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Impact of Groundwater Discharges on Marine Water Quality in Doha, Qatar

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Abstract: Qatar is classified, according to its geographical location and climate, as a hot subtropical desert. Qatar's average annual rainfall is less than 130 mm/year (5 in). Doha, the capital of State of Qatar, is served by a collection system of groundwater and storm water which finally is disposed off into the marine water through three outfalls. In the future, another four proposed outfalls will be operating. This study aimed at assessing the impact of groundwater discharge on the receiving marine water quality. Water Samples were collected from the outfalls it themselves, Sea water from different sites around these outfalls at different distances, sea water Samples from different sites around the proposed points at different distances, and offshore samples as reference. Samples were collected during year 2007 and were analyzed physicochemically and microbiologically. Physicochemical characterization of the discharges showed that all measured parameters were complied with the environmental limits of both Qatar and GCC laws except turbidity and total suspended solids. The values of total and fecal coliform were higher than the permissible limits for Qatar and GCC environmental laws. The Physico-chemical characterization of the sea water samples collected from different sites around the discharged points recorded higher total suspended solids than the permissible limits stated by the Qatari law while the other parameters were complying with the law. Total suspended solids were higher than the permissible limits in all marine water samples while samples around the discharges points were the highest. The excess of some parameters reported by the study is due to the state urbanization and constructions activities in general. An integrated management plan must be carried out by all governmental and non-governmental authorities to protect the groundwater and avoid the deterioration of marine water quality.

INTRODUCTION

The GCC countries are characterized by a harsh desert environment devoid of rivers and lakes. The water resources consist of limited quantities of runoff resulting from flash floods, groundwater in the alluvial aquifers, and extensive groundwater reserves in deep sedimentary formations. Some of these countries also rely on non-conventional water sources such as desalinization of sea and brackish water and limited use of renovated wastewater. Groundwater in the shallow aquifers is the only renewable water source in some countries. Oil pollution in the

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region is very pronounced.[(1)]

Qatar is classified, according to its geographical location and climate, as a hot subtropical desert.[(2)] From May to October the Qatari climate is extremely hot, commonly reaching as high as 50°C (120°F), with high humidity near the coastline. In the other months the weather is generally moderate and pleasant, with daily temperatures averaging 17°C (63°F). Rainfall, which occurs only in the winter, is very slight: Qatar's average annual rainfall is less than 130 mm/year (5 in).[(3)] Sometimes, heavy storms that often flood the small ravines and the usually dry Wadies.[(4)]

The country has no rivers or lakes, and besides the rainfall received, the primary source of fresh water is the groundwater. Surface water is very limited; only after a good winter rainfall, water may be seen in depressions, Wadies, and runnels for a short time.[(2)] The scarcity of rainfall and the limited underground water, most of which has such a high mineral content that it is unsuitable for drinking or irrigation has restricted the population and the extent of agricultural and industrial development of the country could support until desalination projects began.[(4)]

Following rainfall events, runoff flows overland and picks up materials including but not limited to trash, debris, sediments, and organic pollutants. The runoff can often contain pollutants in quantities that will affect water quality. Runoff can carry a variety of pollutants that are associated with a specific land use. These materials can remain in solution or attach to sediment and will eventually be deposited in the lowest part of the landscape or discharged to creeks, rivers, lakes, sea, and wetlands.[(5)]

Increased pollutant loadings and discharges are still another impact of urban storm water runoff from impervious surface areas. Pollutants associated with urban areas are specific to the type and intensity of the land use. Some examples of pollutants associated with urban land uses include sediments, nutrients, oxygen demanding substances, heavy metals, oils and grease, hydrocarbons, and bacteria. Runoff from commercial land uses such as shopping centers, business districts, office parks, and parking lots or garages may contain high hydrocarbon loadings and metal concentrations. Pollutant loadings from these types of land uses can be a significant pollutant source in storm water runoff and can be attributed to heavy traffic volumes and large impervious surface areas. Gas stations are one type of land use that is often designated as a commercial land use and are subject to the same controls as shopping centers and office parks. However, gas stations may generate higher concentrations of heavy metals, hydrocarbons, and other automobile-related pollutants due to day-to-day activities associated with the industry and the volume of clientele that use the facilities. There is also a higher probability for spills to occur at these facilities because of human error.

Sediment is the most common pollutant associated with storm water runoff from construction sites. However, there are several other pollutants associated with construction activities. Some of these pollutants include, but are not limited to, solid wastes, nutrients, pesticides, petroleum products, and chemicals associated with construction activities.(5)

The urban areas in Qatar are experiencing groundwater aquifer contamination from many sources. Wastewater network can practice leaks reaching the surface soils, Septic tanks with soak bottoms which used in areas not served with wastewater collection systems. Road drainage and soak ways are another source of groundwater charge and pollution and Illegal discharges to the groundwater network from tankers emptying septic tanks. Uncontrolled dewatering activities after issuance of permits for new construction site preparations.

Doha, the capital of state of Qatar is served by a collection system of groundwater and storm water which are finally disposed off into the marine water through three outfall. In the future, another fourth proposed outfall will be operating.

This study aimed at assessing: 1-the impact of the discharged groundwater and storm water on the receiving sea water, 2-the water quality in compliance with the environmental laws in the region and with the references sites in Qatar marine water.

MATERIAL AND METHODS

Samples plan as follows:

Water samples were collected from the outfalls themselves through the pump stations. sea water samples were collected from different sites around these outfalls at different distances. Sea water samples were collected from different sites around the proposed points at different distances. Offshore samples were collected as reference. Samples were collected during year 2007. Samples were analyzed physicochemically and microbiologically according to standard methods (SM)[6], USEPA methods[7], UNEP[8] and chemical and biological methods for sea water analysis[9] as presented in table (1). All analyses were done at the Environmental Studies Centre, Qatar University.

RESULTS AND DISCUSION

Characterization of outfalls discharges:

Table (2) presented the physicochemical characterization of the discharges; it was noticed that all measured parameters were complied with the environmental limits of both Qatar and CGC laws except turbidity, total suspended, and dissolved solids. The mean values are 94.3 NTU, 2475.2 ppm, and 19653 ppm, respectively. Turbidity is surrogate of suspended solids. The high values of solids may be due to the seepage from the septic tanks, erosion from soils, and antecedent long dry period. Also the solids may be due to the construction activities which increase the precipitation load.

Toxic and persistent chemicals as presented in table (2) recorded phenol mean value of 0.008 ppb and PAHs 0.0006 ppm which comply with the permissible limits for both Qatar and GCC laws. On the other hand, TPHs and PCBs detected mean values of 9.16 ppb and 0.01 ppb, respectively. No limits for both were reported by the laws.

As presented in table (3), heavy metals were far below the permissible limits of the Qatar and GCC environmental laws. These are due to that this groundwater does not contain industrial sources.

Attributed to the indicator organisms of fecal pollution, the total coliform mean value was 6.9E+04 MPN/100 ml. and fecal coliform mean value was 2.7 E+04 MPN/100 ml. On the other hand, fecal streptococci mean value was 9.0E+10 MPN/100 ml. As shown by figure (1), the values of total and fecal coliform were higher than the permissible limits for Qatar and GCC environmental laws. These results were the guide for the presence of seepage from the septic tanks, illegal tankers empting and sewers system corrosion. Other sources for coliform are the storm water runoff. No limit was recorded for fecal streptococci by both laws. Fecal streptococci have not been widely used as fecal pollution indicators. The use of the fecal streptococci is to assess the relative contributions of animal and human fecal sources to observed levels of microbiological contamination in water systems.[10]

Characterization of marine water:

1- Around the discharge

Physico-chemical characterization:

Waterways and receiving waters near urban and suburban areas are often adversely affected by urban storm water runoff. Urban runoff was the leading source of pollutants causing water quality impairment. Adverse impacts on receiving waters associated with storm water discharges have been discussed in terms of three general classes.[11] These are: • Short-term changes in water quality during and after storm events including temporary increases in the concentration of one or more pollutants, toxics or bacteria levels. • Long-term water quality impacts caused by the cumulative effects associated with repeated storm water discharges from a number of sources. • Physical impacts due to erosion, scour, and deposition associated with increased frequency and volume of runoff that alters aquatic habitat.

Pollutants associated with urban runoff potentially harmful to receiving waters fall into the categories listed below:[11]

• Solids • Oxygen-demanding substances • Nitrogen and phosphorus

• Pathogens • Petroleum hydrocarbons • Metals • Synthetic organics.

As represented in table (4), the Physico-chemical characterization of the sea water samples collected from different sites around the discharged points recorded that: Total suspended solids were higher than the permissible limits stated by the Qatari law while the other parameters comply with the law. Attributed to the high value of suspended solids, 79.5 ppm, it can lead to alterations of the physical, chemical, and biological properties of the water-body. Physical alterations caused by SS include reduced penetration of light and temperature changes.[12]

Chemical alterations caused by SS include the release of contaminants, such as heavy metals and pesticides, and nutrients such as phosphorus, into the water body from adsorption sites on the sediment.[12] High suspended solids attributed to the discharges which already contain high values. In road/highway runoff, suspended solid (SS) is considered as one of the major pollutant since many micro-pollutants are attached to it[13,14]. The pollutants' accumulating behavior depends on SS particle sizes. [15]

Toxic and persistent chemicals:

Phenol is commonly found in phenolic resins used in the plywood, construction, automotive and appliance industries. Some phenolic compounds occur in a variety of residential and commercial cleaning products such as detergents, shampoo, and surface cleaners. At high concentrations, phenol is toxic to aquatic organisms.(16) The present results detected phenol mean value of 9.79 ppb, as presented in table (4), which un-complies with the limits. Sewage and storm-water are the likely sources of such chemicals in the marine environment.(17) The environmental half-lives of phenols are short, rarely as long as month. Some are photo-degraded, especially in air. Once a discharge ceases, environmental levels will drop rapidly due to the bacterial breakdown. The existence of high level in fish tissues indicates chronic or current exposure. At extremely low phenol values, there are two effects apparent in phenol-contaminated waters: toxicity to aquatic life and the generation of an unpleasant taste in fish and shellfish.(18)

Polychlorinated biphenyls (PCBs) are one of the 12 POPs chemicals. PCBs comprise over 200 individual compounds of varying toxicity. POPs are known to have toxicological impact on wildlife and humans.(16) The results reported, as presented in table (4), mean value of PCBs was 30.4 ppb. No limits recorded in Qatari law for it. It is known that PCBs contaminants are generally bound to the soil and sediments and may be released to the water slowly over a long time. The detection of PCBs in marine water reflecting impact of past sewage discharges and urban runoff.(16)

Polycyclic aromatic hydrocarbons are a group of chemicals derived primarily from the incomplete burning of organics; some PAHs are recognized as carcinogenic (e.g., benzo(a)pyrene).(18) The present study detected that PAHs mean value was 22.2

ppb as represented in table (4). There are many traffic- related sources of PAHs which include vehicle exhaust, lubricating oils, gasoline, diesel fuel, and tyre particles [19-21]. Also the contamination of water and soil by PAHs along highways reported by other studies[22, 23].

Other sources of PAHs in theenvironment are diverse, including cigarette smoke, grilling of meat, coal burning, and hazardous waste sites.[15] Micro-pollutants such as PAHs and heavy metals are widely distributed in dust, soils, and sediments, and are found in roof and road runoff[24]. Hoffman *et al*.,[25] estimated that 36% of environmental PAH input was due to urban runoff; for the higher molecular weight PAHs, the figure was 71%. Urban runoff has been recognized as an important PAH pathway to water environments and aquatic ecosystems. Hence, effective control strategies for PAHs in urban runoff are required to assure human and ecosystem safety. Krein and Schorer[22] reported higher molecular weight PAHs attached to coarse particle fraction.

Pollution of sea by petroleum hydrocarbons land based discharges, and atmospheric and natural inputs.[26] Results reveled that TPHs mean value was 2.7 ppb as presented in table (4). It complies with the limits while its maximum value of 18.9 ppb does not comply. The concentration of hydrocarbons and metals related to the land use, commercial, roads, and industrial land uses had higher concentrations of both metals and PAHs than residential land uses.[27] Though a considerable fraction of petroleum hydrocarbons entering the marine environment is removed by evaporation, a portion gets distributed in water, accumulated in sediment and transferred to biota. The input of petroleum hydrocarbons to the marine environment from different sources as follows: 65.2% is discharged through municipal and industrial waste, urban and river runoffs, oceanic dumping and atmospheric fallout; 26.2% derives from discharges during transportation, dry docking, tanker accidents, de-blasting,…,etc.; and remaining 8.5% comes from fixed installations like coastal refineries, offshore production facilities, marine terminals,…,etc.[26] the concentration of TPHs is often high in the bottom water particularly at inshore shallow areas. The sediment particles rich in TPHs dispersed in the water column by strong tidal currents sweeping these zones could contribute to dissolve TPHs. The concentrations of TPHs in the coastal waters of India vary widely and values in the range 0-139 ppb.[28,29] Chouksey *et al*.,[26] reported TPHs in water off Bassein-Mumbai (India) varies widely (2.9-39 ppb).

Metals

Results indicated that, 4 metals were detected in higher values than the permissible limits. These are Iron with mean value of 134.7 ppb, Copper with mean value of 85.9 ppb, Cadmium with mean value of 318.4, ppb and lead with mean value of 23.3 ppb as presented in table (5).

In Qatar, there are many projects for road construction and maintenance which causes various types of environmental concerns. Asphalt may come into contact with many chemicals generated from road traffic during use of the pavement: vehicle exhaust, gasoline, lubricating oils, and metals from tyres and brake lining wear. The major chemicals typically investigated in relation to asphalt pavement are heavy metals (Cd, Cr, Cu, Ni, Pb, and Zn) and polycyclic aromatic hydrocarbons (PAHs)[30]. Moreover, zinc and cadmium are produced mainly from tyre wear and the corrosion of galvanized steel crash barriers, and brake lining wear constitutes a source of copper[18] the heavy metal contamination of highway runoff water and roadside soils was reported by other studies.[31,32]

2- Around the proposed discharged points:

Physico-chemical characterization:

As presented in table (6) total suspended solids are still higher than the permissible limits but it is lower than the samples around the discharges points. Suspended solids here may be due to the dewatering activities during the construction which are disposed to the sea directly. This proved that there is non point source. The others characterization are complying with the limits.

Generally, most parameters were detected in lower values than values detected in samples around the discharges points. Turbidity, COD, and oil and grease are higher which also indicate presence of non-point source. Oil and grease may be due to the fishing boats activities.

There is depletion of DO more than in samples around discharge points which indicate the presence of oxygen depleting compounds deposited from the high values of oil and grease and suspend ded solids.

Toxic and persistent chemicals:

Phenol was detected in mean value of 19.3 ppb, as presented in table (6), which un-complies with the limits and higher than values of samples around discharges. This was attributed to the urbanization in these areas.

PCBs were detected in mean value of 0.0004 ppb and PAHs mean value of 0.434 ppm. These values are far below the values recorded in samples around discharges. This may be due to the decrease in suspended solids detected and also the slowly release of such compound to the water from the soils and sediments which they are bound by them. As contributed to the TPHs as presented in table (6), the mean value was 2.737 ppb and complies with the limits. Also the maximum value was higher than the limits but lower than detected in samples around discharges. Generally these results indicated that the discharges are the main source of the input of such contaminant to the marine environment.

Metals

According to the limits presented by Qatari law, all metals detected mean values complying with the law except for iron, copper, and cadmium which detected mean values of 110 ppb, 91 ppb, and 446 ppb, respectively, as presented in table (7). This is again resulting from the new roads construction and maintenance. Heavy metals including lead, copper, cadmium, Zinc, mercury, and chromium come from many sources: industrial activates and waste, illicit sewage connections, automobile wear exhaust and fluid leaks, and atmospheric deposition. These metals increase the toxicity of runoff and availability of metals that can enter into the food chain. Consequently, they accumulated in certain animal tissues that could be ingested by humans or other animals.[6] In comparison with the samples collected from sites around the discharges points; Magnesium, Beryllium, Chromium, Copper, Zinc, and Cadmium were higher. This may be due to the urbanization and new constructions projects near these points.

2- Offshore reference point:

Physico-chemical characterization:

Samples were collected from offshore sites to take it as references points. As represented in table (8), total suspended solids were slightly higher than the limits. It was noticed that inshore marine samples salinity were close to offshore samples which indicate that the discharged water did not change the marine ecology. Offshore sites detected the highest values of the oil and grease, 10.45 ppm, and total chloride, 27139.5 ppm in comparison with the shore sites. This could be attributed to the low dilution factors for the offshore points and the increase of the boats activities.

Toxic and persistent chemicals:

Phenol compounds are physic-chemical degradation by-products of many chemicals used in off-shore digging activities and oils discharged from ships engines cooling water. Their values are not complying with the law limits as their detected values were high with a mean value of 31.9 ppb. This can also be attributed to their low biodegradability. PCBs were detected mean value of 0.0005 ppb and TPHs mean value of 0.064 ppb. TPHs were far below the permissible limits as represented in table [8].

Metals

Metals measurements results, as presented in table (9), revealed that iron and copper are still higher than the limits and detected highest values. Iron mean value was 199.5 ppb and copper mean value was 150.2 ppb. Katz and Rosen[33] in their study reported that both copper and zinc concentrations were predictive of toxicity.

It was noticed that these offshore samples detected highest values of some metals: calcium (1991.5 ppm), Beryllium (246.2 ppb), cobalt (0.82 ppb), Nickel (4.5 ppb), and selenium (69.2 ppb).This was due to the digging activities for gas.

3-Sea water microbiological characterization:

Indicator organisms:

The public health impacts of microbial contaminants are often a particular concern. Studies have identified potential links between storms and the outbreak of waterborne disease in human populations[34, 35].

Results recorded that as shown in figure (2), all indicator organisms examined were detected in highest values in the samples collected from sites around discharges points. This is related to the discharges itself. Total coliform was the highest one with mean MPN value of 5.62E+03/100 ml followed by fecal streptococci with mean MPN value of 1.36E+03/100 ml and finally fecal coliform with mean MPN value of 1.86E+02/100 ml. No limits were reported by Qatari law concerning the indicator organisms in sea water quality. Storm events and the resulting runoff generally account for a disproportionate fraction of total microbial loading to many receiving waters [36].

Samples collected around the proposed points showed that fecal streptococci were the highest indicator, as shown in figure (2), with mean MPN value of 2.67E+02/100 ml. On the other hand, no fecal coliform was detected in reference samples. While total coliform value(6.35 MPN/100 ml) was higher than fecal streptococci (1.8 MPN/100 ml).

Microbes associated with particles, particularly denser inorganic particles, will tend to settle out of the water column more quickly, while free phase organisms or those associated with less dense particles will remain more mobile in the marine environment. It has also been observed that microbes associated with particles tend to survive longer in natural waters[(37)]. Tidal water action can influence fecal indicator bacteria regrowth and its remobilization from sand leading to erroneous water quality postings [(38)]

Generally, as shown in figure (2), fecal streptococci are higher than fecal coliform in all sites. Faecal streptococci (which were termed "enterococci" survived longer in sea water than coliforms and *E. coli.* The *Enterococcus* organism may be the best indicator of recent pollution in sea water. Coliforms are sensitive to salinity, surviving more poorly in sea water (T90 of 2.2 h) compared to fresh water. However, the phenomenon of superior survival of streptococci in sea water may, in part, be the result of superior resistance to sunlight. The authors concluded that faecal streptococci would make the most accurate indicators in sea water containing organic material since they do not multiply in such water and they show appreciable die-off rates within a 2-3-day period".[(10)] *E. coli* survival in marine water was 0.8 d while enterococci survival was 2.4 d. *E. coli* degraded more rapidly with increased sunlight intensity than did enterococci.[(39)]

Phytoplankton and Zooplankton:

Phytoplankton and zooplankton were counted in sea water samples collected from sites around the discharges and from offshore sites as reference sites. Results, as shown in figure (3), indicated higher count for both around discharges than offshore samples. Samples around discharges sites recorded phytoplankton and zooplankton mean values of 1.05E+03 cells/l and 3.6E+03 cells/l, respectively. On the other hand, offshore samples recorded phytoplankton and zooplankton mean values of 5.0E+02 cells/l and 6.0E+01 cells/l, respectively.

Direct and interactive effects of available solar radiation, and total phosphorus concentrations were found to be the best predictors of phytoplankton populations.[40] Results revealed that the total phosphorus was higher in samples around discharges than in offshore samples.

Phytoplankton far from being negatively affected by the level of NH_3 <2.5 mg/l. it appear to be the main factor responsible for its increase. An intense photosynthetic activity and high related pH, leads to a decrease in zooplankton biomass.[41] Results reported NH_3 <2.5 mg/l for both sites.

Phytoplankton primary production was not affected by $N0_3$ enrichment up to 1 mg of N per liter. NO_3^- uptake is directly dependent on or related to electron transport to produce photoreductant.[42] Results reported NO_3-N <1.0 mg/l for both sites. Relatively low levels of PCB can adversely affect certain physiological functions of algae in nature. Perhaps the most important impact was the marked reduction in biomass of all size classes for several days, an effect that might influence the availability of food for grazers (10' 23) in a complete plankton community.[43] This can explain the generally low count recorded in samples.

CONCLUSIONS AND RECOMMENDATIONS

Suspended solids are the major highest parameter in all samples of discharges to marine water. Consequently, the other pollutant may adhere with it and exceeds their values. Qatar must proceed with an integrated management plan for the groundwater. All governmental and non-governmental authorities should be committed to participate in the plan covering the following items:

- Primary Treatment of the groundwater before it's discharged to the sea to minimize the amount of suspended and settleable solids with their burden of microorganisms.
- The use of advanced technology for sweeping streets to confirm the removal of all small particulates which carry out the microbes and adsorbed pollutants.
- Increase greening and landscaping to decrease the surface runoff.
- Monitoring of the dewatering activities of new constructions through construction permit.
- Monitoring the illegal discharge of tankers carrying industrial and septic tanks wastes.

- Monitoring to the quality of the discharged water.
- Sewage sewers system must cover all the urban areas as planned in the near future.
- Qatar climate characterized by long period of sandy wind, so cultivation and maintaining a green belt surrounding the state can reduce its adverse effects on the environment.
- The environmental laws must report limits for fecal indicators in marine water.

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Table (1): The different Physico-chemical and microbiological analytical methods used in the study

No.	Parameter	Analytical Methods number and reference	Technique
1	pH, Temperature, Salinity , Conductivity , and Turbidity	Calibrated according to manufacture instruction	YSI 6820
2	DO	SM-4500-O(6)	Titration
3	Total Residual Chlorine/Free Chlorine, and COD	HACH	Spectrometry
4	TSS/TDS	SM-2540(6)	Gravimetric
5	BOD_5	SM-5210-B(6)	Membrane Electrode
6	TOC	USEPA 415.1(7)	C/N analyzer
7	Alkalinity	SM-2320-B(6)	Titration
8	Total Chloride	SM-4500-Cl-(6)	Titration
9	Sulfide	UNEP, 1991, No. 50(8)	Spectrometry
10	Sulfate	SM-4500-SO4-2 -D(6)	Gravimetric
11	Nitrate-Nitrogen	USEPA 353.3(7)	Spectrometry
12	Nitrite-Nitrogen	USEPA 354.1(7)	Spectrometry
13	Ammonia-Nitrogen	Reference (9)	Spectrometry
14	Phosphate	USEPA 365.2(7)	Spectrometry
15	Phenols	SM-5530(6)	Spectrometry
16	Oil and Grease	USEPA 1664(7)	Gravimetric
17	PAHs	USEPA 8270(7)	GC-MS
18	TPHs	USEPA 8015b(7)	GC-FID
19	Metals	USEPA 200.8(7)	ICP/MS
20	Mercury	USEPA 245.2(7)	CVAAS
21	PCBs	USEPA 8082(7)	GC-ECD
22	Total coliform	SM- 9221B(6)	Tube Fermentation
23	Fecal coliform	SM- 9221E(6)	Tube Fermentation
24	Fecal streptococci	SM- 9230B(6)	Tube Fermentation
25	Phytoplankton	SM- 10200C, F(6)	Concentration and counting
26	Zooplankton	SM- 10200C, G(6)	Concentration and counting

Table (2): Physico-chemical characterizations and persistence and toxic chemicals for water samples collected from discharge points

Parameter (ppm)	Mean	Max.	Min.	Limits	
				Qatar	GCC
Temperature (°C)	-	30	24	Not to exceed 3 degrees above the prevailing temperature	10^0 C above the ambient temperature
Conductivity (mS/cm)	22.8	61.6	4.7	-	-
DO	7.0	7.9	6.1	-	-
pH	-	8.23	8.03	6	9
Turbidity (NTU)	94.3	301	13.8	50	50-75
Total Suspended Solids	2475.2	20950.0	25.2	50	15-50
Total Dissolved Solids	19653.1	44674	3954	1500	1500
COD	47.8	149.8	0.0	100	100-250
BOD	1.3	1.8	0.12	50	20-50
Total Organic Carbon	52.3	248	6.02	-	75
Oil and Grease	1.6	10.1	0.0	15	10-15
Total Alkalinity	158.7	198	75.1	-	-
Ammonia-N (NH_3)	0.4	2.5	0.002	3	1-3
Nitrate-N (NO_3^-)	1.9	6.5	0.3	-	-
Nitrite-N (NO_2^-)	0.1	0.2	0.002	-	-
Total Kjeldahl Nitrogen	0.1	0.5	0	10.0	5.0
Dissolved Inorganic Phosphorus	0.1	0.7	0	2.0	2.0-5.0
Total Chloride	9227.9	24192	1303	--	-
Sulfide	0.1	0.4	0	0.1	0.1-0.5
Sulfate	4360.3	11447	1632	-	-
TPAHs (ppm)	0.00055	0.00065	0.00049	0.1	0.001-0.2
TPHs (ppb)	9.16	22.44	0.05	-	-
PCBs (ppb)	0.01	0.01	0.001	-	-
Phenol (ppm)	0.008	0.018	0	0.5	0.002-5

Table (3): Metals concentrations in water samples collected from discharges

Parameter(ppm)	Mean	Max.	Min.	Limits	
				Qatar	GCC
Magnesium (Mg)	581.3	1292	63	-	-
Calcium (Ca)	1383	5031	140	-	-
Mercury (Hg)	0.0002	0.0001	0.00002	0.001	0.001-0.005
Beryllium (Be)	0.0004	0.0005	0.000002	-	-
Aluminium (Al)	0.153	0.636	0.0046	3.0	3-25
Chromium (Cr)	0.052	0.172	0.005	0.2	0.1- 0.5
Manganese (Mn)	0.015	0.060	0.00049	0.2	0.2-1
Iron (Fe)	0.066	0.0334	0.00014	1.0	1.5-10.0
Cobalt (Co)	0.0009	0.001	0.00049	2.0	0.5-2.0
Nickel (Ni)	0.008	0.013	0.004	0.5	0.1-2
Copper (Cu)	0.036	0.113	0.00049	0.5	0.2-1.5
Zinc (Zn)	0.008	0.032	0.00049	2.0	0.1-2
Arsenic (As)	0.007	0.015	0.00049	0.5	0.1
Selenium (Se)	0.099	0.460	0.00049	0.02	0.02
Silver (Ag)	0.0007	0.004	0	0.005	0.005-0.1
Cadmium (Cd)	0.191	0.621	0.00049	0.05	0.01-0.2
Antimony (Sb)	0.0007	0.002	0	-	-
Barium (Ba)	0.032	0.058	0.009	2.0	2.0
Lead (Pb)	0.007	0.041	0.0001	0.1	0.08-5

Table (4): Physico-chemical characterizations and persistence and toxic chemicals for marine water samples collected from points around discharges

Parameter (ppm)	Mean	Max.	Min.	Qatar Limits
Temperature (°C)	-	30.5	17.1	-
Conductivity (mS/cm)	57.85	63.45	45.23	-
Salinity (PSU)	39.83	42.66	32.19	33-45 (PSU)
DO	6.73	10.09	5.55	>4 (ppm)
DO%	106.13	132.7	89.6	-
pH	-	8.49	7.42	6.5-8.3
Turbidity (NTU)	56.53	207	0.11	-
Free chlorine	0.20	1.02	0.02	-
Total chlorine residual	0.16	0.51	0.01	-
Total Suspended Solids	76.49	429.91	15.33	30 (ppm)
Total Dissolved Solids	40105.38	48045	19099	-
COD	39.56	110	0	-
BOD	1.29	2.37	0.65	-
Total Organic Carbon	25.90	178	9.17	-
Oil and Grease	1.32	6.0	0	-
Total Alkalinity	158.72	203	103	-
Ammonia-N (NH_3)	0.07	0.29	0.004	0.7 (ppb)
Nitrate-N (NO_3^-)	0.69	3.84	0.11	100 (ppb)
Nitrite-N (NO_2^-)	0.02	0.11	0.004	35 (ppb)
Total Kjeldahl Nitrogen	0.37	1.39	0	-
Dissolved Inorganic Phosphorus	0.05	0.92	0	30 (ppb)
Total Chloride	21964.38	33529	9201	-
Sulfide	0.03	0.15	0	-
Sulfate	7776.65	38014	1222	-
TPAHs (ppb)	22.15	39.59	0.386	-
TPHs (ppb)	2.737	18.95	0.057	5 (ppm)
PCBs (ppb)	30.39	549	0	-
Phenol (ppb)	9.79	73.4	0	Not to be present

Table (5): Metals concentrations in marine water samples collected from points around discharges

Parameter(ppb)	Mean	Max.	Min.	Qatar Limits
Magnesium (Mg) (ppm)	1154.74	1748	9.09	-
Calcium (Ca) (ppm)	2042.85	6296	0.31	-
Mercury (Hg)	0.120	0.49	0.005	<0.4 (ppb)
Beryllium (Be)	101.11	518	0.006	-
Aluminium (Al)	1907.73	18297	0.49	-
Chromium (Cr)	52.35	94	0.49	-
Manganese (Mn)	12.99	311.97	0	-
Iron (Fe)	134.733	12742	0	90 (ppb)
Cobalt (Co)	1.403	6.03	0.36	-
Nickel (Ni)	6.929	19.03	0.49	20 (ppb)
Copper (Cu)	85.959	179.73	0	15 (ppb)
Zinc (Zn)	26.298	250.2	0	-
Arsenic (As)	121.997	2570	0.31	-
Selenium (Se)	500.896	2655	0.89	-
Silver (Ag)	74.925	1698	0.059	-
Cadmium (Cd)	318.410	2228	0.49	0.7 (ppb)
Antimony (Sb)	2.154	37.69	0	-
Barium (Ba)	14.919	37.26	0.013	-
Lead (Pb)	23.325	547	0	12 (ppb)

Table (6): Physico-chemical characterizations and persistence and toxic chemicals for marine water samples collected from points around proposed sites

Parameter (ppm)	Mean	Max.	Min.	Qatar Limits
Temperature (°C)	-	30.1	16.7	-
Conductivity (mS/cm)	61.5	63.9	52.7	-
Salinity (PSU)	41.9	43.1	40.1	33-45 (PSU)
DO	6.4	10.4	4.6	>4 (ppm)
DO%	96.6	141	64.8	-
pH	-	8.5	7.5	6.5-8.3
Turbidity (NTU)	61.3	511	0.3	-
Free chlorine	0.05	0.15	0	-
Total chlorine residual	0.152	0.33	0	-
Total Suspended Solids	46.5	96.7	23.7	30 (ppm)
Total Dissolved Solids	32114.5	57552	41.24	-
COD	52.2	120	0	-
BOD	1.3	2.2	0.9	-
Total Organic Carbon	25.1	63.5	10.3	-
Oil and Grease	7.1	35.6	0	-
Total Alkalinity	145.8	178	77	-
Ammonia-N (NH_3)	0.04	0.1	0.01	0.7 (ppb)
Nitrate-N (NO_3^-)	0.13	0.53	0.004	100 (ppb)
Nitrite-N (NO_2^-)	0.01	0.02	0	35 (ppb)
Total Kjeldahl Nitrogen	0.42	0.75	0	-
Dissolved Inorganic Phosphorus	0.004	0.04	0	30 (ppb)
Total Chloride	20818.7	33498	9834	-
Sulfide	0.013	0.035	0	-
Sulfate	4325.4	9668	2369	-
TPAHs (ppb)	0.434	0.435	0.426	-
TPHs (ppb)	1.848	12.3	0.056	5(ppm)
PCBs (ppb)	0.0004	0.0008	0	-
Phenol (ppb)	19.3	80.4	0	Not to be present

Table (7): Metals concentrations in marine water samples collected from points around proposed sites

Parameter(ppb)	Mean	Max.	Min.	Qatar Limits
Magnesium (Mg) (ppm)	1326.9	1803	122	-
Calcium (Ca) (ppm)	1323.4	3624	31	-
Mercury (Hg)	0.093	0.4	0.009	<0.4 (ppb)
Beryllium (Be)	148.7	518	0.002	-
Aluminium (Al)	10.5	34.3	0.49	-
Chromium (Cr)	95.8	237	5	-
Manganese (Mn)	1.01	2.94	0	-
Iron (Fe)	110.8	314	0	90 (ppb)
Cobalt (Co)	0.73	1.25	0.49	-
Nickel (Ni)	3.9	8.5	0.49	20(ppb)
Copper (Cu)	91.4	173.7	11.2	15 (ppb)
Zinc (Zn)	144.7	1227	0.49	-
Arsenic (As)	15.7	22	1.7	-
Selenium (Se)	55.04	88.9	6.49	-
Silver (Ag)	0.34	0.49	0.11	-
Cadmium (Cd)	446.4	1979	0.49	0.7 (ppb)
Antimony (Sb)	0.89	3.62	0	-
Barium (Ba)	9.25	21.96	0.38	-
Lead (Pb)	2.01	15.3	0	12 (ppb)

Table (8): Physico-chemical characterizations and persistence and toxic chemicals for marine water samples collected from offshore points

Parameter (ppm)	Mean	Max.	Min.	Qatar Limits
Temperature (°C)	-	29	23	-
Conductivity (mS/cm)	62.6	63.2	61.9	-
Salinity (PSU)	41.6	41.6	41.6	33-45 (PSU)
DO	5.9	6.4	5.5	>4 (ppm)
DO%	89.4	89.4	89.4	-
pH	-	8.5	8.3	6.5-8.3
Turbidity (NTU)	11.9	22.9	0.8	-
Free chlorine	ND	ND	ND	-
Total chlorine residual	ND	ND	ND	-
Total Suspended Solids	36.9	37	36.8	30 (ppm)
Total Dissolved Solids	22018.6	43997	40.27	-
COD	31.4	62.9	0	-
BOD	0.76	1.33	0.19	-
Total Organic Carbon	16.2	17.1	15.3	-
Oil and Grease	10.45	20.9	0	-
Total Alkalinity	145.5	149.9	141	-
Ammonia-N (NH_3)	0.25	0.49	0.01	0.7 (ppb)
Nitrate-N (NO_3^-)	0.027	0.027	0.007	100 (ppb)
Nitrite-N (NO_2^-)	0.001	0.002	0	35 (ppb)
Total Kjeldahl Nitrogen	0	0	0	-
Dissolved Inorganic Phosphorus	0.005	0.01	0	30 (ppb)
Total Chloride	27139.5	33290	20989	-
Sulfide	0.017	0.02	0.014	-
Sulfate	5083	5818	4348	-
Phenol (ppb)	31.9	63.9	0	Not to be present
TPHs	0.064	0.08	0.047	5 (ppm)
PCBs (ppb)	0.0005	0.0009	0	-

Table (9): Metals concentrations in marine water samples collected from offshore points

Parameter(ppb)	Mean	Max.	Min.	Qatar Limits
Magnesium (Mg) (ppm)	1239.5	1344	1135	-
Calcium (Ca) (ppm)	1991.5	3702	281	-
Mercury (Hg)	0.012	0.014	0.01	<0.4 (ppb)
Beryllium (Be)	246.2	492	0.49	-
Aluminium (Al)	4.555	8.6	0.49	-
Chromium (Cr)	55.2	63.4	47	-
Manganese (Mn)	1.035	1.58	0.49	-
Iron (Fe)	199.5	285	114	90 (ppb)
Cobalt (Co)	0.82	1.15	0.49	-
Nickel (Ni)	4.5	8.51	0.49	20 (ppb)
Copper (Cu)	150.2	181.3	119	15 (ppb)
Zinc (Zn)	88.4	176.3	0.49	-
Arsenic (As)	12.2	15.6	8.8	-
Selenium (Se)	69.2	78.9	59.5	-
Silver (Ag)	0.28	0.49	0.07	-
Cadmium (Cd)	0.49	0.49	0.49	0.7 (ppb)
Antimony (Sb)	0.39	0.49	0.29	-
Barium (Ba)	5.8	11.1	0.49	-
Lead (Pb)	0.33	0.49	0.17	12 (ppb)

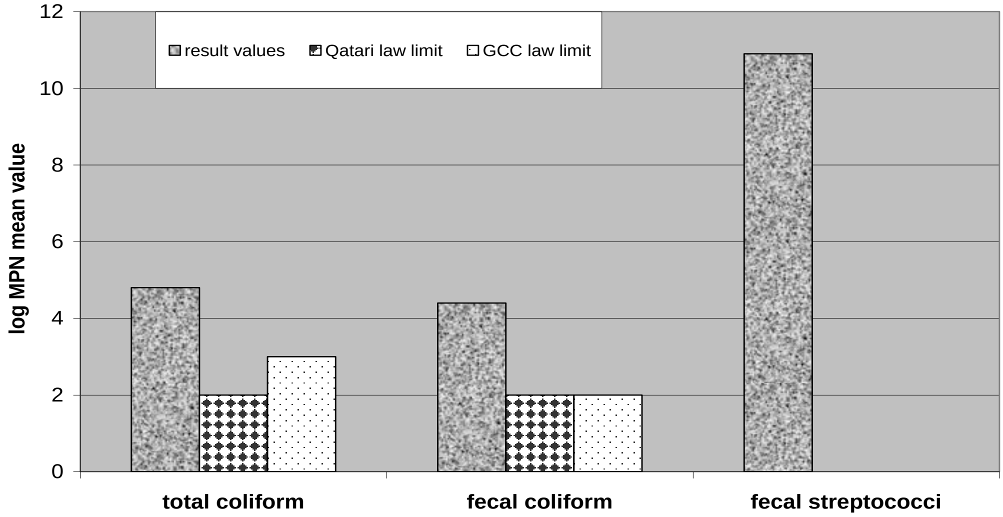
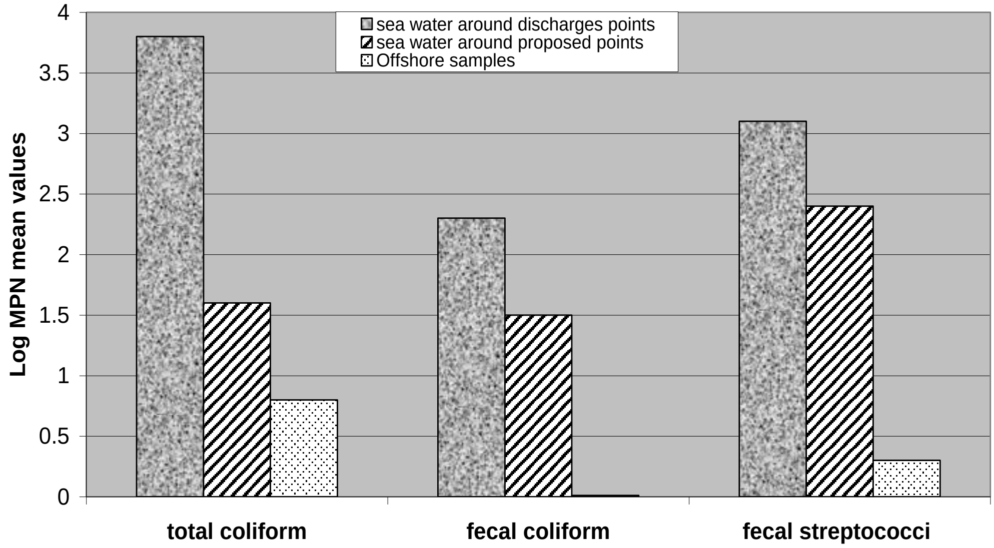
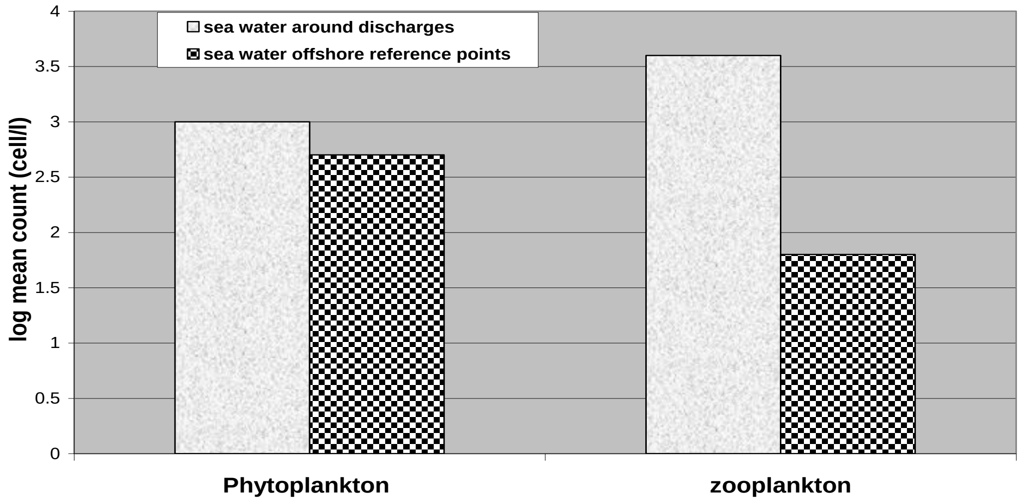


Figure (1): Fecal indicators detected in discharged water samples compared with the environmental laws



Figure(2):Fecal Indicators detected in sea water samples



Figure(3): Phytoplankton and Zooplankton mean count in sea water samples collected from sites around discharges and offshore.

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