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Assessment of Impact Sewage Effluents on the Coastal Water Quality Around the Mouth of Wadi Gaza (Gaza and Middle Governorates, Gaza Strip, Palestine)

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Abstract

Gaza Strip is a narrow coastal region locates at the southeastern coastal plain of Mediterranean Sea. Along the beach of the Gaza Strip eight sewage stations are observed in addition to mouth of Wadi Gaza, which are pumping untreated sewage into the seawater. The aim of the study is to assess the impact of the wastewater disposal and pollutant sources along the study area, focusing around the mouth of Wadi Gaza. This study is carried out along the beach of Gaza and Middle Governorates. Sampling has done at 36 stations along three lines survey extending from SW to NE, these lines locate at distance 100 m; 200 m; and 350 m respectively in the sea. The results of geochemical analysis show variations in physico-chemical parameters: pH; electrical conductivity (EC); total suspended solids (TSS); total dissolved solids (TDS); nitrates; chlorides; calcium; sodium; and potassium. The results reveal that the pollution had significantly higher level round the raw sewage discharge points and decrease towards north direction and significantly decrease at distance greater than 200 m in the sea.

Keywords: sewage, seawater, pollution, Wadi Gaza, Gaza beach, Palestine

1. Introduction

The problems associated with sewage disposal have become a major problem of the urban world due to increase in human population and urbanization. The commonality of sewage related problems throughout coastal areas of the world is significant since these areas are inhabited by over 60% of the human population. Consequently, domestic wastewater discharges are considered one of the most significant threats of the coastal environments worldwide (GPA 2001). Environmental effects associated with domestic wastewater discharges are generally local with transboundary implications in some areas.

Coastal waters are facing variety of pressure affecting both the ecosystem and human health through sewage wastewater discharge and disposal practices that may lead to introduction of high nutrient loads, hazardous chemicals and pathogens causing diseases. The adverse public health, environmental, socio-economic, food quality and security, and aesthetic impacts from sewage contamination in coastal areas are well documented (Tyrrel, 1999; Danulat et al., 2002; WHO, 2003).

Legislation, directives and water quality standards for various coastal uses like shellfish harvesting, recreation, dinking and aquaculture have been developed in many countries to limit problems associated with sewage. These standards are usually not realized due to poor sewage management. The poor management usually arises from the fact that waste-management decisions take place in complex situations governed by political, bureaucratic, and financial forces that often interfere with the implementation of existing regulations and standards. In most cases, waste disposal decisions encounter resistance and inefficiency in the eventual administrative implementation and financial difficulties that affect the disposer's ability to comply with the original decision.

The fact that the majority of urban populations depend on coastal surface waters which are usually used for sewage disposal, in one way or another, makes water pollution the principal problem that requires sound management practices to contain impacts.

The aim of this study is to conduct the seawater quality commuting the impact of the wastewater disposal and pollutant sources along the Mediterranean beach of Gaza and the Middle and Gaza Governorates in Gaza Strip focusing around the mouth of the Wadi Gaza. The study tried to answer the following question: To what extent does the sewage discharge/ disposal impact on the water quality along the study area?

2. Study area

the Gaza Strip is a narrow coastal region locates at southwestern part of Palestine, and in the southeastern coastal plain of Mediterranean Sea (Fig. 1 A), between longitude 34o 20` and 34o 25` East and latitude 31o 16` and 31o 45` North. Gaza Strip is bordered by Egypt from the south, Negev desert from the east and the green line from the north (GEP, 1994; Ubeid, 2014). The width of the strip ranges between 6 km at the middle to 8 km in the north and 12 km in the south. Its length is about 40 km along the coastline and its area is about 378 km2 (UNDP, 2009). The coast shelf of Gaza Strip is part of the Nile littoral cell (Nir, 1989; Ben-Dor et al., 2006; Zveily et al., 2007 & Ubeid, 2011). The southern Mediterranean coast has been shaped by the sediment transport from the Nile river upward via the north coast of Sinai to Gaza Strip (Ubeid, 2011). Gaza Strip is divided administratively into five governorates: North; Gaza; Middle; Khan Younis; and Rafah. The current population in Gaza Strip is estimated to be around 1.85 million.

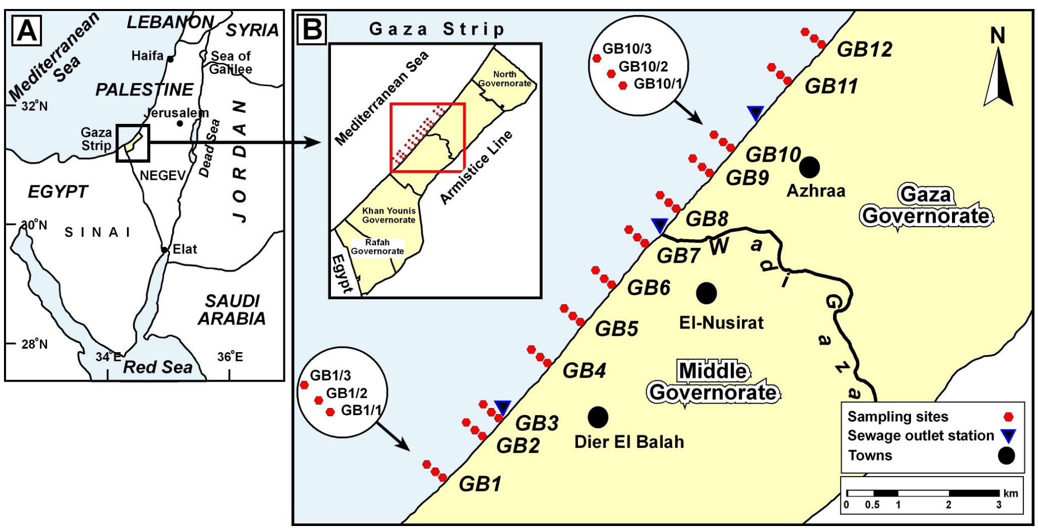

Figure 1: Location map. (A) Location map of the study area. (B) Shows the sampling sites. Note that the numbers, e.g. GB10/1; GB10/2; and GB10/3 mean the no. 10 represents the site number, and 1; 2; and 3 represent the sample no. at stations 1; 2; and 3 at site 10 at distances 100 m; 200; and 350 m within the sea respectively.

Only about 40% of the sewage generated in Gaza Strip is properly treated. The percentage of population served by sewage system is about 79% (WASH, 2011), leaving the rest of population unconnected to the network and dependent on alternative means for excreta disposal. Most of the wastewater treatment plants (WWTPs) in Gaza are overloaded and working beyond their designed capacities (Abd Rabou, 2011). About 110,000 m3 per day of untreated or partially treated wastewater is discharged into the Mediterranean Sea, which mostly coming from these WWTPs and Wadi Gaza (Abualtayef et al., 2014). The sewage is either disposed near the seashore or few meters inside the seawater (Fig. 2).

Along the coast of Gaza Strip around eight sewage stations are observed in addition to Wadi Gaza, which are pumping sewage into the seawater. One of sewage stations is located in North; three stations in Gaza; two stations in the Middle; one in Khan Younis; and one in Rafah Governorate.

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; Abualtayef et al., 2014).

3. Materials and methods

3.1 The field Sites

The field work was carried out in May 2014 along the onshore of Gaza Strip, Palestine. It was Started from fishers station at Dier El Balah locality in the Middle Governorate of Gaza Strip and extended up to E-Sheikh Ejleen locality towards the north in Gaza City in Gaza Governorate of Gaza Strip (Fig. 1 B). A total of 36 samples were collected at 12 sites. The lateral separation distance between the sites are shown in Table 1. Three samples of about 1 liter were taken at three stations for each site. The sampling at each site was started at 100 meter from shoreline towards the sea, with depth around 1 meter below mean sea level (MSL); the second sample was taken at distance 200 meters with depth about 2 meters below MSL; and the third sample was taken at distance 350 meters with depth about 3 meters below MSL. The sampling was done by sampling tube. GPS location for each site was taken at first station at distance 100 m in the sea, and presented in Table 1. The site locations were transferred into digital map by using ArcGis software. All the samples at distance 100 m in the sea are said to be line survey I; sampling at distance 200 m in the sea are said to be line survey II; and sampling at distance 350 m are said to be line survey III (Fig. 1B). Within the study area two pumping stations of sewage discharge at the beach are observed, in addition to sewage outlet at mouth of Wadi Gaza (Fig. 1B; Fig. 2).

3.2 Laboratory analysis

Seawater samples were analyzed at the laboratories of Geology Department and Institute of Water and Environment in Al Azhar University – Gaza for the pH; electrical conductivity (EC); total suspended solids (TSS); total dissolved solids (TDS); nitrates; chlorides; calcium; sodium; and potassium.

For the pH determination, the stable reading were recorded (Grasshoff, 1983), using pH meter 3310 (Jewnway, UK). The EC values for the sample were measured by the EC meter (HACH Sension, Germany). The TSS values are determined by filtering the samples through a glass fiber. The filters are dried and weighed to find the amount of TSS in mg/l of sample. After the filtration the filtrate (liquid) is dried and the remaining residue is weighed and calculated as mg/l of TDS. The nitrates concentration was determined by Spectrophotometer 6305 UV/Vis (Jenway, UK). The chlorides concentration was determined by adding 1-2 drops potassium chromate to 50 ml of seawater sample, then titrate with standard AgNO3 solution till AgCrO3 starts precipitating. Satndarize AgNO3 against standard sodium chloride to take accurate concentration of AgNO3 as MNacl VNacl = MAgNO3 VAgNO3. Then the chloride concentration was calculated by the formula: Cl– (mg/l) = {(ml of AgNO3)-(ml of AgNO3)}*{normality of AgNO3}*35.45*1000/ml of sample. The calcium concentration in seawater samples determined by using graduate cylinder pour 25 ml of seawater sample into clean dry Erlenmeyer flask, then diluted it to 50 ml with distilled water. Two ml of sodium hydroxide solution added, followed by 0.2 g indicator powder. Then titrated with standards EDTA titrant until the end point. The volume of EDTA titrant recorded. After that the calcium concentration was calculated by the formula: Ca2+ (mg/l) = (ml titrant used)*(molarity of EDTA titrant)*40067/ml sample. The sodium and the potassium concentrations were determined by spectroscopy “Flame photometer” instrument.

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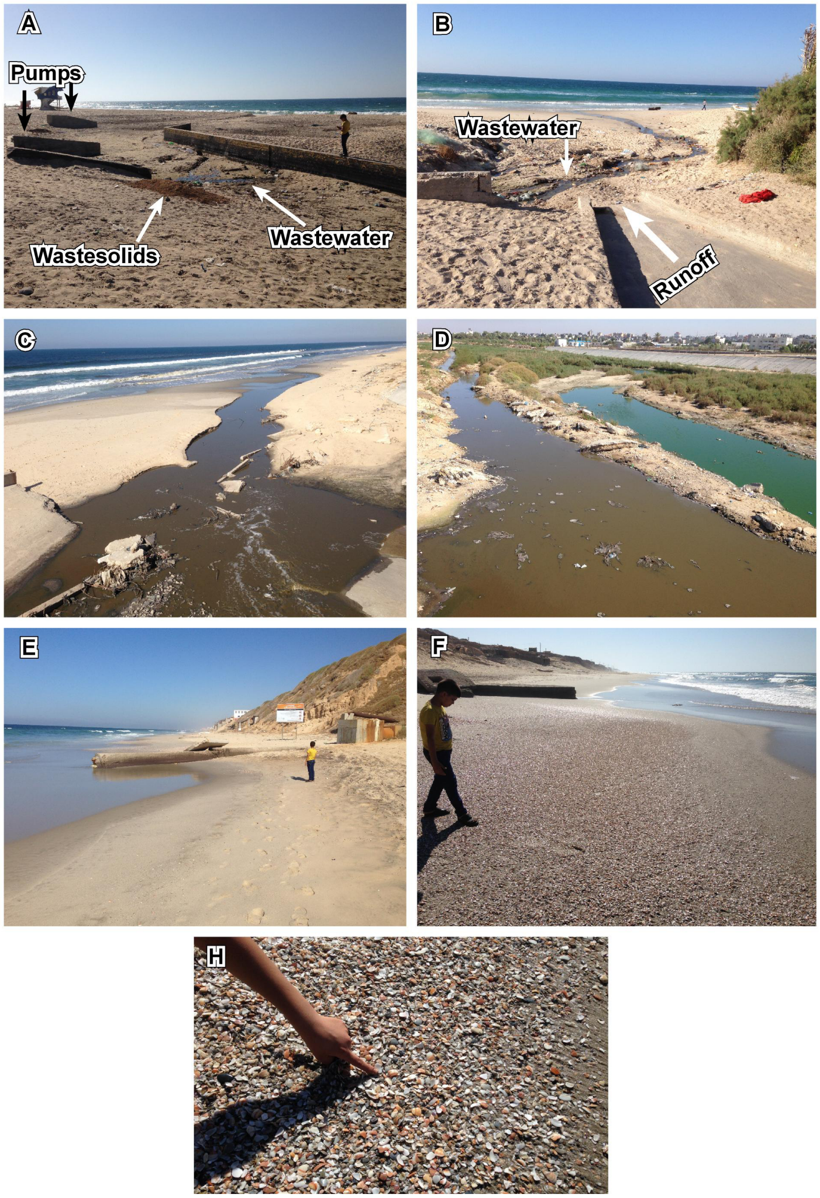


Figure 2: Shows the sewage pumping stations on the Gaza Beach, Gaza Strip. (A) Pumping sewage station at Deir El Balah Beach locality, Middle Governorate, Gaza Strip. (B) Shows untreated wastewater and runoff discharge into Deir El Balah Beach, Middle Governorate, Gaza Strip. (C) Sewage discharge at the Wadi Gaza mouth, on the Gaza Beach, Middle Governorate, Gaza Strip. (D) Shows the sewage running through the Wadi Gaza course to Gaza Beach, Middle Governorate, Gaza Strip. (E) Sewage pumping station at Al Zahraa Beach locality, Gaza Governorate, Gaza Strip. (F & H) Show the shells and bioclasts accumulation around the Al Zahraa station due to anoxic conditions due to sewage discharge into seawater. Note in F & H the gray color around the station due to sewage discharge.

Table 1: GPS location of the observation sites in the study area.

Station no.	Coordinates N	Coordinates E	Distance (m) From S to N	Separation stations (m)
GB1	31° 25` 13.4``	34° 19` 50.3``	0	0
GB2	31° 25` 40.9``	34° 20` 19.5``	1155	1155
GB3	31° 26` 03.4``	34° 20` 14.0``	1877	722
GB4	31° 26` 28.6``	34° 21` 05.6``	3481	1604
GB5	31° 26` 59.9``	34° 21` 21.5``	4585	1104
GB6	31° 27` 19.2``	34° 21` 53.9``	5660	1075
GB7	31° 27` 44.5``	34° 22` 20.7``	6718	1058
GB8	31° 28` 06.2``	34° 22` 41.4``	7610	892
GB9	31° 28` 36.5``	34° 22` 57.1``	8649	1039
GB10	31° 28` 57.3``	34° 23` 05.1``	9352	703
GB11	31° 29` 30.3``	34° 24` 04.0``	11220	1868
GB12	31° 29` 58.1``	34° 24` 20.1``	12180	960

4. Results and discussion

The seawater samples collected from the beach are colorless and some of the samples are yellowish and odor especially that are close to mouth of the Wadi Gaza. The results of ion concentration of seawater for May 2014 are presented in Table 2; 3; and 4. In Table 2, the results are presented for line survey number I which located in land direction; the results in Table 3, and 4 are represented for line II and III respectively, where line III located in marine direction.

4.1 Temperature

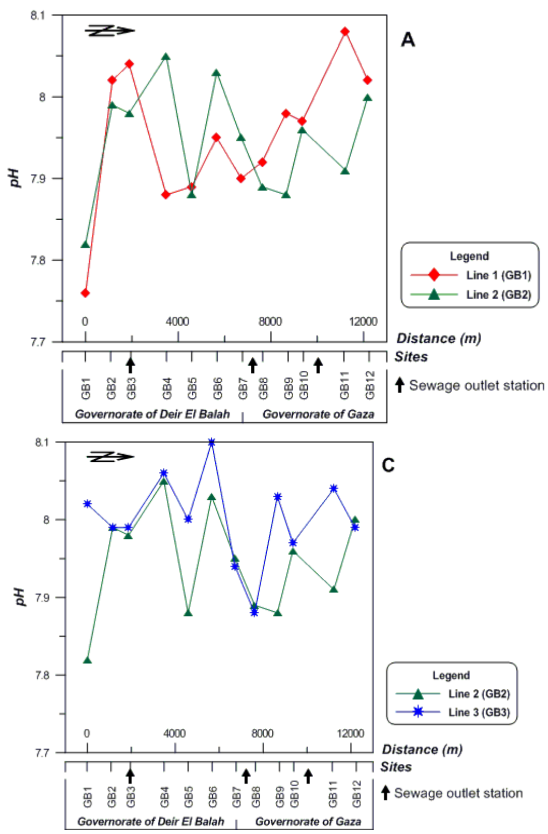
The temperature of the seawater ranged from 25 to 28o C. The highest temperature occurred at the shallow depth, while the lowest one recorded at deep water and on the morning at the beginning of the sampling.

4.2 pH value

The pH values revealed wide variations, ranged from 7.76 to 8.10 within the study. The minimum value (7.76) was observed at station GB1/1 at line survey I, and the maximum value (8.10) was observed at station GB6/3 at line survey III area. The average, minimum, and maximum values at line survey I and II are very close, where there are no significant differences between them, whereas the values of these factors slightly increase at line survey III (Tables 2; 3 & 4 & Fig. 3). In spite these variation fall within typical value of pH seawater which range from 7.5 to 8.4 at salinity 3.8% (PHL, 1998; USEPA, 1993); these results suggest that the effect of the raw sewage discharge and the runoff are clear in lines survey I and II within distance in the seawater about 200 m. Whereas greater than this distance (> 200m) the effect of the raw sewage discharge and the runoff decreases, which is revealed by the results of line survey III. The variation in the results from south to north direction due to the effect of the raw sewage discharge and the runoff is not clear enough. Since the pollution effects distributed along the beach within distance 200 m in the sea and decrease more than this distance.

4.3 Electrical conductivity (EC)

The results of electrical conductivity (EC) of the seawater samples in the study area show that the values of EC vary from 60053 µS/cm at station GB3/1 in line survey I to 66256 µS/cm at station GB9/3 in line survey III. The average values of EC in different lines survey increase from minimum average value (62679 µS/cm) in line survey I to maximum average value (63884 µS/cm) in line survey III (Tables 2 & 4). This is also referred to dilution that has caused by the raw sewage discharge and runoff (Afifi et al., 2002: El Manama et al., 2006). Where the effects decrease to the minimum at line survey III, which located at 350 m in the sea. On the other way, the line survey I shows increasing in the values of EC from south to north direction, whereas there is no variation in line survey III in the same direction (Fig. 4). The relatively low value in the south and middle parts of the study area along line survey I are referred to these parts are received more quantities of pollutions especially from Wadi Gaza that contain the anions and cations of chemical pollutantas that intact with the seawater when mixed together in Wadi Gaza mouth causes a decrease in TDS and EC.



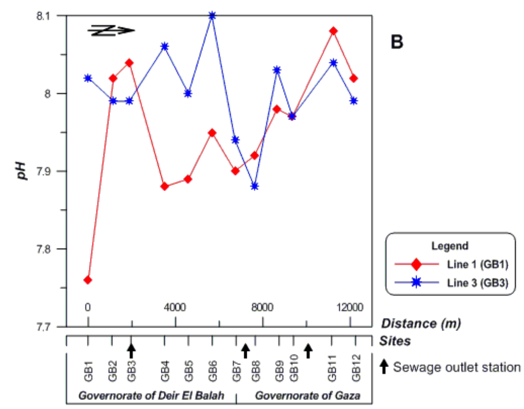


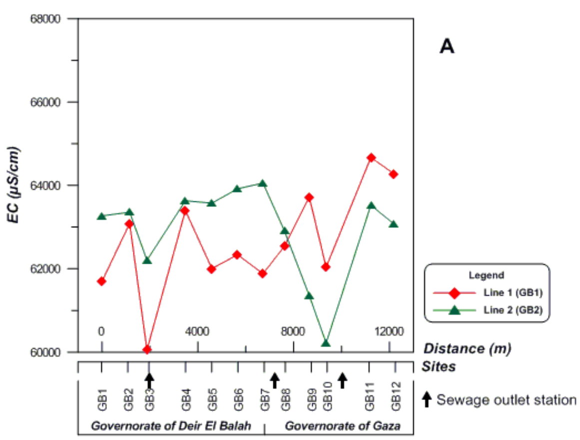
Figure 3: Shows the variation of the pH values of seawater samples at the study sites in the study area. (A) The variation of the values of pH seawater samples along the survey line I and II of the study area. (B) The variation of the values of pH seawater samples along the survey line I and III of the study area. (C) The variation of the values of pH seawater samples along the survey line II and III of the study area.

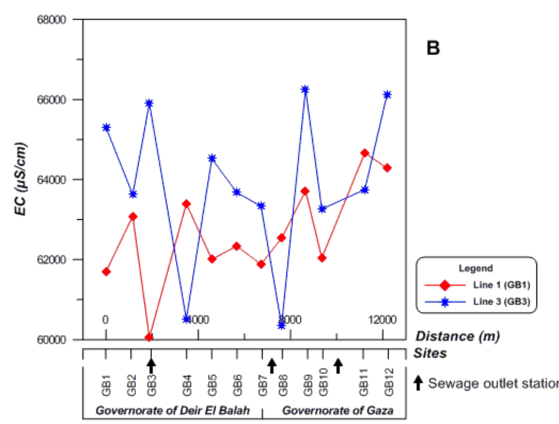
4.4 Total suspended solids (TSS)

Tables 2; 3; 4 and Figure 5 present the results of total suspended solids (TSS) in the study area along the three lines survey. The results show that the minimum value of TSS is 39812 mg/l which observed at station GB10/1 in line survey I; whereas the maximum values is 43156 mg/l, which observed at station GB2/3 in line survey III. There are no significant differences in the average; minimum; and maximum values of the results in line survey I and II; whereas, the average and maximum values are increase in line survey III. These results suggest that the effect of the pollution from sewage discharge and the runoff decrease in TDS and EC.

Table 2: Results of geochemical analysis for the major constituents of seawater samples along line survey I in the study area.

Station no.	Sample no.	pH	EC (µS/cm)	TSS (mg/l)	TDS (mg/l)	Nitrate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
GB1/1	763	7.76	61700	41868	39488	5.0	21478	511	10725	427
GB2/1	775	8.02	63088	41640	40376	7.6	20945	476	11031	378
GB3/1	917	8.04	60053	41996	40524	7.8	21123	521	11210	367
GB4/1	987	7.88	63394	40968	40572	5.2	19348	496	11061	409
GB5/1	912	7.89	62006	41952	39684	7.8	22365	436	10840	402
GB6/1	776	7.95	62338	41812	39896	9.7	21655	531	10257	389
GB7/1	1126	7.90	61881	40420	39604	9.5	21833	476	10993	332
GB8/1	631	7.92	62538	40984	40024	9.2	22010	556	10241	315
GB9/1	918	7.98	63719	40920	40780	8.7	18815	596	11217	411
GB10/1	905	7.97	62038	39812	39704	8.3	19170	501	11008	330
GB11/1	903	8.08	64669	40664	41388	9.9	21478	661	11157	334
GB12/1	766	8.02	64281	41816	41140	7.6	22543	521	10549	332
Average		***7.95***	***62679***	***41238***	***40256***	***8.0***	***21064***	***524***	***10857***	***369***
Minimum		***7.76***	***60053***	***39812***	***39488***	***5***	***18815***	***436***	***10241***	***315***
Maximum		***8.08***	***64669***	***41996***	***41388***	***9.9***	***22543***	***661***	***11217***	***427***
Stand. Dev.		***0.09***	***1192***	***712***	***629***	***1.6***	***1267***	***59***	***345***	***39***





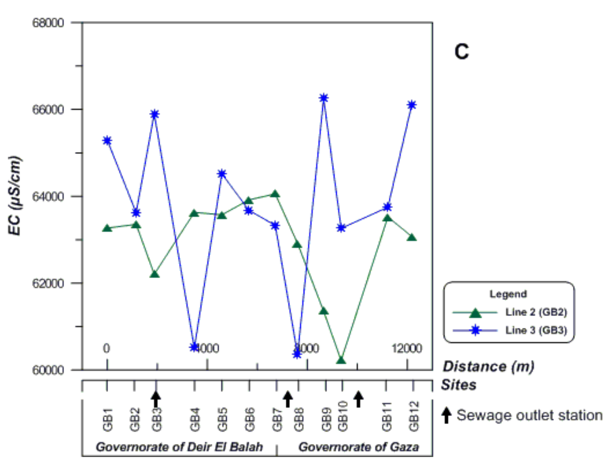


Figure 4: Shows the variation of the electrical conductivity (EC) values of seawater samples in the study area. (A) Comparison between the variation of the EC values of seawater samples along the survey lines I and II in the study area. (B) Comparison between the variation of the EC values of seawater samples along the survey lines I and III in the study area. (C) Comparison between the variation of the EC values of seawater samples along the survey lines II and III in the study area.

Table 3: Results of geochemical analysis for the major constituents of seawater samples along line survey II in the study area.

Stop no.	Sample no.	pH	EC (µS/cm)	TSS (mg/l)	TDS (mg/l)	Nitrate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
GB1/2	772	7.82	63269	42176	40492	5.1	21123	461	10937	410
GB2/2	874	7.99	63356	41792	40548	7.9	21478	646	11004	375
GB3/2	842	7.98	62206	42436	39812	9.3	22188	511	11304	344
GB4/2	900	8.05	63631	40932	40724	5.0	21655	481	11129	429
GB5/2	820	7.88	63575	42464	40688	8.3	21833	511	11020	340
GB6/2	761	8.03	63919	40972	40908	8.5	22543	651	11000	400
GB7/2	895	7.95	64056	40996	40996	7.5	22365	551	11115	364
GB8/2	878	7.89	62913	40580	40264	6.6	21123	486	10799	310
GB9/2	800	7.88	61356	40348	39268	6.3	21123	611	10359	425
GB10/2	804	7.96	60223	41344	39108	7.7	19701	601	10271	418
GB11/2	863	7.91	63525	40968	40656	8.1	22365	511	11177	425
GB12/2	843	8.00	63075	40512	40368	8.1	22010	576	10534	400
Average		***7.95***	***62925***	***41293***	***40313***	***7.4***	***21626***	***550***	***10887***	***387***
Minimum		***7.82***	**60223**	***40348***	***39108***	***5***	***19701***	***461***	***10271***	***310***
Maximum		***8.05***	***64056***	***42464***	***40996***	***9.3***	***22543***	***651***	***11304***	***429***
Stand. Dev.		***0.07***	***1134***	***748***	***613***	***1.3***	***794***	***66***	***331***	***39***

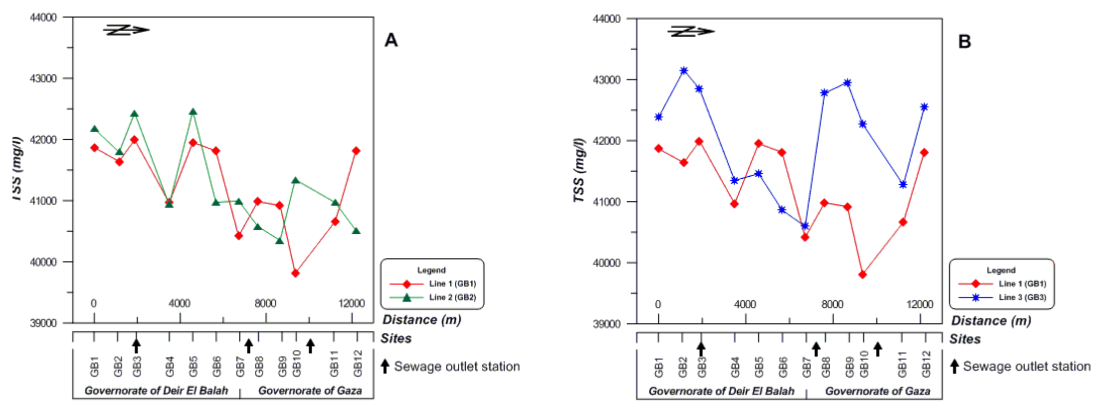
Table 4: Results of geochemical analysis for the major constituents of seawater samples along line survey III in the study area.

Stop no.	Sample no.	pH	EC (µS/cm)	TSS (mg/l)	TDS (mg/l)	Nitrate (mg/l)	Chloride (mg/l)	Calcium (mg/l)	Sodium (mg/l)	Potassium (mg/l)
GB1/3	899	8.02	65294	42388	41788	3.2	21478	401	10910	391
GB2/3	986	7.99	63625	43156	40720	3.5	21565	551	11003	422
GB3/3	779	7.99	65900	42848	42176	3.2	21398	561	11123	422
GB4/3	768	8.06	60519	41348	37768	2.7	22698	531	10150	412
GB5/3	985	8.00	64519	41460	41292	3.2	21945	546	10417	331
GB6/3	796	8.10	63681	40864	40756	2.5	21300	601	10041	355
GB7/3	1127	7.94	63331	40596	40532	3.5	21655	541	11009	393
GB8/3	875	7.88	60359	42780	37644	3.7	20413	441	10850	415
GB9/3	991	8.03	66256	42956	42404	3.4	21478	521	10456	325
GB10/3	1155	7.97	63263	42276	40488	3.2	22010	451	11181	429
GB11/3	868	8.04	63750	41276	40800	3.3	21300	441	11108	339
GB12/3	891	7.99	66119	42552	42316	3.0	22188	476	10904	421
Average		***8.00***	***63884***	***42041***	***40724***	***3.2***	***21619***	***505***	***10763***	***388***
Minimum		***7.88***	***60359***	***40596***	***37644***	***2.5***	***20413***	***401***	***10041***	***325***
Maximum		***8.10***	***66256***	***43156***	***42404***	***3.7***	***22698***	***601***	***11181***	***429***
Stand. Dev.		***0.09***	***1947***	***884***	***1474***	***0.34***	***982***	***83***	***393***	***39***

Distributed within the distance less than 200 m in the seawater, and their effects decrease at line survey III which is further than them (> 200 m in the sea). On the other direction, the results in line survey I and II show that the values decrease from south to north direction. The variation in the values from south to north direction very possible refer to the quantity of the sewage discharge from outlet stations; where the Wadi Gaza and Al Zhraa stations in Gaza Governorate carry large quantity comparing with Deir El Balah station in the Middle Governorate. Also it could be refer to sea currents which are directed from SWW to NNE direction along the Gaza sea and make dilution to the pollution towards N direction (Ubeid, 2011).

4.5 Total dissolve solids (TDS)

The seawater TDS values in the study area range from 37644 mg/l at station GB8/3 of line survey III to 42404 mg/l at station BG11/1 of line survey I. The results display that the average values of the TDS in line survey I & II are very close to each other, this means that no significant differences between them. Whereas, there are differences between their average values and the average value seawater TDS of line survey III (Tables 2; 3; & 4). Which is far away from the beach about 350 m. The average values of seawater TDS in the study area at the three lines survey are greater than the international standard seawater TDS which range from 34489 mg/l to 38600 mg/l (PHL, 1998; USEPA, 1993). The variations of seawater values between lines I and II on one side and the line III on the other side suggest that the effect of sewage discharge decrease in distance more than 200 m in the sea. On the other way, the results of seawater TDS in Lines I; II; and III show that there are no too much significant variations in sites from south to north direction (Fig. 6).



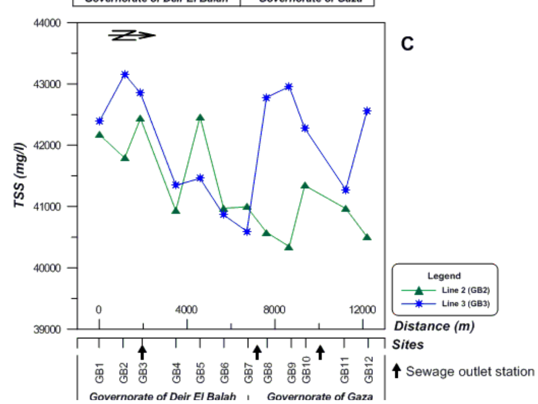


Figure 5: Shows the variation of the total suspended solids (TSS) concentrations in seawater samples in the study area. (A) Comparison between the TSS concentrations in seawater samples along the line survey I and II in the study area. (B) Comparison between the TSS concentrations in seawater samples along the line survey I and III in the study area. (C) Comparison between the TSS concentrations in seawater samples along the line survey II and III in the study area.

4.6 Nitrates (NO3 -)

The seawater nitrates results in the study area in both Middle and Gaza Governorates show that the values range between 2.5 mg/l to 9.9 mg/l. The maximum value is observed at station GB11/1 in line survey I, while minimum value is observed at station GB6/3 in line survey III. The results show differences in the average values of seawater nitrates in the study area, where the maximum value average was observed at line survey I (8.01 mg/l), while the minimum average value was observed at line survey III (3.02 mg/l) (Tables 2 & 4). The difference between average values of the nitrates in lines survey I and II are not too much significant, note that the average nitrates value in line survey II is 7.37 mg/l (Table 3). These results indicate that the nitrate pollution in the seawater from raw sewage discharge are high in lines survey I and II, i.e. the nitrate pollution reaches to distance up to 200 m in the sea. While the pollution from sewage discharge significantly decreases in line survey III, which locate at distance 350 m in the sea, where the minimum value in sites and the minimum average of the nitrate are observed in this line. On the other way, the results show that the seawater nitrates in the study area at line survey I significantly increase from south to north direction. Whereas, the nitrate values slightly increase from south to north in line survey II, while line survey III shows no clear changes from south to north direction (Fig. 7). This indicate that the nitrates pollution are higher in south and middle part of the study area. This could be interpreted due to large quantities of sewage discharge at the mouth of Wadi Gaza and high possibly due to sea currents which make dilution during their transportation from SWW to NNE (Ubeid, 2011).

4.7 Chloride (Cl -)

Chloride concentrations in seawater samples of the study area range between 18815 mg/l to 22698 mg/l. Anyway, the lowest chloride concentration (18815 mg/l) was found at station GB9/1 at line survey I; and highest concentration (22698 mg/l) was observed at station GB4/3 in line survey III. It was observed that

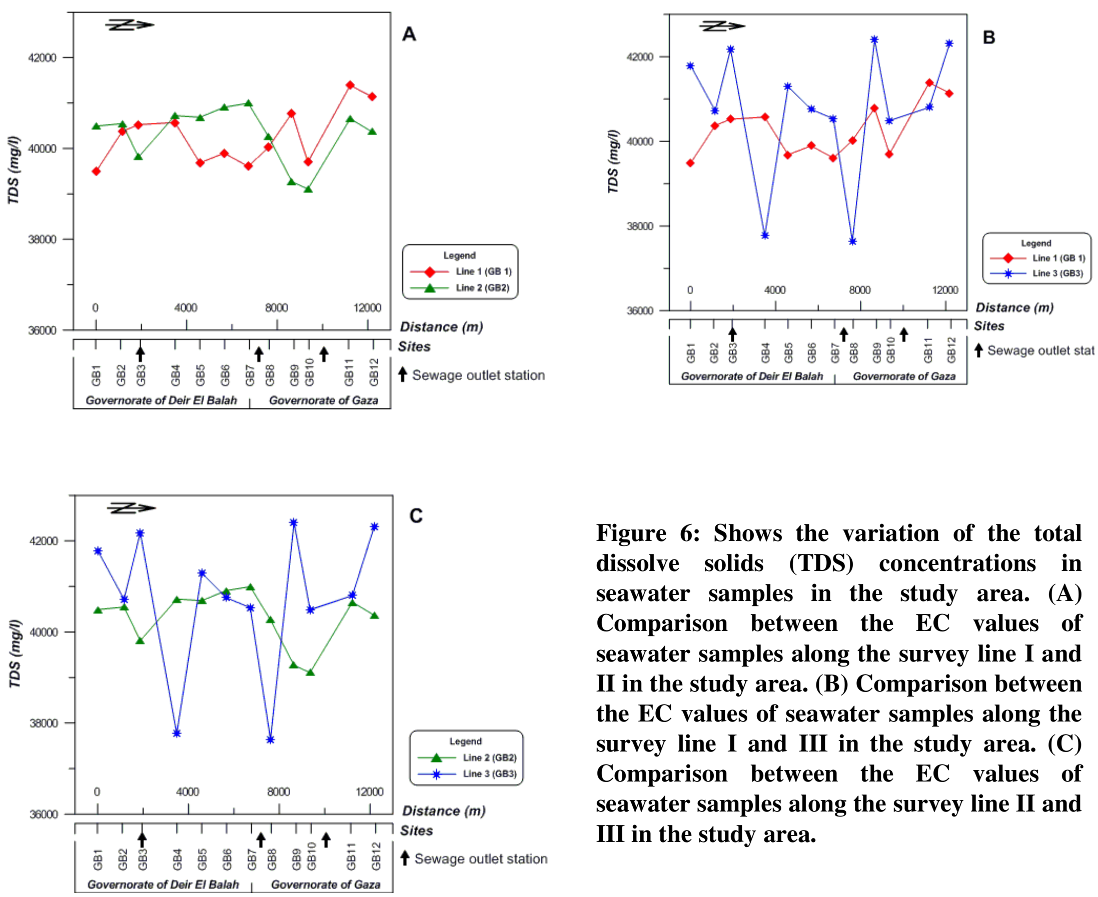
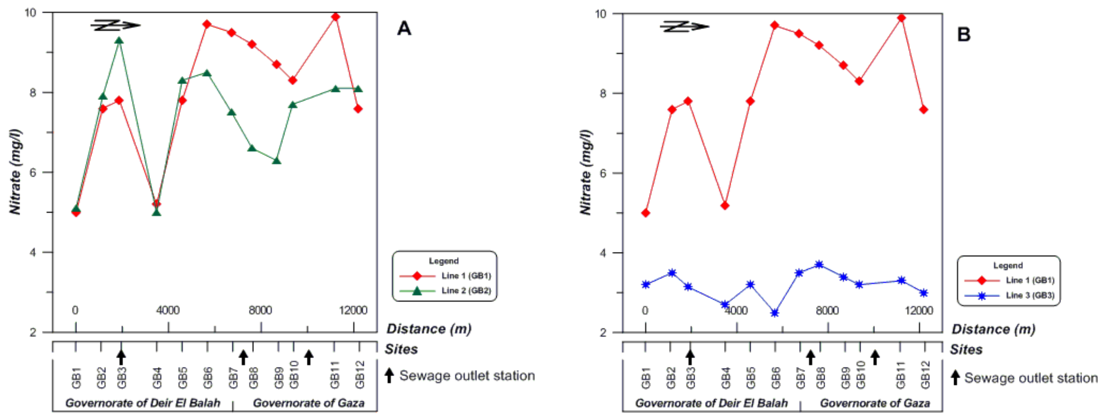


Figure 6: Shows the variation of the total dissolve solids (TDS) concentrations in seawater samples in the study area. (A) Comparison between the EC values of seawater samples along the survey line I and II in the study area. (B) Comparison between the EC values of seawater samples along the survey line I and III in the study area. (C) Comparison between the EC values of seawater samples along the survey line II and III in the study area.

The average values of seawater concentrations in line survey II and III are approximately equals (~ 21623 mg/l); while the average value at line survey I slightly decreases (21064 mg/l) (Tables 2; 3; & 4). Overall, the results show that there are no significant changes in seawater concentrations in different lines survey from south to north direction (Fig. 8). These results of seawater chloride concentrations show that the effects of raw sewage discharge and runoff were distributed at distance of 100 m in the sea and no significant effects are observed within distance more than 200 m in the sea.



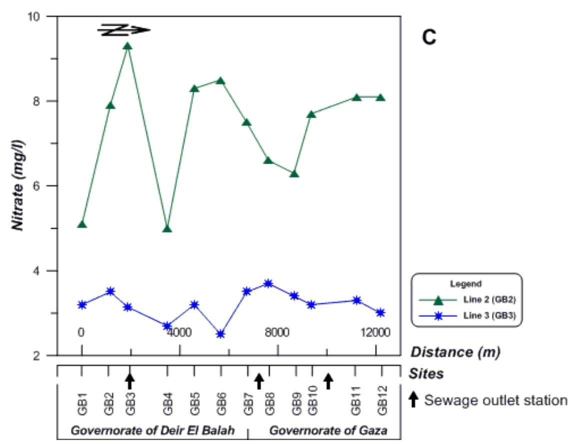
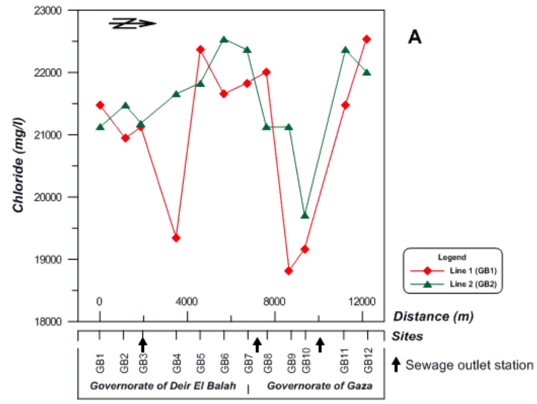
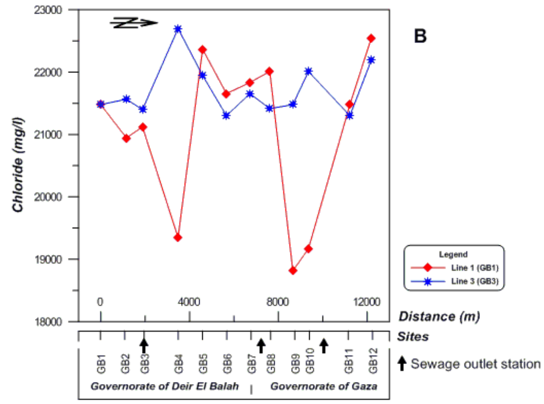


Figure 7: Shows the variation of the nitrate concentrations in seawater samples in the study area. (A) Comparison between the nitrate concentrations of seawater samples along the survey line I and II in the study area. (B) Comparison between the nitrate concentrations of seawater samples along the survey line I and III in the study area. (C) Comparison between the nitrate concentrations of seawater samples along the survey line II and III in the study area.

4.8 Calcium (Ca 2+)

The calcium concentration in seawater samples of the study area range between 401 mg/l at station GB8/3 at line survey III to 661 mg/l at station GB11/1 at line survey I. There are no too much significant differences between the average values of the calcium concentration in line survey I and II, but the average value in line survey III is slightly smaller than their average values (Tables 2; 3; & 4). On the other way, the values of the calcium concentrations in seawater increase in the study area from south to north direction in lines survey I and II (Fig. 9). In line survey III it was observed that the values of calcium concentration values in Deir El Balah (Middle Governorate) greater than that are found in line survey II and III. Conversely; whereas it was observed that the opposite occurs in Gaza Governorate (Fig. 1B; Fig. 9). These variation of calcium concentrations in the lines survey refer to the raw sewage discharge and runoff, where their effects start to decrease in regions further than 200 m in the sea, i.e. further than line survey II.





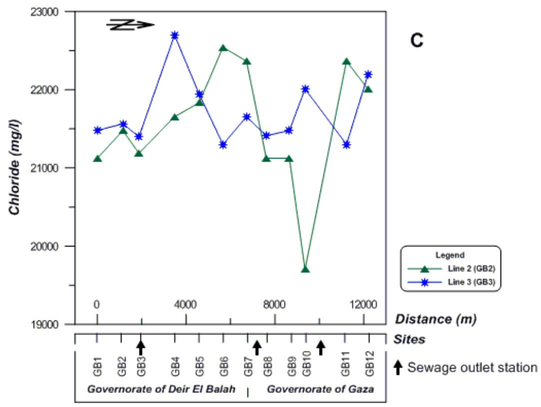
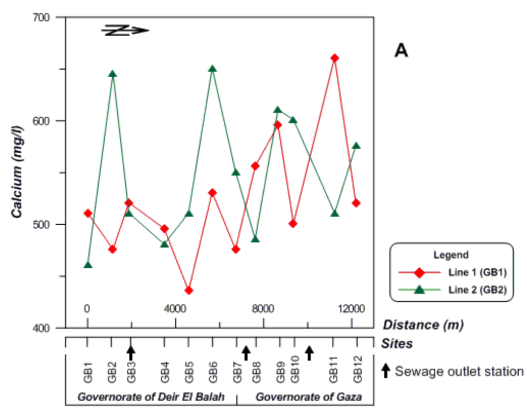
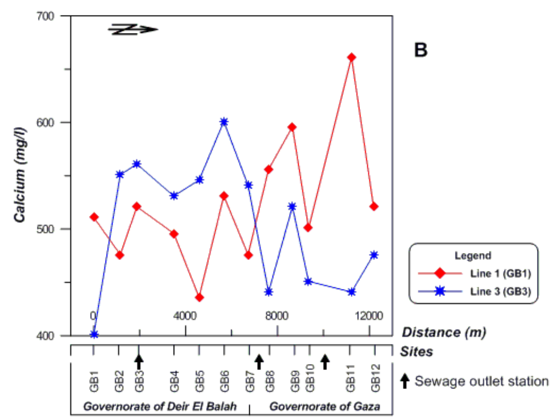


Figure 8: Shows the variation of the chloride concentrations in seawater samples in the study area. (A) Comparison between the chloride concentrations of seawater samples along the survey line I and II in the study area. (B) Comparison between the chloride concentrations of seawater samples along the survey line I and III in the study area. (C) Comparison between the chloride concentrations of seawater samples along the survey line II and III in the study area.





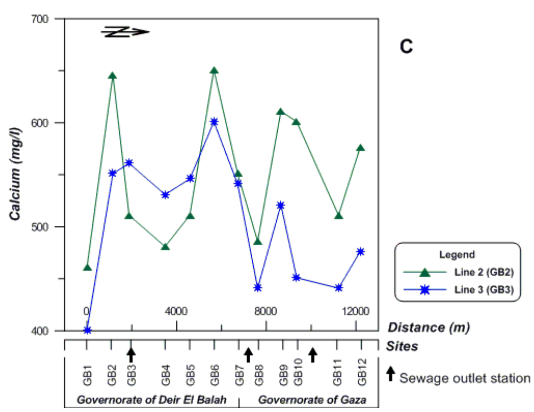


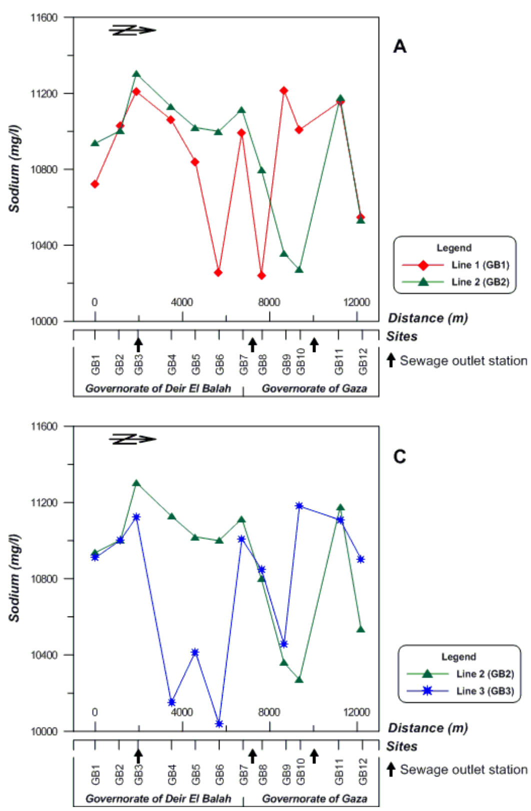
Figure 9: Shows the variation of the calcium concentrations in seawater samples in the study area. (A) Comparison between the calcium concentrations of seawater samples along the survey line I and II in the study area. (B) Comparison between the calcium concentrations of seawater samples along the survey line I and III in the study area. (C) Comparison between the calcium concentrations of seawater samples along the survey line II and III in the study area.

4.9 Sodium (Na +)

The sodium seawater concentrations in the study area vary between 10041 mg/l at station GB6/3 at line survey III to 11304 mg/l at station GB3/2 at line survey II. The average values of sodium concentration in the three lines survey are very close to each other (~ 10836 mg/l) (Tables 2; 3; & 4), and adequate with typical seawater sodium concentration (10800 mg/l) (PHL, 1998; USEPA, 1993). It was observed that some sites e.g. between GB4- to GB10 have relatively low sodium concentration, this could be happened due to their locations that are close and around to sewage outlet stations (Fig. 10).

4.10 Potassium (K +)

The potassium concentration in seawater samples of the study area range from 310 mg/l at station GB8/2 at line survey II to 429 mg/l at station GB4/2 at line survey II. There are no significant differences between the average values of the potassium concentration in the three lines survey (Tables 2; 3; & 4); and the average values at these survey lines approximately adequate with potassium concentration in typical seawater (392 mg/l at salinity 3.8%) (PHL, 1998; USEPA, 1993). In line survey I it was observed that the values of potassium concentrations in Gaza Governorate are smaller than that are found in the Middle Governorate (Fig. 11). This could be suggest the dilution that has been happened by the carrying sea currents from SWW to NNE (Ubeid, 2011).



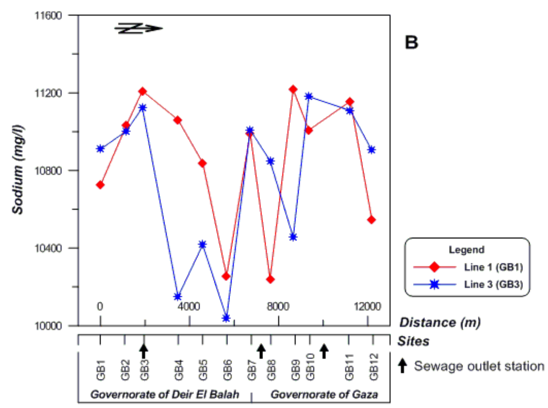


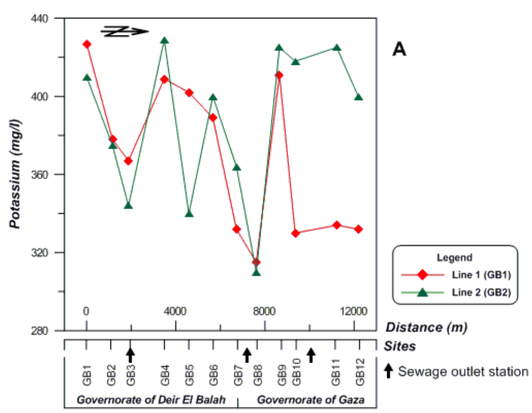
Figure 10: Shows the variation of the sodium concentrations in seawater samples in the study area. (A) Comparison between the sodium concentrations of seawater samples along the survey line I and II in the study area. (B) Comparison between the sodium concentrations of seawater samples along the survey line I and III in the study area. (C) Comparison between the sodium concentrations of seawater samples along the survey line II and III in the study area.

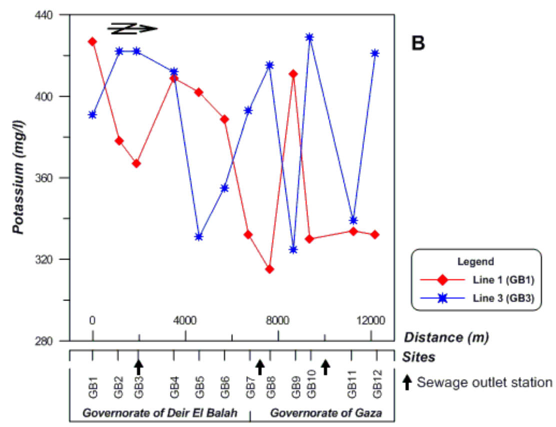
5. Correlations between each paired of major ion composition of seawater

Table 5A and Figure 12 summarize and depict the values of R-squared (coefficient determination) of the correlation between the paired of the major ion concentrations in the sample of the seawater along the line survey I at distance about 100 m in the study area. The results of R-squared of the correlations are approximately about to zero; except the relationships between Na+ and Cl-; and K+ and NO3- show slightly positive relationships (0.3 to 0.4).

The results of the correlations between the paired of the major ion concentrations in the seawater samples at line survey II at distance about 200 m in the study area are summarized and depicted in Table 5B and Figure 13. The results of the correlation show that the R-squared values are approximately about to zero; except the relationship between Na+ and Cl- shows slightly positive relationship (0.3).

Along the line survey III at distance about 350 m in the study area, the R-squared values of the correlation between the paired of major ion concentrations of the samples are summarized and depicted in Table 5C and Figure 14. The results of the correlation show that the R-squared values are approximately about to zero; except the relationship between Na+ and K+; and Na+ and NO3- show slightly positive relationships (0.2 to 0.3).





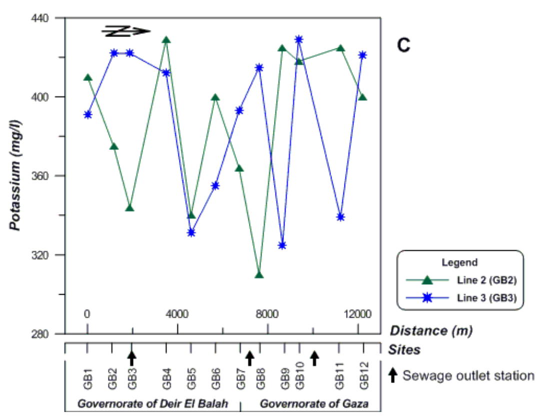


Figure 11: Shows the variation of the potassium concentrations in seawater samples in the study area. (A) Comparison between the potassium concentrations of seawater samples along the survey line I and II in the study area. (B) Comparison between the potassium concentrations of seawater samples along the survey line I and III in the study area. (C) Comparison between the potassium concentrations of seawater samples along the survey line II and III in the study area.

Table 5: R-squared (Coefficient determination) values of correlation between major ion concentrations of seawater samples. (A) Line survey I (see Fig. 12). (B) Line survey II (see Fig. 13). (C) Line survey 3 (see Fig. 14) of the study area.

A

	Ca^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}
Ca^{2+}	1				
Na^{+}	0.010	1			
K^{+}	0.051	0.034	1		
Cl^{-}	0.026	0.312	0.087	1	
NO_3^{-}	0.176	0.021	0.370	0.044	1

B

	Ca^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}
Ca^{2+}	1				
Na^{+}	0.167	1			
K^{+}	0.050	0.094	1		
Cl^{-}	0.001	0.339	0.001	1	
NO_3^{-}	0.178	0.030	0.126	0.050	1

C

	Ca^{2+}	Na^{+}	K^{+}	Cl^{-}	NO_3^{-}
Ca^{2+}	1				
Na^{+}	0.256	1			
K^{+}	0.026	0.206	1		
Cl^{-}	0.000	0.070	0.112	1	
NO_3^{-}	0.150	0.340	0.005	0.133	1

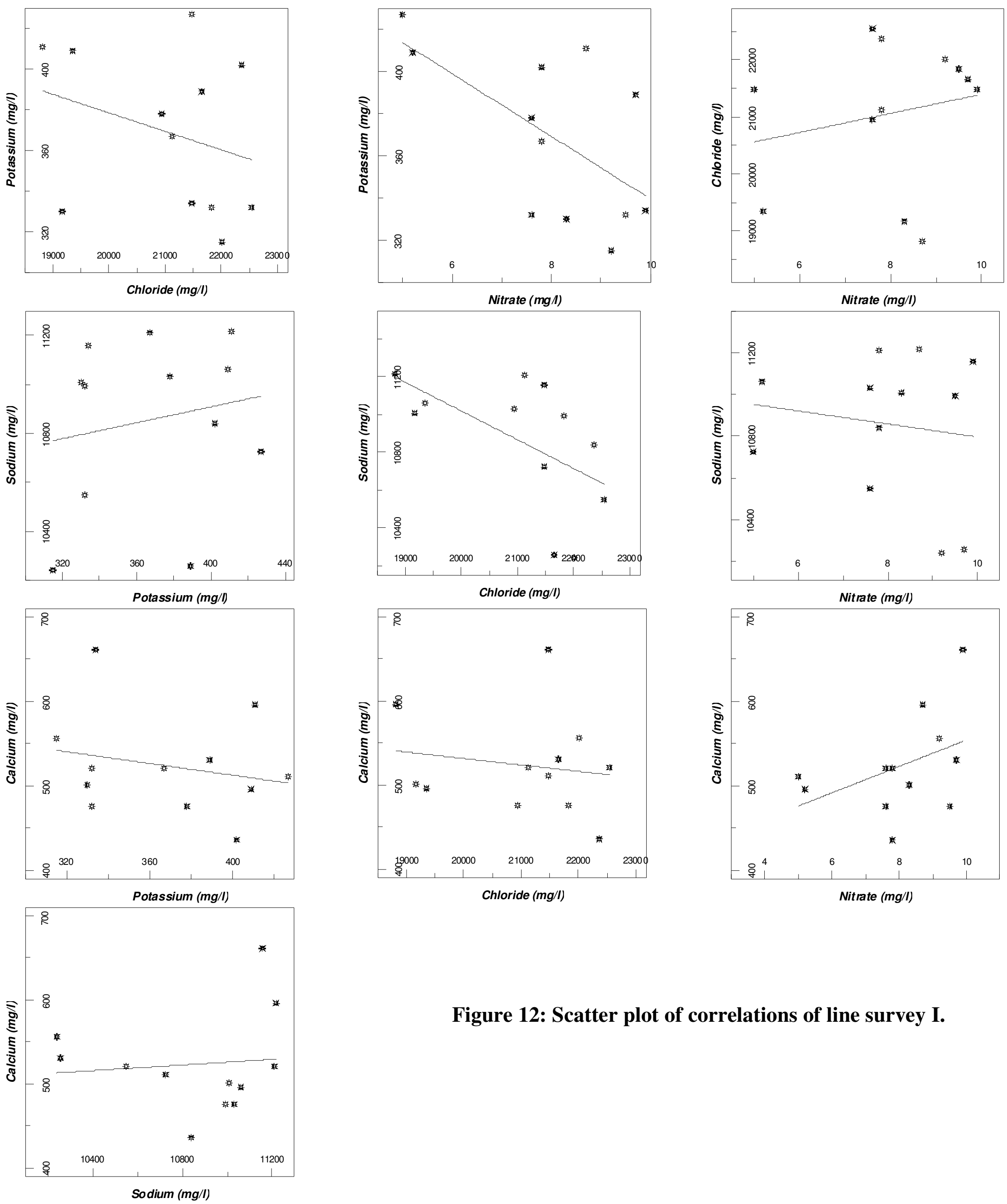


Figure 12: Scatter plot of correlations of line survey I.

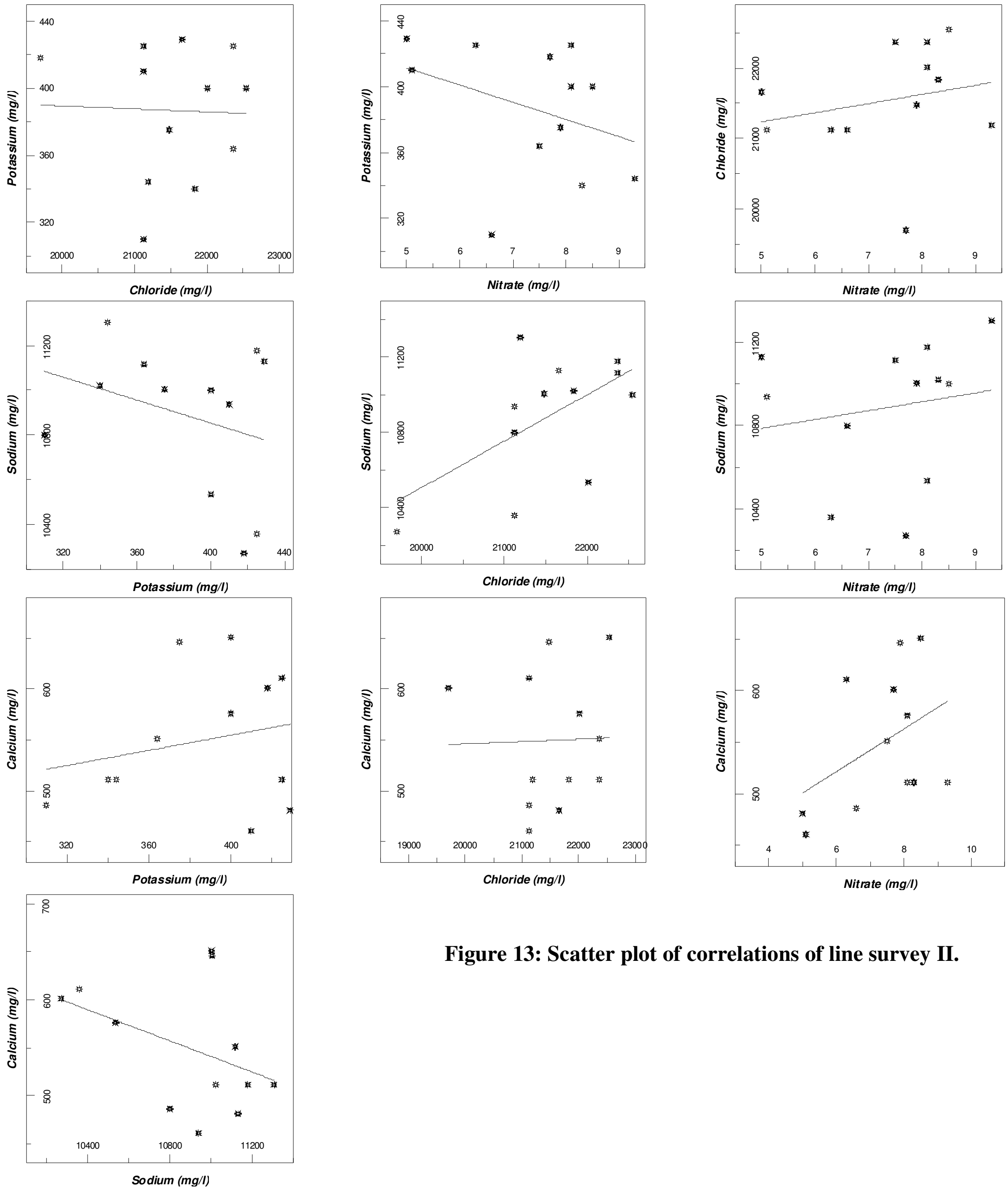


Figure 13: Scatter plot of correlations of line survey II.

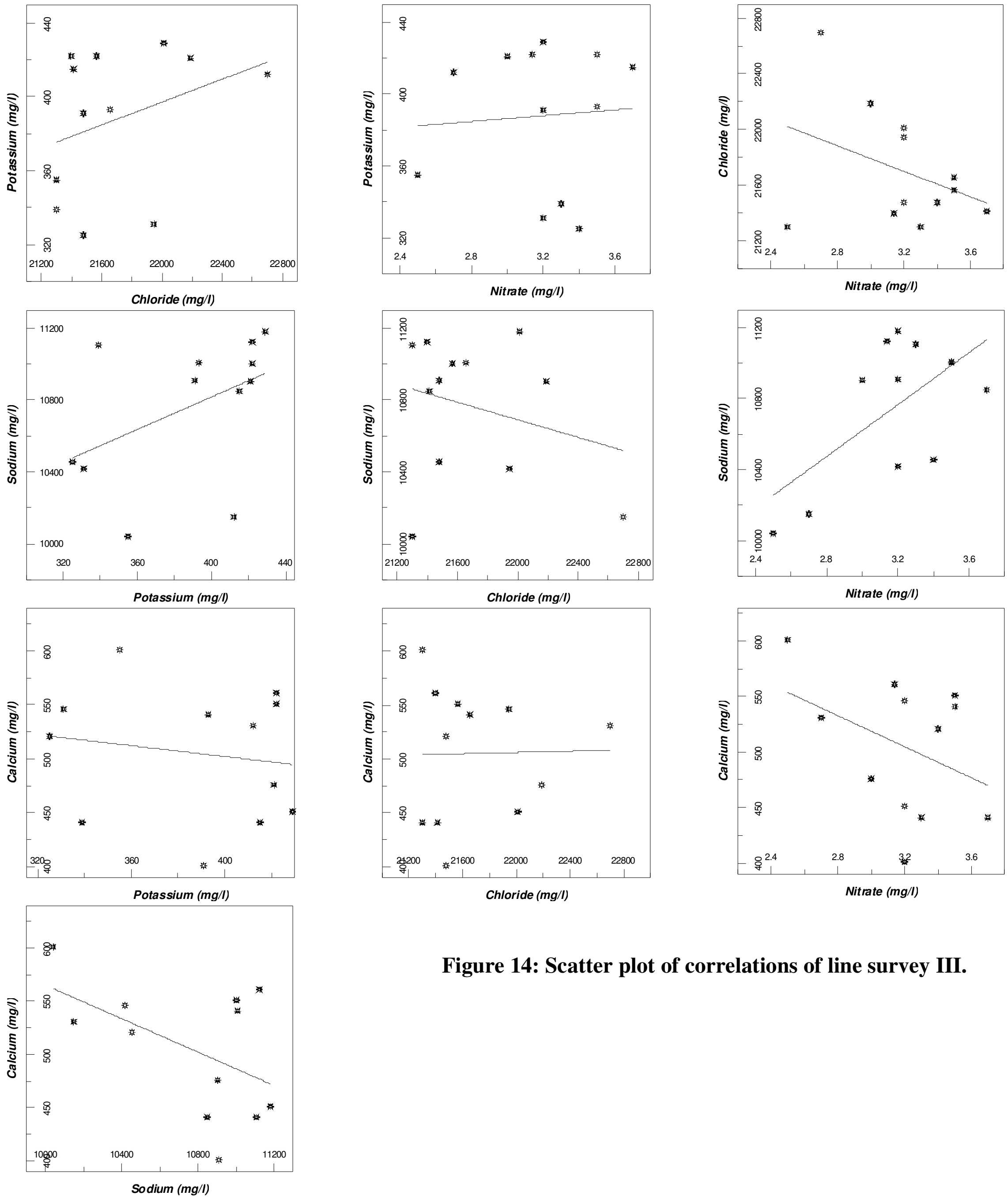


Figure 14: Scatter plot of correlations of line survey III.

6. Conclusion

Along the beach of Gaza Strip eight sewage stations are observed in addition to mouth of Wadi Gaza, which are pumping sewage into the seawater.

The pumping of the sewage into the beach of Gaza Strip causes the pollution in the seawater. The results of geochemical analysis show variations in physico-chemical parameters: pH; electrical conductivity (EC); total suspended solids (TSS); total dissolved solids (TDS); nitrates; chlorides; calcium; sodium; and potassium.

The results of pH value of the seawater samples in the study area ranged from 7.76 to 8.10. The effect of the raw sewage discharge and the runoff are clear in distance less than 200 meters within the sea.

The electrical conductivity (EC) of the seawater samples in the study area vary from 60053 µS/cm to 66256 µS/. The raw sewage discharge and runoff effects decrease to the minimum at distance 350 m in the sea.

The results show that the minimum value of the total suspended solids (TSS) vary from 39812 to 43156 mg/l. These results suggest that the effect of the pollution from sewage discharge and the runoff distributed was within the distance less than 200 m in the sea.

The seawater total dissolve solids (TDS) values in the study area range from 37644 mg/l to 14388 mg/l.

The effect of sewage discharge decrease in distance more than 200 m in the sea.

The seawater nitrates results in the study area show that the values range between 2.5 mg/l to 9.9 mg/l. The results indicate that the nitrate pollution in the seawater from raw sewage discharge are high in distance less than 200 meters in the sea.

Chloride concentrations in seawater samples of the study area range between 18815 mg/l to 22698 mg/l. The results of seawater chloride concentrations show that the effects of raw sewage discharge and runoff were distributed at distance of 100 m in the sea.

The calcium concentration in seawater samples of the study area range between 401 mg/l and 661 mg/l. The variation of calcium concentrations in the study area refer to the raw sewage discharge and runoff, where their effects start to decrease in regions further than 200 m in the sea.

The sodium seawater concentrations in the study area vary between 10041 mg/l to 11304 mg/l. The variation of sodium concentrations in the study area refer to the raw sewage discharge and runoff within distance less than 200 m in the sea.

The potassium concentration in seawater samples of the study area range from 310 mg/l to 429 mg/l. There are no significant differences between the average values of the potassium concentration in different location sites of the study area, and the average values at these sites approximately adequate with potassium concentration in typical seawater.

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