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Microbial water quality of coastal recreational water in the Gaza Strip, Palestine

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Abstract. *Abualtayef MT, Abd Rabou AN, Abu Foul AA, Ghabayen SM, Elsinwar HM. 2014. Microbial water quality of coastal recreational water in the Gaza Strip, Palestine. Nusantara Bioscience 6: 26-32.* Wastewater disposal into the Mediterranean coast of the Gaza Strip has many negative effects, whether on the environment or on human health, thus microbiological analysis of seawater samples was carried out. The microbial analysis was confined on two types of fecal indicators (fecal coliform and fecal streptococci), in addition to a single type of bacteria (pseudomonas). This study was conducted between the beginning of July 2012 to the mid of October 2012 over an area extended from the proposed Khan Younis fishing port to Gaza fishing port, with a length of about 23 km. The study area was divided into five zones. The samples were collected in two rounds: the first round included 75 samples that collected along the study area during the summer season. The second round included 19 samples that collected in the autumn season to compare it with their counterparts that have been collected in the summer season. Laboratory analysis showed the presence of contamination in many of these samples. The results also showed that the pollution was concentrated in and surrounding the mouths of wastewater outfalls. Depending on the microbial analyses, which have been collected in the first round, the fecal coliform appeared in 61% of the samples, while fecal streptococci appeared in all samples and pseudomonas appeared in 33% of the samples. The pollutants were widespread along the study area, which are the result mainly from wastewater discharge into the sea. A risk analysis was done for season variations using the second moment method; in general, it was found that risk in both seasons was high especially in summer.

Key words: Gaza Strip, microbial analysis, recreational seawater

INTRODUCTION

Recreational use of water and beaches is an important feature of leisure and tourism worldwide. Recreational seawaters generally contain a mixture of pathogenic and nonpathogenic microbes derived from wastewater effluent; industrial process; farming activities and wildlife in addition to any truly indigenous microorganisms. This mixture can present a hazard to the bathers where an infective dose of the pathogen colonizes a suitable growth site in the body and leads to a disease (WHO 1998).

Only about 40% of the sewage generated in the Gaza Strip is properly treated. The percentage of population served by sewerage systems is 78.9% (WASH 2011), leaving nearly half a million people unconnected to the network and dependent on alternative means for excreta disposal. Most of the wastewater treatment plants (WWTPs) in Gaza are overloaded and are working beyond their designed capacities (Abd Rabou 2011). According to an ongoing study for the de-pollution of the Mediterranean Sea findings, about 110,000 m^3 per day of untreated or partially treated wastewater, mostly coming from these WWTPs and Wadi Gaza, is discharged into the Mediterranean Sea. The untreated wastewater contains many pathogens such as bacteria, viruses, and harmful parasites. These objects may find suitable environment when they reach water bodies to multiply and spread (Castro and Huber 2007). The present disposal practices in the Gaza Strip are likely to have an adverse effect on the quality of seawater, marine biota and public health (MoEA 2001; Abd Rabou et al. 2007; Abd Rabou 2013). Microbiologically contaminated seawater, beach sand and fishes were found along the Gaza Strip coast (Afifi et al. 2000; Abed Rabou 2003; Elmanaema 2004; Elmanaema et al. 2004; Aljubb 2012; Al-Safadi 2013), and there is an evidence of sanitation-related infections in the Gaza Strip (Abu Mourad 2004; Astal 2004; El-Kichaoi et al. 2004). According to Hilles (2012) and Hilles et al. (2013), it was found that 48.1% of the seawater samples were parasitically contaminated with six species of human gastrointestinal parasites that have been discovered and determined in seawater samples in most of the study area. The species were; *Entamoeba histolytica*, *Ascaris lumbricoides, Giardia lamblia, Strongyloides stercoralis, Hymenolepis nana* and *Cryptosporidium parvum.* These parasitic species and many others are common in the Gaza Strip environment which is deteriorating day by day (Abd Rabou 2011).

The population of the Gaza Strip continues to grow rapidly, thus increasing the amounts of poorly treated or untreated sewage being discharged into the coastal water. With a Palestinian population growth rate of around 3.5

percent per annum that would result in a doubling of the population in 15 years. Effective management and sustainable development of Gaza resources will be a huge challenge to the Palestinian Authority (UNEP 2003).

The aim of this study is to estimate the microbial pollution (fecal coliform and fecal streptococci and pseudomonas) of recreational seawater of the Mediterranean coast of Gaza, to determine the coastal area that suitable for recreation and to raise awareness of local people towards contaminated coasts.

MATERIALS AND METHODS

The Gaza Strip is a narrow piece of land lying on the eastern coast of the Mediterranean Sea. Its position on the cross road from Africa to Asia made it a target for occupied and conquerors over the centuries. The Gaza Strip is very crowed place with an area of 360 km^2. The coastal area along the eastern Mediterranean Sea is about 42 km long, and about 6 to 12 km wide, bordered by Egypt from the south.

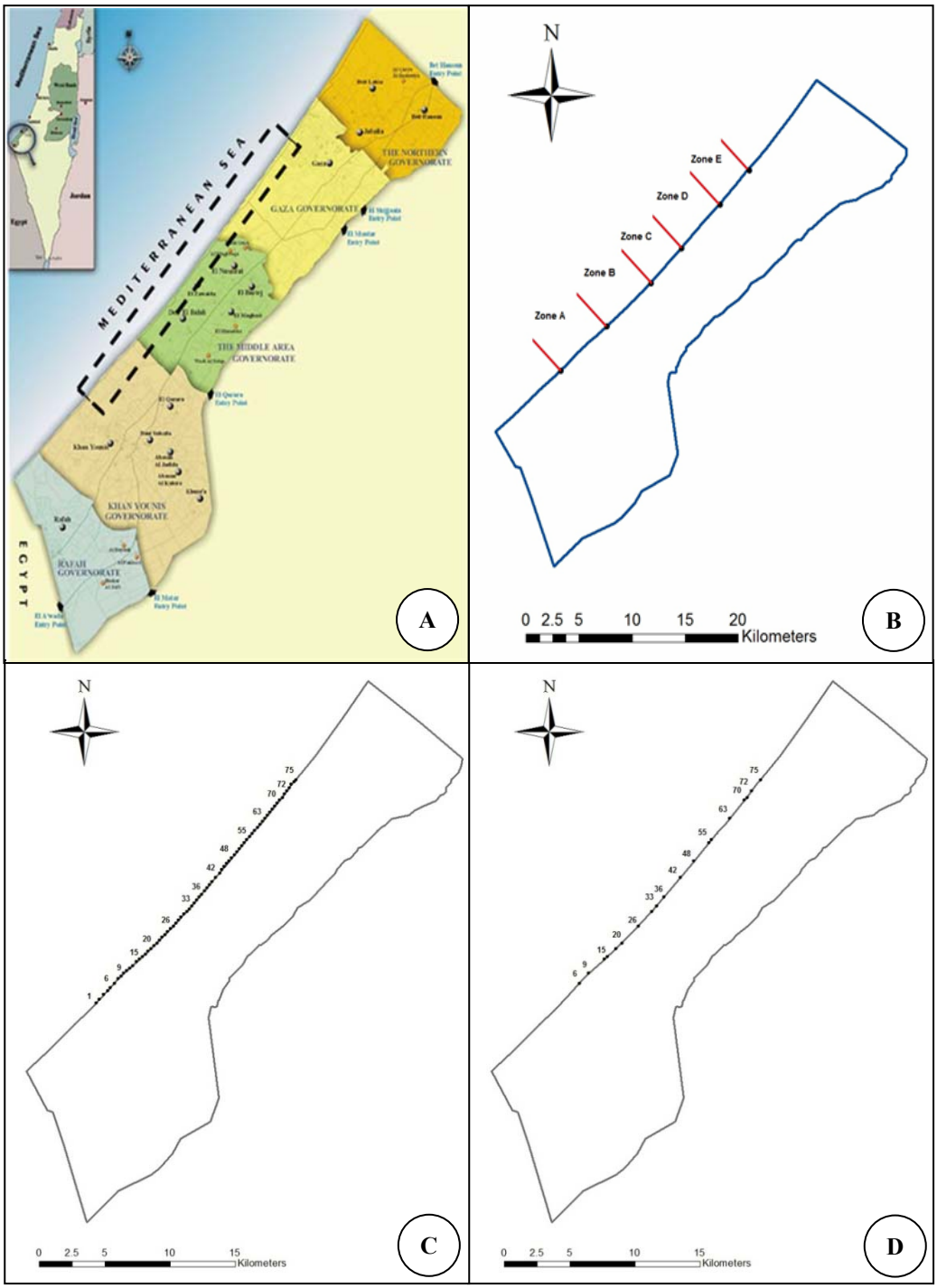

Figure 1. A. The study area location map. B. The zones of the study area along Gaza coast, C. Sample locations during summer season and D. Sample locations during autumn season**.**

The study area expanded from the Khan Younis fishing area to Gaza fishing port (Figure 1.A), which is about 23 km. The study area covers most busy beaches along the Gaza Strip and serves 1,120,000 inhabitants. Samples of seawater were collected from different locations, starting from February 2012 to December 2012. The study area was divided into five main zones as follows: (i) Zone A extends from the proposed Khan Younis fishing port to Asdaa sewage outfall. (ii) Zone B extends from Asdaa sewage outfall to Deir Al Balah sewage outfall. (ii) Zone C extends from Deir Al Balah sewage outfall to Wadi Gaza. (iii) Zone D extends from Wadi Gaza to El Shiekh Ejleen sewage outfall. (iv) Zone E extends from El Shiekh Ejleen sewage outfall to Gaza fishing port (Figure 1.B).

A total of 94 seawater samples was collected within several sampling trips from the different locations. The samples were collected on two rounds; the first round included 75 samples collected every 300 m in summer season along the study area, and the second round included 19 samples collected in autumn and cover the study area as illustrated in Figure 1.C and 1.D.

Seawater samples were collected in sterile (600 mL) glass bottles according to the American Public Health Association (APHA) standard methods (APHA 1995) at approximately 15 cm below the sea surface at a point where the depth of the water is approximately 0.5 meters (based on McBride et al. 1998). The seawater sample bottles were labeled directly after the collection process, and kept at less than 10^{o}C using an ice box, and were transferred in the laboratory and processed within 24 hours of collection.

Concentrations of microbial pollutant analyzed in seawater samples by Membrane Filter Technique. All the concentrations reported are in CFU. The procedure in microbiological analysis was recommended by the APHA Standard Methods (APHA 1995). The membrane technique was used in the determination of bacteria in seawater samples.

Samples passed through Gellman Millipore filter under negative pressure (vacuum). Volume of samples ranges from 100 mL to 1000 mL according to the organisms needed for isolation. These membranes were transferred by a forceps in the media and placed on the surface of the media and passed carefully to avoid any air bubbles. The plates used for isolation of fecal coliform, fecal streptococci and pseudomonas were incubated at 37^{o}C for 24 to 48 hours, while the plates used for isolation of fecal coliform were incubated at 44^{o}C for 24 to 48 hours. The colonies appeared on the surface of the membrane were counted and identified by the Gram stain, Biochemical tests and specific antisera.

RESULTS AND DISCUSSION

Fecal contamination of coastal marine habitat is a global problem manifesting, as increased beach closures, water contact-associated illness and shellfish harvest restrictions (Knap et al. 2002; Kumar et al. 1984). In some countries, identifying waters that are not fecally-impaired has become a challenge (McLaughlin et al. 2005). Once bacteria, viruses and protozoa enter the ocean, invertebrates can efficiently concentrate these potential pathogens through filter-feeding activity (Miller et al. 2008).

Sewage disposal in natural waters is a common practice among many nations (Rajagopalan 2005). Large inputs of organic matter, pathogens and nutrients from raw sewage to a weak hydrodynamic environment poses environmental and health problems of deterioration of water quality (Al Dahmi 2009). Inadequate or faulty sewerage and/or sewage treatment system are major causes of pollution in natural waters (Cimino et al. 2002). The exponential growth in urbanization through migration of people from rural and semi-urban areas to cities in search of livelihood, has contributed to the deploring sewerage situations in most major cities of the world notably in developing countries (Longe and Ogundipe 2010).

Microbial contamination along the Mediterranean Coast of Gaza

Based on an ongoing study for the de-pollution of the Mediterranean Sea findings, 110,000 m^3/day is discharged along the coastal line of the Gaza Strip from multiple points. The main outfalls along the Gaza coast are Rafah outfall which disposes about 11,300 m^3/day, Asdaa outfall in Khanyounis city which disposes raw sewage directly to the sea of about 12,000 m^3/day, Deir Al-Balah outfall and Wadi Gaza, which both dispose raw sewage to the sea with a rate of 11,700 m^3/day, El-Shiekh Ejleen outfall which disposes partially treated wastewater to the sea with a rate of 75,000 m^3/day and Al-Shalihat outfall.

Eutrophication is a process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae and nuisance plants weeds). This enhanced plant growth, often called an algal bloom, reduces dissolved oxygen in the water when dead plant material decomposes and can cause other organisms to die (Abd Rabou 2013). Nutrients can come from many sources, such as fertilizers applied to agricultural fields, erosion of soil containing nutrients, and WWTP discharges. During sample collection, it was observed the presence of the eutrophication in various areas of the beach, which can be traced to the large quantities of wastewater which discharged directly into the sea. This phenomenon is known to be harmful to the marine environment and its biota in the Gaza Strip (Abd Rabou et al. 2007).

It is noted that the highest concentrations were found in the summer season in the north of the sewage outfalls higher than the concentrations in the south of the outfalls, this is due to the direction of the currents from the south to the north direction.

Fecal coliform (FC)

The results showed that the bacterial count of fecal coliform during summer season ranged from 0 to 30,000 CFU per 100 mL with a mean value of 4,795 CFU per 100 mL. The maximum value of 30,000 CFU per 100 mL was found at two locations (sample locations 48 and 57), which

locates in the north of Wadi Gaza and El Shiekh Ejleen sewage outfall as shown in Table 1.

The results did not indicate the presence of FC at locations 6, 8 and 13 which located to the north of Asdaa sewage outfalls, it was noticed that the discharge of wastewater was stopped during the sampling collection. The concentration of FC northern the outfalls was higher than those to the south.

While the bacterial count of fecal coliform during autumn season ranged from 0 to 40,000 CFU per 100 mL with a mean value of 2,995 CFU per 100 mL. The maximum value 40,000 CFU per 100 mL was found at El Shiekh Ejleen sewage outfall. Contrary to the results in summer, the results indicated the presence of FC at locations 6, 9 and 14 that located to the north of Asdaa sewage outfall and it was in operation during sampling collection in autumn. The concentration of FC southern the outfalls was higher than those to the north.

Fecal streptococci (FS)

The bacterial count of fecal streptococci during summer season ranged from 16 to 1,000 CFU per 100 mL with a mean value of 180 CFU per 100 and maximum value of 1,000 CFU per 100 mL was found at location 71 which is near Al Shalihat sewage outfall as shown in Table 1. Contrary to the results of FC at the locations 6, 9, and 14 which located to the north of Asdaa outfall, FS pollution appeared at these locations, since FS is more resistance to the environmental conditions. The bacterial count of fecal streptococci during autumn season ranged from 30 to 1,200 CFU per 100 mL with a mean value of 772 CFU per 100 mL. The maximum value of 1200 CFU per 100 mL was found at El Shiekh Ejleen outfall.

Pseudomonas aeruginosa

The bacterial count of pseudomonas during summer season ranged from 0 to 60 CFU per 250 mL with a mean value of 4.8 CFU per 250 mL. The maximum value of 60 per 250 mL was found at the Al Shalihat sewage outfall as shown in Table 1. Generally, pseudomonas appears at the locations near the outfalls. The bacterial count of pseudomonas during autumn season ranged from 0 to 25 per 250 mL with a mean value of 2.2 CFU per 100 mL. The maximum value of 25 CFU per 250 mL was found to the north of Wadi Gaza. Contrary to the results of summer, pseudomonas did not appear at locations 71 and 73 that located near at the Al Shalihat outfall, since it was stopped discharge into the sea at that time.

Water quality variation along the Mediterranean Coast of Gaza

Changes in the concentrations of each of FC, FS and pseudomonas were tracked along the beach in the study area. Based on the microbiological analysis of the samples; the results were classified into five zones (Table 2):

Zone A expanded from Khan Younis port to Asdaa outfall. The results show that there is no FC pollution in this zone. The maximum value of FS was 120 CFU per 100 mL. The maximum value of pseudomonas was 2 CFU per 250 mL. The average value of FS was 102 CFU per 100 mL. It should be noted that the discharge of wastewater from Asdaa outfall was stopped during sampling collection.

Zone B expanded from Asdaa outfall to Deir Al Balah outfall. The FC contamination can be neglected at this zone. The maximum value of FS was 400 CFU per 100 mL and the average value was 129 CFU per 100 mL.

Table 1. Comparison between fecal coliform, fecal streptococci, and *Pseudomonas aeruginosa* results in summer and autumn seasons

Site	Coordinates		Fecal coliform		Fecal streptococci		*Pseudomonas aeruginosa*	
no.	N	E	Summer	Autumn	Summer	Autumn	Summer	Autumn
6	31.38435	34.28879	0	40	100	80	1	0
7	31.38707	34.29211	0	70	400	60	0	2
8	31.38907	34.29428	0	90	240	30	0	4
9	31.39105	34.29644	0	900	350	120	0	2
10	31.39310	34.29853	0	1000	110	200	2	2
11	31.39494	34.30083	60	1000	150	220	0	3
12	31.39669	34.30323	750	700	50	160	1	1
13	31.39892	34.30666	100	10000	100	1000	1	25
14	31.40073	34.30902	10000	20	240	120	5	0
15	31.40273	34.31118	30000	20	200	90	0	1
16	31.40472	34.31332	400	40	100	40	6	0
17	31.40655	34.31564	90	3000	30	300	0	1
18	31.40849	34.31788	30000	40000	60	1200	1	0
19	31.41041	34.32019	8000	0	100	40	0	1
20	31.41228	34.32251	90	10	60	40	1	0
21	31.41409	34.32483	900	0	50	30	0	0
22	31.41611	34.32695	20	10	16	40	0	0
23	31.41800	34.32917	10000	10	1000	50	60	0
24	31.42003	34.33152	700	0	60	40	13	0
25	31.42188	34.33383	0	40	100	80	1	0
26	31.42377	34.33609	0	70	400	60	0	2
27	31.42591	34.33808	0	90	240	30	0	4
28	31.42790	34.34031	0	900	350	120	0	2
29	31.43001	34.34221	0	1000	110	200	2	2

Zone C expanded from Deir Al Balah outfall to Wadi Gaza. The maximum values of FC and FS was 750 and 150 CFU per 100 mL, respectively. The largest values of FC occurred to the north of small outfall located at the Al Zawaida beach. The maximum value of FS occurred to the north of Deir Al Balah outfall. The average values of FC and FS was 153 and 64 CFU per 100 mL, respectively. As compared with the previous zones, there is a significant increase in the fecal contamination in this zone; because it's located between the two major wastewater outfalls. It is noted that there is a significant increase in the values closer to wastewater outfalls, whether near Deir Al Balah outfall to the south or the Wadi Gaza to the north.

Zone D expanded from Wadi Gaza to El Shiekh Ejleen outfall. The maximum values of FC and FS was 40,000 and 700 CFU per 100 mL, respectively. These values occurred to the north of Wadi Gaza. This zone is the most polluted by fecal contamination due to the large amounts of wastewater discharged by Wadi Gaza and El Shiekh Ejleen outfall. It should be noted that the currents direction was from south to the north. The average values of FC and FS was 11,086 and 154 CFU per 100 mL, respectively. It is noted that the fecal contamination decreased gradually as going far from Wadi Gaza until reaching the minimum values of100 CFU per 100 mL for FC and 18 CFU per 100 mL for FS, then a significant increase occurred as be coming closer to El Shiekh Ejleen outfall.

Zone E expanded from El Shiekh Ejleen outfall to Gaza fishing port. The maximum value of FC was 30,000 CFU per 100 mL which occurred to the north of El Shiekh Ejleen outfall. The maximum value of FS was 1,000 CFU per 100 mL which occurred at the El Shalihat outfall. It is noted that the pollution in the north of El Shiekh Ejleen outfall was greater than the pollution to the south. The average values of FC and FS was 4,215 and 137 CFU per 100 mL, respectively. It is noted that the fecal contamination decreased gradually as going far from El Shiekh Ejleen outfall until reaching the minimum values at 66 and 67 locations, then a significant increase occurred as be coming closer to El Shalihat outfall.

Table 2. Results of microbial analysis at zone A, B, C, D, and E

No.	Coordinates N	E	FC	FS	*Pseudomonas*
	Zone A				
1	31.37037	34.27432	-	110	-
2	31.37266	34.27697	-	120	-
3	31.37620	34.28045	-	80	-
4	31.37914	34.28315	-	100	-
5	31.38127	34.28516	-	100	2
	Zone B				
6	31.38435	34.28879	-	100	1
7	31.38707	34.29211	-	200	-
8	31.38907	34.29428	-	400	-
9	31.39105	34.29644	-	200	-
10	31.39310	34.29853	-	250	-
11	31.39494	34.30083	-	20	-
12	31.39669	34.30323	-	10	-
13	31.39892	34.30666	-	240	-
14	31.40073	34.30902	-	40	-
15	31.40273	34.31118	-	100	-
16	31.40472	34.31332	-	40	-
17	31.40655	34.31564	20	40	-
18	31.40849	34.31788	-	100	-
19	31.41041	34.32019	-	60	-
20	31.41228	34.32251	-	20	2
21	31.41409	34.32483	-	50	-
22	31.41611	34.32695	10	300	-
23	31.41800	34.32917	-	350	-
24	31.42003	34.33152	-	300	-
25	31.42188	34.33383	-	30	-
26	31.42377	34.33609	-	40	-
27	31.42591	34.33808	-	20	-
28	31.42790	34.34031	10	80	-
29	31.43001	34.34221	-	110	2
	Zone C				
30	31.43195	34.34435	60	150	-
31	31.43405	34.34634	90	100	1
32	31.43613	34.34834	-	100	-
33	31.43807	34.35041	80	20	-
34	31.44026	34.35246	60	25	1
35	31.44238	34.35442	60	40	-
36	31.44446	34.35643	700	40	1
37	31.44567	34.35838	750	50	1
38	31.44864	34.36040	20	50	-
39	31.45071	34.36243	50	50	-
40	31.45279	34.36445	50	60	-
41	31.45487	34.36644	60	50	-
42	31.45786	34.36951	60	60	-
43	31.46084	34.37257	100	100	1
	Zone D				
44	31.46292	34.37456	120	80	1
45	31.46498	34.37661	10,000	240	5
46	31.46498	34.37661	40,000	700	-
47	31.46707	34.37864	20,000	300	-
48	31.46915	34.38062	30,000	200	-
49	31.47123	34.38263	40,000	80	-
50	31.47327	34.38468	900	20	3
51	31.47541	34.38657	2,000	18	5
52	31.47748	34.38860	400	100	6
53	31.47956	34.39056	100	120	4
54	31.48170	34.39254	103	100	8
55	31.48375	34.39459	90	30	-
56	31.48599	34.39710	400	20	2
	Zone E				
57	31.48818	34.39903	30,000	60	1
58	31.49024	34.40106	9,000	100	-
59	31.49228	34.40311	8,000	100	-
60	31.49439	34.40511	6,300	100	-
61	31.49640	34.40725	90	60	1
62	31.49853	34.40923	80	100	4
63	31.50063	34.41120	800	20	-
64	31.50273	34.41316	900	50	-
65	31.50484	34.41512	700	30	5
66	31.50694	34.41709	20	4	-
67	31.50915	34.41895	-	30	-
68	31.51132	34.42080	120	6	-
69	31.51350	34.42268	20	16	-
70	31.51572	34.42446	3000	400	25
71	31.51800	34.42619	10,000	1,000	60
72	31.52023	34.42800	10,000	400	18
73	31.52252	34.42968	700	60	13
74	31.52381	34.43247	-	30	5
75	31.52508	34.43374	360	30	-

Note: "-" = negative

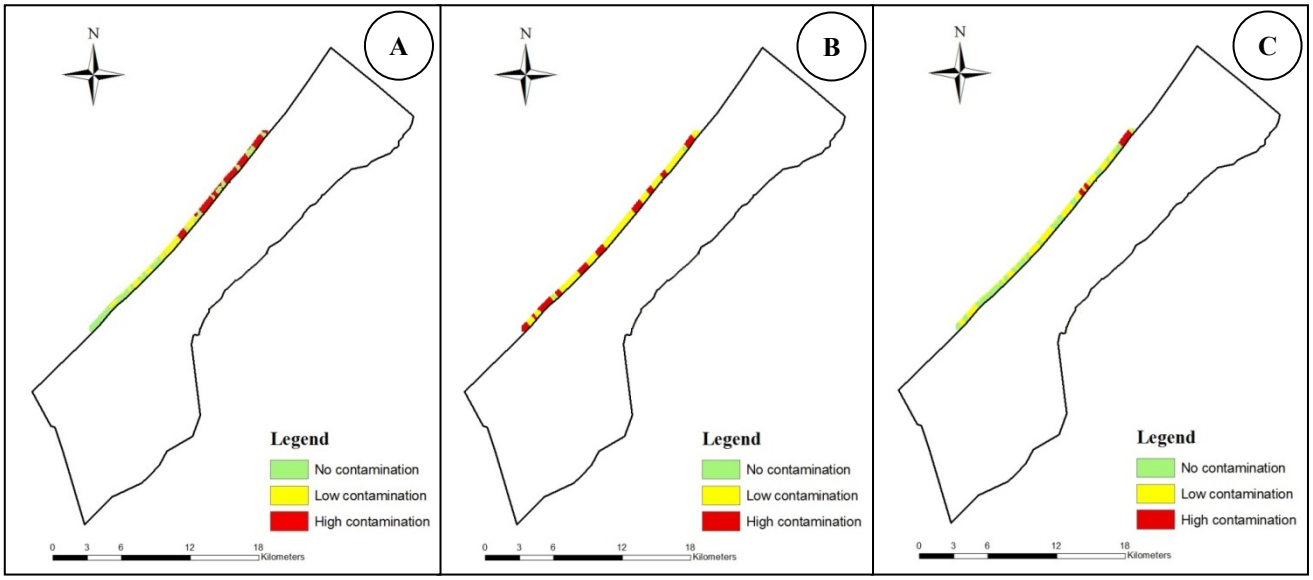

Figure 2. A. Fecal coliform distribution along the study area. B. Fecal streptococci distribution along the study area. C. Pseudomonas distribution along the study area.

From the results, it is clear that there is a significant pollution in Gaza seawaters mainly from the discharge of wastewater directly into the sea. Figure 2 shows the distribution of pollutants along the study area beach based on summer season measurements.

The study area beach had been classified according to suitability for recreation depending on the concentration of fecal contamination (Figure 3). This classification was created on the consideration that the contaminated areas are the areas that reached a concentration of 100 CFU per 100 mL for any of fecal coliform or fecal streptococcus. Based on Figure 8, the contamination mainly appeared at the wastewater outfalls and the surrounding areas. The Gaza city beach is the most contaminated, the reason can be traced to the huge amount of wastewater that is discharged from El-Shiekh Ejleen outfall.

The risk of fecal coliform and fecal streptococci was significantly higher during summer than autumn, which were 69% , 64% and 62.17%, 62.17%, respectively. That was different for pseudomonas which was 63.31% and 65.17% during the summer and autumn, respectively. However, the risk was higher in both cases.

CONCLUSION

Generally, the pollution was significant at the zone C, and was very severe at the zones D and E. These zones contain the major wastewater outfalls which dispose huge amounts of wastewater to the sea. Water contaminated by human excreta may contain a range of pathogens (disease-causing) microorganisms, such as viruses, bacteria and protozoa. These organisms may pose a health hazard when the water is used for recreational activities such as swimming and other high-contact water sports. In this section, the study area beach had been classified according to suitability for recreation depending on the concentration of fecal contamination. This classification was created on the consideration that the contaminated areas are the areas that reached a concentration of 100 CFU per 100 mL for any of fecal coliform or fecal streptococcus. Based on Figure 8, the contamination mainly appeared at the wastewater outfalls and the surrounding areas. The Gaza city beach is the most contaminated, the reason can be traced to the huge amount of wastewater that is discharged from El Shiekh Ejleen outfall.

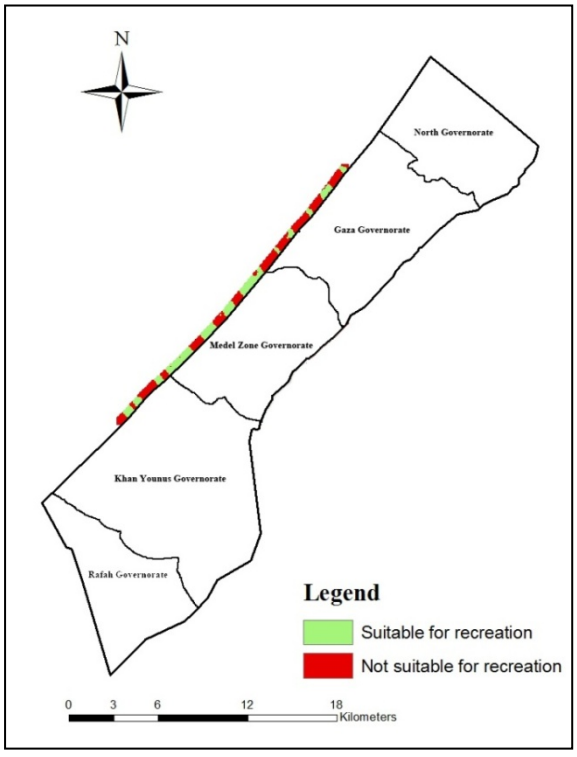

Figure 3. Classification of the study area beach

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