent was poured inside the tube, so an acid layer formed under the sample. For two hours, the sample tubes were wholly mixed and placed in a block digester (COD incubator) at 150 C. After cooling the tube to room temperature, about 0.05 - 0.1 ml of Ferroin indicator was added titration was conducted. The concentrations of COD in mg/l were calculated using the dichromate reflux standard method (Allan Moore et al., 2002)

Phosphorus Analysis

Measurement of Phosphorus was done using a special spectrometer kit (HI96706C). The method is an adaptation from the Standard Method for the Examination of Water and Wastewater. The phosphorus results can be reported as "P" or "PO_4" in mg/l. The PO_4 molecule is three times as heavy as the P atom; thus, the results reported as PO4 are three times the concentration of those reported as P, and to convert PO4 to P the result must divide by 3 (Federation & APH Association, 1999).

Total Suspended Solids Analysis

Total Suspended sediments (TSS) were estimated using the total evaporation methods, where the TSS was calculated from the difference between total solids (TS) and total dissolved solids (TDS) (EPA, 2001)

Results and discussion

Secchi disk depth (SDD) and Seawater clarity

The SDD measurements range between 0.54 m and 8 m, with an average value of about 4.88 m for the entire coastal area. The values show the SDD consistency of seawater turbidity and polluted seawater due to effluent discharge, where the lowest SDD values are attributed to the most contaminated area, Figure 2.

The HELCOM Eutrophication Assessment Tool (HEAT) classified the Eastern Mediterranean water quality according to Secchi depth ranges (in meter) and other related parameters into four groups: Highly Eutrophic seawater if SDD ≤ 5 m, Eutrophic SDD ranges 6-7 m, Mesotrophic SDD ranges 8-10 m and Oligotrophic if SDD ranges from 11-13 m, where the reference value for a high quality of seawater is SDD ≥ 14 m (HELCOM, 2009; Pawlak et al., 2009; Andersen et al., 2011; Tugrul et al., 2019). The HEAT method has been significantly used in coastal water receiving large quantities of wastewater discharges.

However, the SDD as an indicator for water clarity and the eutrophic-related parameter was measured in the study area. The SDD values range from 0.2 – 8 m in the entire shallow zone, where water depth ranges from 0- 25 m. The sewage outlets regions show SDD values below 0.5 m, indicating a high nutrient and turbidity. Nutrients, mainly Nitrogen and Phosphorus, can come from point sources such as wastewater effluents (EPA, 2004; Preston, 2013; Ngatia et al., 2019). Therefore, discharging wastewater, raw or partially treated, has negatively influenced the coastal water quality and significantly increased the eutrophication process in the Gaza coastal zone. According to the HEAT classification of eutrophication, the SDD values in the Gaza coastal water can be classified as a High eutrophic zone, which means a bad water quality with a high level of nutrient and turbidity. Besides that, light penetration into seawater should not be decreased by more than 10 % above the natural seasonal average (Ministry of Environment, 2002). The finding shows that the light penetration decreased by an average value of 30% in the water depth range between 15-25 m and decreased by 48 % in coastal water directly influenced by wastewater effluents in the coastal water of Gaza city, Table 3. These conditions can endanger marine lives and form a health risk to human lives. In addition, the growth of green algae along the coastline is a piece of evidence that the coastal zone is subjected to eutrophication (UNEP, 2009). Figure 3 illustrates the SDD distributions, showing an inferior water quality, the SDD less than 3 m, extending along the shoreline and surrounding sewage outlets.

Table 3: Penetration of light into seawater measured by SDD

Botton Depth (m)	The SDD Value (m)	Light Penetration Percentage (%)
4	1.95	48 %
15	4	26.7 %
20	6.35	31.75 %
25	7.7	48 %

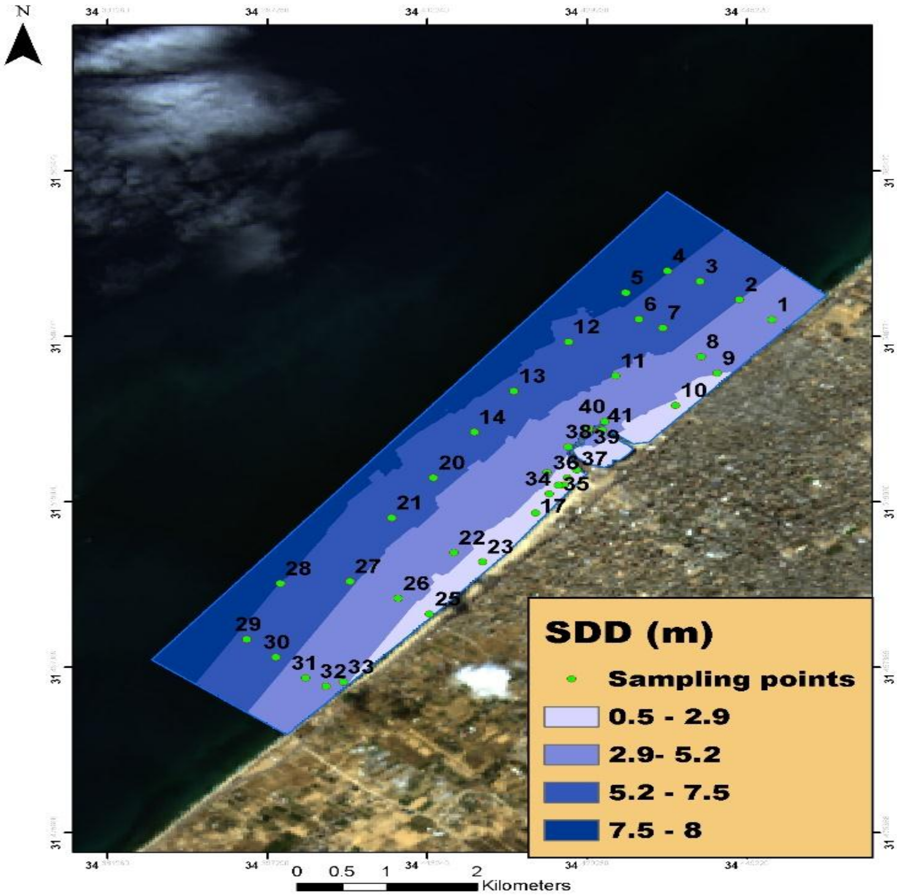

Fig (2): Seawater clarity distribution measured by Secchi Disk Depth (SDD). The map shows the deterioration of water quality along the region where wastewater is discharged, SDD ≤ 3 m.

Fecal coliforms (FC)

Assessment of microbiological pollution in seawater is one of the essential criteria in assessing the quality of seawater, as the increased pumping of wastewater into seawater, especially untreated and industrial water, results in a deterioration in water quality and a defect in the concentration of pathogenic bacteria and affects human health and marine life. Furthermore, pathogenic microorganisms are known to be found in coastal waters and among local populations in high populated Mediterranean coasts (UNEP, 1996).

The Gaza Strip coastal zone has been subjected, almost daily, to large amounts of untreated wastewater, which poses a real threat to the health of vacationers, the marine environment, and the operation of seawater desalination plants. Typical municipal raw sewage can contain 10 to 100 million coliform bacteria per 100 ml (Chapman et al., 1996). The UNEP environmental assessment report of the Gaza Strip, conducted after the escalation in 2008, analyzed eight seawater sites, revealing very high concentrations of bacteriological contamination (UNEP, 2009). Therefore, the Fecal coliform as a microbiological contamination indicator has been tested for 40 sites of the Gaza seawater. The results showed that the average concentration of fecal bacteria in the seawater is about 70 cfu/100 ml, and the maximum value was 252 cfu/100 ml.

The maximum concentration of fecal coliform, 252 cfu per 100 ml, was found in water samples collected from the surrounding sewage outlet of Al-Shati Camp, where the lower values of fecal coliform were recorded at points offshore and located far enough from sewage outlets, Figure 3. Based on fecal coliforms concentration, the coastal water can be classified into two ranges; fecal coliforms less than100 cfu/100 ml which is an acceptable limit for fecal bacteria in bathing water, and fecal coliforms greater than 100 cfu/100 ml which beyond the allowable limit of microbiological contamination of coastal water and swimming in these waters poses a threat to human health. Figure 3 shows the fecal coliforms pollution plumes resulting from Al-Shati wastewater effluent outlets which drift northwards with longitudinal currents. Measuring the concentration of fecal coliforms revealed that the coastal water of Gaza city is heavily contaminated by microbiological pollutants, which pose a threat to human health, especially fisheries and children, due to wastewater discharge on the shallow coastal water and directly at the shoreline.

Table 4: Microbiological quality criteria and standards for bathing waters in EU Mediterranean countries (Fecal coliform)

Guideline Standard	The concentration of Fecal coliforms per 100 ml Not to be exceeded
EC 1976	100
UNEP/WHO 1985 UNEP 1985,	100 in 50% of the samples
UNEP 1997	100 in 80% of the samples
UNEP/MAP, 2008	100 in 80% of the samples
U.S. EPA 2012a	200

(EC, 1975; UNEP/WHO, 1985, 1996b; UNEP, 1985, 1996; UNEP/MAP-MED & POL/WHO, 2008)

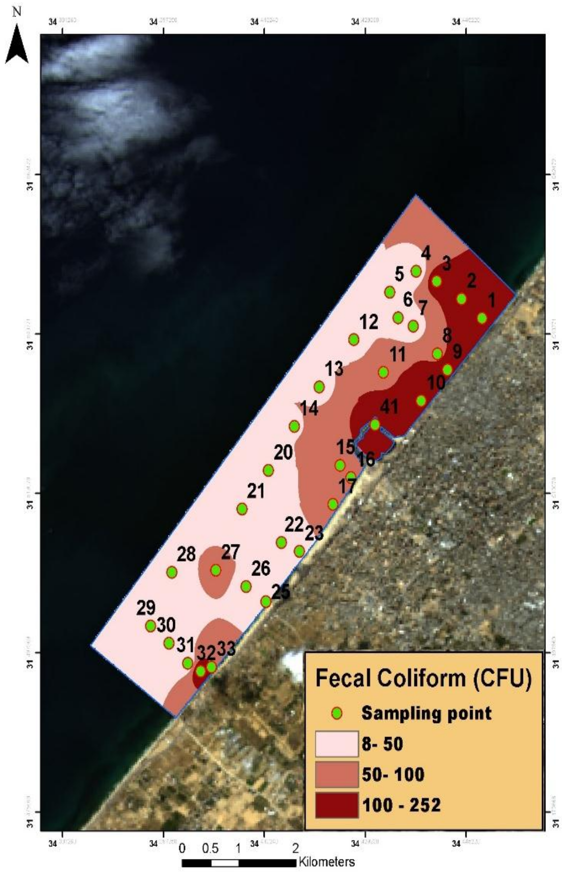

Fig (3): Concentration of Fecal coliforms distribution in the Gaza coastal water

Chemical Oxygen Demand (COD)

The chemical oxygen demand COD is the amount of oxygen required to oxidize organic matter in the wastewater chemically and expressed in milligram oxygen per liter (Hauser, 1996). The COD measures water and wastewater quality to monitor water treatment plant efficiency, and it is a parameter for the characterization of polluted waters. The Palestinian standard threshold amount of direct wastewater discharge into the sea is 200 mg/l (EMCC, 2014). However, the tests showed that COD concentrations ranged between 32 mg/l - 288 mg/l. A higher concentration of the COD was found in the southern part of the fishing port and surrounding the major wastewater outfall that comes from the Al-Sheikh Ejleen treatment plant, Figure 4. The distribution of high concentrations of COD in the coastal area and the beach starts from the wastewater outfall and extends northward and westward due to the drift by longshore and offshore currents. The results demonstrated the polluted seawater by high COD level and provided an idea about the risky bathing or fishing regions on the shore.

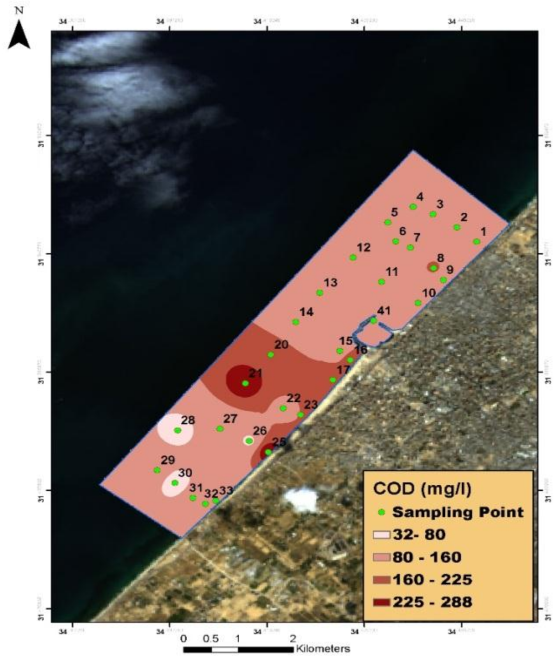

Fig (4): The concentration of the COD along the study area. The figure shows the high polluted seawater by the high level of COD

Total Suspended Solids (TSS)

The TSS samples were collected from the top seawater surface layer within the first 50 cm of water surface. The results showed that the TSS concentration ranges between 0.45 and 90.5 mg/l. The highest concentration was found mainly close to the shoreline and directly opposite the wastewater outfall from Al-Shati camp, about 900 meters to the west at point 11 on the map, Figure 5. This effluent is mainly untreated wastewater with a high level of suspended sediments. Therefore, the suspended sediments in the water column were drifting seaward influenced by the fishing port breakwater. However, the TSS distribution in the Gaza city's coastal water is probably influenced by sewage flux discharging from outfalls along the study area. Moreover, the current direction from Southwest toward Northeast and verse verses during the day play an essential role in the dilution and the distribution processes of the TSS.

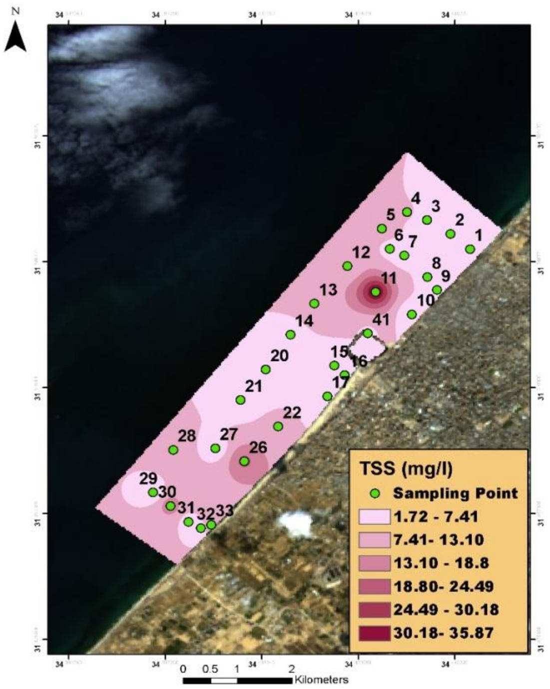

Fig (5): The TSS concentration along the study area

The Phosphorus (P)

The largest site with high phosphorus concentrations is attributed to the fish farms and sewage outfalls. As shown in figure 6, the high phosphorus concentrations were noticeably located in the densely populated residential area, Al-Shati camp, where much-untreated sewage was disposed directly into the sea. In addition, it was evident that the Gaza fishing port basin had high phosphorus levels as a semi-enclosed area lagoon with a high eutrophication level.

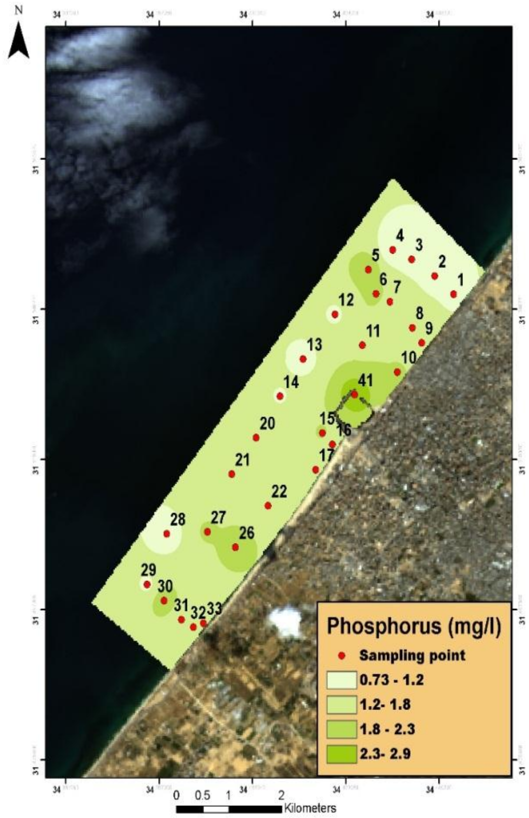

Fig (6): Average P distribution along the study area

Table 6 demonstrated the descriptive statistical information of the water quality criteria that were measured for the samples in the study area, which show that most of the parameters are higher than the limits for coastal waters quality indicating high levels of pollutants result of continuous pumping of untreated or partially treated wastewater along the coast. All concentrations of quality criteria (

COD, P, Fecal Coliforms, TSS, and Water clarity (SDD)) exceed coastal water local and Mediterranean quality standards. Accordingly, coastal waters in the Gaza Strip are classified as poor quality waters ranging between Eutrophic and Mesothpohic states.

Table 6 Summarize the descriptive statistics of seawater quality criteria for all samples

	Seawater Quality Criteria					
	COD (mg/l)	*P (mg/l)*	*Turbidty (NTU)*	*FecalColiform (cfu/100 ml)*	*TSS (mg/l)*	*SDD (m)*
Mean	129.85	1.64	0.62	106.36	8.07	4.15
Minimum	32.00	0.03	0.20	4.50	0.35	0
Maximum	288.00	3.30	1.60	386.00	88.95	8
St. Deviation	53.04	0.56	0.34	95.95	12.56	2.49

Conclusion

According to the findings, disposing of untreated or semi-treated wastewater into the coastal water of Gaza city has clearly led to a deterioration in the quality of the coastal seawater. The in-situ measurements of different seawater quality parameters showed that the coastal zone is characterized by a low seawater quality. The eutrophication parameters indicate that the nearshore zone of the Gaza City falls into the mesotrophic to the eutrophic category. Thus, seawater has a moderate to high level of biological productivity. This environment is considered pathogenic and poses a risk to the health of bathers and marine organisms. Moreover, using GIS tools to generate pollutant distribution maps has helped to clarify the spatial distribution and prevalence of these pollutants in coastal water.

In conclusion, monitoring the quality of seawater is necessary to preserve the environment ecosystem and limit pathogenic infection and human health risks. Moreover, as the Gaza Strip depends on seawater desalination for drinking purposes, seawater quality monitoring is an essential routine in seawater desalination procedures. Furthermore, by completing the final stages of the Central Desalination Plant, open intake for feeding the plant will be the only source for desalination. Therefore, regular monitoring of seawater quality will help rapid response in emergence cases and lock down the plant to avoid exposing the desalination systems to polluted seawater and ensure optimal performance.

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