JFE JOURNAL OF FLOOD ENGINEERING
1(1) January–June 2010; pp. 1–15

ASSESSMENT OF WATER QUALITY IN THE COASTAL ENVIRONMENT OF KARACHI BORDERING NORTHERN ARABIAN SEA

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ABSTRACT: In view of the ever-increasing threat of marine pollution along Karachi coast and its possible danger to the coastal and marine environment this study was undertaken. Although there have been a number of overviews on status of marine pollution in Pakistan, however this study was the first effort to quantify the level of oil pollution in the coastal environment of Karachi, Pakistan. Water and sediment samples were collected from various locations along Karachi coast bordering northern Arabian Sea during July to November 1999. Water quality was assessed using the parameters salinity, dissolved oxygen, suspended load, organic matter (in particulate carbon) and total oil and grease. The salinity in Karachi Harbour ranged between 25.062–36.042 ppt in the Down Stream Lyari River Mouth and outside Manora Channel to open sea respectively. The dissolved oxygen values observed at all stations ranged between 0–6.01 mg/l. Complete anoxic condition with zero oxygen value was found at Lyari River Mouth the discharge point of mostly untreated industrial and domestic wastes. The very high concentrations of suspended load have been found at Korangi creek and Gizri creek Tip which are 177.6 ppm, and 100 ppm respectively. Concentrations of the suspended load in Karachi Harbour were in the range of 28.30–61.60 mg/l however, higher values have been found in the Manora Channel and its surrounding area. The level of organic matter ranged between 2.35–11.50 mg/l, with high values detected in Korangi creek and Gizri creek, which were 11.5mg/l and 7.15 mg/l respectively. The concentration of total oil and grease in seawater was detected in the range of 0.9–49.9 mg/l. The highest concentration of total oil and grease (49.9 mg/l) in seawater had been observed in Manora Channel. Similar results were also observed for total oil and grease in sediments. The highest concentration in sediment was found in Manora Channel, and Korangi creek which were 115 mg/kg, and 81 mg/kg respectively. The lowest value 0.9 mg/l was detected in water sample collected out side Manora Channel in the open sea, which clearly showed that the pollution level decreased from Karachi Harbour towards open sea, due to tidal flushing and mixing of pollutant with seawater. Karachi the largest industrial and thickly populated city of Pakistan which is situated at the northwestern boundary the Arabian Sea is highly vulnerable to flood damages either due to flash floods during SW monsoon or impact of sea level rise and storm surges coupled with cyclones passing through Arabian Sea along Pakistan Coast.

Keywords: Coastal Pollution, Water Quality, Marine Environment, Arabian Sea.

1. INTRODUCTION

Pakistan bordering Northern Arabian Sea has a coast line of about 990 Kilometers long, extending from Jiwani near Iranian border in the west to Sir Creek near Indian border in the east. The total marine area is approximately 240,000 km^2 (Rizvi, 1997). There are more than 6000 industrial units in Karachi which include chemical, metal, oil refineries, textile, pharmaceutical, beverage, paints and dyes, fish processing, etc. As such, the city of Karachi generates more than 400 million gallons per day of domestic waste and industrial effluents (Qureshi *et al.*, 2001).

Prior to this work according to NIO report Karachi (National Institute of Oceanography, 1996), the largest and thickly populated city of Pakistan, generates about 295 MGD of sewage and industrial wastes out of which 111 MGD is generated by municipal sources while 184 MGD is generated by industries. Assuming the 46% losses through evaporation and seepage, about 158 MGD reaches the coastal waters. Approximately 42 MGD of wastewater enters the coastal waters through Gizri/Korangi creeks via Malir River and about 116 MGD enters through Karachi Harbour via Lyari River. The disposal of this large quantity of untreated sewage is causing serious pollution in the coastal environment of Karachi and affecting the marine life and ecological balance.

Due to rapid industrialization and increase in population of Karachi, a huge amount of untreated industrial and urban waste has been dumped out into the sea causing pollution problems in the coastal areas (Karachi Harbour and Indus Deltaic Creek area, etc) of Pakistan (Beg *et al.*, 1975).

About 80% untreated urban waste, which also include untreated industrial wastewater, drains into the Coastal Environment of Karachi mostly through Lyari and Malir Rivers.

The status of marine pollution in coastal water as well as Exclusive Economic Zone (EEZ) of Pakistan has been discussed in a number of studies (Beg *et al.*, 1975; Haq *et al.*, 1976; Ahmed, 1977; Ahmed, 1979; Ahmed, 1997; United Nation Environment programme, 1986; United Nation Economic and Social Commission for Asia and the Pacific, 1996; Amjad *et al.*, 1998) but oil pollution has not been quantified.

Since there have been no quantification of oil pollution in the coastal environment of Karachi this study was undertaken for the first time during 1999 to quantify the levels of oil and grease in water and sediments and the results were presented in M.E Thesis (Zaqoot, 2000).

Currently Pakistan coast does not seem to be highly polluted with oil. However, the prevailing oil pollution along Pakistan coast appears to be caused by heavy maritime shipping traffic along its coast, bilge cleanings from ships and from local mechanized fishing boats and trawlers, effluents from refineries and industries and untreated municipal waste. According to an estimate about 15–20,000 tons of oil was released per year into Karachi Harbour and adjacent waters connected with it through Manora channel (United Nation Economic and Social Commission for Asia and the Pacific, 1996).

In Pakistan during SW monsoon floods are commonly observed along Indus River and its tributaries. The climate of coastal zones of Pakistan is semi arid and Karachi being in this zone

experiences highly variable intensity and duration of rainfall. Rehman and Battarai (Rehman *et al.*, 2005) have reported that concentrated spell of rain in the catchment of Malir River and Lyari River occasionally cause flash floods such as in the years 1967, 1973, 1977, 1978, 1984, 1989, and in 2003 adversely affecting the thickly populated areas of the city in the vicinity of these rivers. Rehman *et al.* (2005) have also mentioned that due to proximity of Arabian Sea and being major economic hub Karachi is more vulnerable to flood damages than any other city in Pakistan.

Khan *et al.* (2002) have reported that along Sindh coast the area nearby Karachi is more vulnerable to coastal erosion and accretion than the deltaic region due to human activities together with natural phenomena such as wave action, strong tidal currents and sea level rise. After studying sea surface and air temperatures as well as sea level variations have observed 1.1 mm/year sea level rise at Karachi and concluded that thermal expansion of seawater and melting of continental and polar ice due to global warming are contributing to SLR in this area which may have many adverse impacts on coastal population and environment. Inam *et al.* (2007) while discussing geological hazards along the Sindh coast with special reference to Karachi cost have given detail account of the impact of earthquake and tsunami in the area. They have also mentioned that cyclone or tsunami may have different impact on different locations along the coast of Karachi.

In this paper assessment of water quality along the coast of Karachi has been made through selected parameters to provide the level of marine pollution in the coastal environment of Karachi. We hope that this work will help concerned authorities and decision makers in designing plans and policies and in implementing actions to reduce marine pollution along Karachi coast.

2. MATERIALS AND METHODS

2.1. Sampling Site Selection

A total of ten locations were selected for the assessment of seawater quality along Karachi coast. The sampling sites were selected with regard to sources of marine pollution along Karachi coastal areas. All the selected ten sampling sites are shown in Figure 1.

2.2. Sample Collection

Sampling was carried out according to FAO (Food and Agricultural Organization, 1975) manual of methods in aquatic environment research and Parsons *et al.* (1984), a manual of chemical and biological methods for seawater analysis. Seawater and sediment samples were collected regularly once a month during July 1999–November 1999 from all locations (Figure 1).

Glass bottles of one-liter capacity were used for the sampling of surface seawater to analyze petroleum hydrocarbons. The sediment samples were collected by using Peterson's grab from the surface of bottom sediment and then sub-sampling was done for total oil and grease. The sediment samples thus collected were wrapped in an aluminum foil and immediately frozen at –20ºC for further analysis at a later time.

Figure 1: Sampling Locations at Karachi Harbour and Adjoining Creeks along Karachi Coast

2.3. Samples Analysis

The seawater samples were transported to the National Institute of Oceanography (NIO) Chemical Oceanography and Marine Environment Laboratory within 2 to 3 hours after collection and analyzed for total oil and grease in seawater and sediments. The extraction was carried out immediately using hexane of high priority (HPLC grade). The other parameters were analyzed afterwards.

2.4. Temperature, Salinity and pH

The temperature of surface seawater at the sampling sites was measured by using laboratory thermometer.

The salinity of water samples was analyzed using the OSK 2058 T.S SALINOMETER (Japan) and expressed as 35 ppt (Clark, 1986).

For measuring the pH of seawater, pH meter TPX-90, TOKA Model, Japan was used. Samples were stirred gently and stable readings were recorded (Grasshoff, 1983).

2.5. Dissolved Oxygen and Suspended Matter

The method used for the determination of dissolved oxygen in sea water was oxidation–reduction by titration described by Winkler (1965) and modified by Carritt and Carpenter (1966) and described in FAO Manual (Food and Agricultural Organization, 1975).

For analysis of suspended matter, 500 ml water sample was filtered through a glass fiber filter (GF/F, 0.7 mm) and the retained material was dried at 100°C. After 2 hours of drying the suspended matter was determined by weighing, and subtracting the weight of the filter from the total weight (Food and Agricultural Organization, 1975). The suspended matter content was calculated using the following formula:

$$X = \frac{1000(a-b)}{c}$$

where, a = weight of filter and residue in mg

b = weight of filter in mg

c = volume of sample water in ml

X = Suspended matter, content in mg/l

2.6. Organic Matter in Particulate Carbon

Simple method was used for the determination of organic matter in particulate carbon based on the use of the spectrophotometer. The method involves the wet oxidation of carbon by acid dichromate and is based on the procedure described by Johnson, and adapted for spectrophotometer as described by Parsons *et al.* (1984). The organic matter in particulate carbon content is given by the following expression:

$$Mg\left(\frac{c}{liter}\right) = \frac{Ex\,Fx\,v}{V}$$

where,

E = the absorbance, $E = 1.1\ E_f$

F = Factor, $F = 120/Es$

v = Volume of oxygen

V = the volume of seawater filtered in liters

Es = the average of standard extinction corrected for trivalent chromium absorption at 440 nm.

2.7. Total Oil and Grease in Seawater

The method used to determine the concentration of total oil and grease in seawater was U.S. EPA Method 413.1 (Gravimetric, separatory Funnel Extraction). One liter of sample was acidified to a low pH (>2) and serially extracted with 30ml of *n*-hexane in a Separatory funnel. After separating the layers the solvent was passed through sodium sulfate for drying any water present. Then the solvent was evaporated from the extract at room temperature and the residue weighed by the analytical balance.

The concentration of total oil and grease has been calculated using the following formula;

$$Total\,oil\,and\,grease\left(\frac{mg}{L}\right) = \frac{R-B}{V}$$

where,

R = residue, gross weight of extraction flask minus the tare weight, in milligrams.

B = blank determination, residue of equivalent volume of extraction solvent in milligrams.

V = volume of sample.

2.8. Total Oil and Grease in Marine Sediments

For determining total oil and grease in marine sediments, 80g of wet sediment was Soxhlet–extracted with 100ml of *n*-hexane for 1 hour and 30 minutes. The extracted solvent was evaporated by immersing the lower half of the flask in water at 70ºC by using a hot plate and a solvent blank was accompanied with each set of the samples (International Oceanographic Commission, 1982). After drying, the flask was removed from the hot plate and the outer side was wiped to remove excess moisture and finger prints. The concentration of total oil was calculated using the same formula as used for seawater samples.

3. RESULTS AND DISCUSSIONS

3.1. Oil Slicks Appearance

In Karachi Harbour oil slicks were very commonly observed in Manora channel (location-4), Oil pier (location-5), and Karachi Fish Harbour area (location-2). Their possible source appears to be mostly from heavy shipping traffic in the port area, oil discharge from the local mechanized boats, fishing trawlers and oil discharges from terminal points. Similarly oil slicks were also observed in Gizri creek and Korangi creek area (location-8). The presence of these oil slicks may be attributed to fishing and shipping activities as well as effluents of Korangi Industrial Area discharged into Gizri Creek through a drain.

3.2. Temperature

The temperature of surface seawater of Karachi coastal waters were found to range between 27ºC–29ºC during July–October (post SW monsoon) and 19.8ºC–21ºC during November (early NE monsoon). Seasonal variation in temperature of surface seawater along the coast of Karachi is shown in Figure 2.

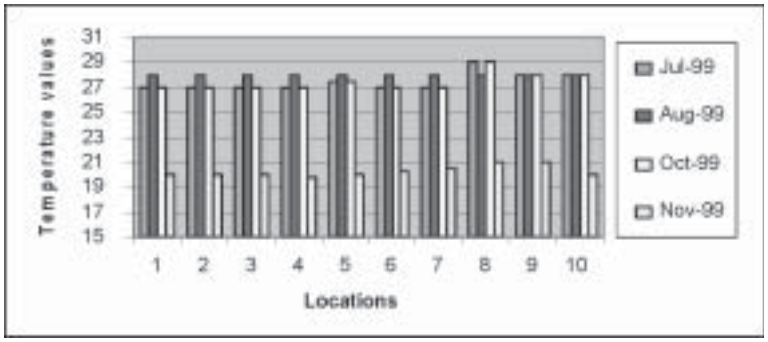

Figure 2: Seawater Surface Temperature Variation along Karachi Coast

3.3. pH

Most pH measurements were found to be in the range of 7.75–8.3 for all locations during the whole monitoring period (Figure 3). The values have been described as acceptable values for sea water (Harvey, 1955). The values of pH in Karachi Harbour ranged from 7.85 to 8.30. The lower values of pH were observed near Lyari River mouth (location-1), and Karachi Fish Harbour which may be due to the mixing of seawater with the effluents discharged through Lyari River which brings fresh water in the form of domestic and industrial wastes into the Karachi Harbour. Similarly lower values of pH 7.75 were observed at Gizri Creek Top end (location-9) which receives effluents from Korangi Industrial area.

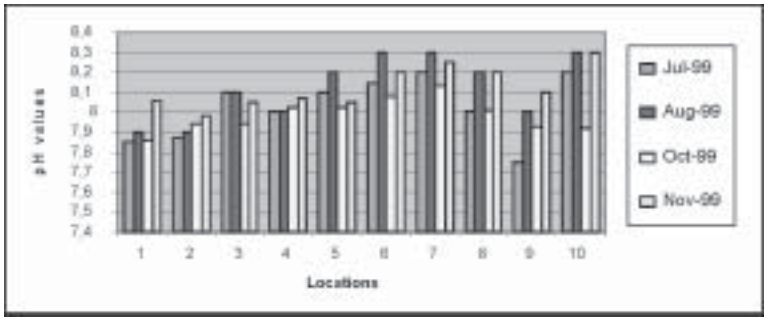

Figure 3: pH Values along Karachi Coast

3.4. Salinity

Salinity distribution presented in Figure 4, clearly shows that the lower value of salinity (25.062 ppt) was recorded in Karachi Harbour at Down Stream Lyari River mouth where the polluted effluents of Karachi city are discharged in Karachi Harbour. As high as 30 ppt and 35 ppt salinity values have also been observed at Lyari mouth and Karachi Fish Harbour during October, 1999 this could be due to the influence of high tide. Our data clearly shows the influence of seawater up-to upper reaches of Karachi Harbour during high tide.

Similarly the low salinities 28.286 ppt and 31.918 ppt were observed at the top end at Gizri creek and Korangi creek during low tide where the polluted effluents are discharged and influence

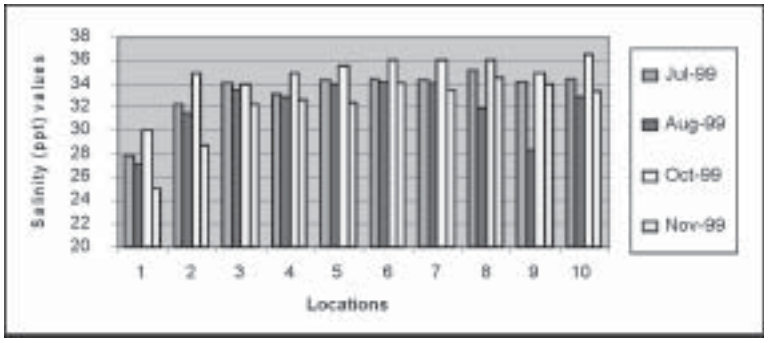

Figure 4: Salinity Distribution along Karachi Coast

the seawater at these creeks. During high tide the values as high as 36.5 ppt and 39 ppt have been recorded at Gizri creek and Korangi creek respectively. Similar results have also been reported for Indian waters where the salinity values ranged 18–39.1 (Gupta *et al.*, 2005),

3.5. Dissolved Oxygen (DO)

Distribution of dissolved oxygen in Karachi Harbour as well as the areas under study clearly shows the deteriorating water quality along Karachi coast particularly in Karachi Harbour (Figure 5). The extremely low dissolved oxygen concentrations were detected at Lyari River mouth, Karachi Fish Harbour and Manora Channel where the values as low as zero, 0.1841, and 1.627 mg/l were found respectively. Khan and Saleem (1986) in their study also found the dissolved oxygen values in the range of 0.71–1.90 mg/l in surface waters of Karachi Harbour. In the present study further depleted values of 0.1841–1.147 mg/l were found from July to November, 1999. Similarly very low concentration of dissolved oxygen was also observed in Gizri creek (1.399 mg/l).

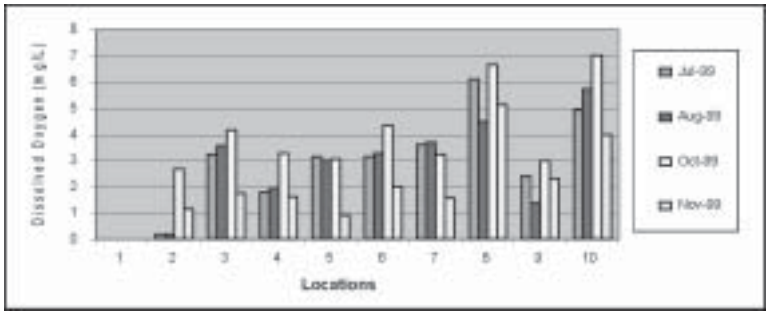

Figure 5: Dissolved Oxygen Levels along Karachi Coast

The highest value observed at Karachi Fish Harbour which is near Lyari River mouth showed the gradual deterioration of water quality of Karachi Harbour due to continuous discharge of domestic and industrial wastes of Karachi city being brought into Harbour area. The higher value was 2.659 mg/l and it observed during October, 1999 for the samples collected at the highest tidal level when sea greatly influences Karachi Harbour.

The concentration of dissolved oxygen in seawater samples collected from opposite to Lyari River mouth during July to November has always been found zero. These results clearly show that during high tide whole of Karachi Harbour is affected by Arabian Sea water. Dissolved oxygen concentration at other localities in Karachi Harbour such as, backwater of Sandspit (location-3), between the Oil pier, and Manora Channel have been found in the range of 1.775–4.162, 0.918–3.132 and 1.627–3.287, mg/l respectively. These values clearly indicate that western back waters of Karachi Harbour where the domestic and industrial effluents bring organic and inorganic wastes through Lyari River have greater influence on the water quality and the marine environment of these areas which is badly influenced creating de-oxygenation to poorly oxygenated area. The highest values of dissolved oxygen were found in the creeks area and open sea near Manora Channel (location-7). The dissolved oxygen values found along Karachi

Coast are similar to the results reported by Central Pollution Control Board of India for Thana Creek (0.14 mg/l) and Malwan Creek (5.4 mg/l) (Gupta *et al.*, 2005).

The low oxygen concentration in water and high organic wastes interacted to form anaerobic environment at certain locations in Karachi Harbour. The concentration of dissolved oxygen gradually increased towards the entrance of Manora Channel (zero to 3.72 mg/l) indicating decrease magnitude of pollution.

3.6. Suspended Load

During the study period generally the values of suspended load for Karachi Harbour ranged from 28.30 to 77.75 ppm (Figure 6). However, very high concentration of suspended load was found at Korangi creek and Gizri Creek Tip (location-10) which were 177.6 ppm and 100 ppm respectively.

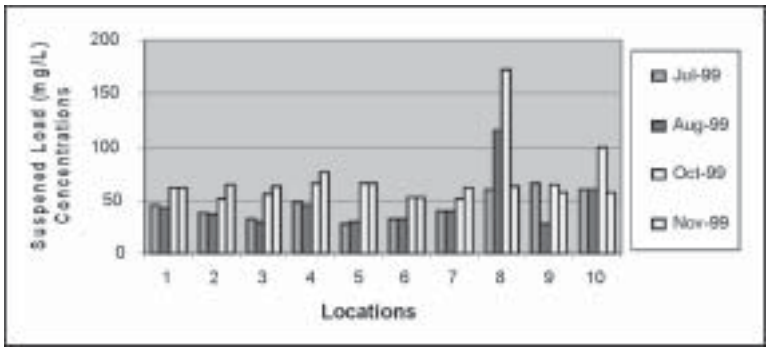

Figure 6: Concentration of Suspended Load along Karachi Coast

In Karachi Harbour higher concentration of the suspended load had been found in the Manora Channel and its surrounding areas throughout the year. This could be due to enclosed nature of Karachi Harbour. The data shows that at the entrance of Manora channel towards open sea, the level of suspended load gradually decreased indicating a decreased influence in level of pollution brought through Lyari River.

3.7. Particulate Organic Matter (POM)

The particulate organic matter (POM) in the upper layers of the sea consists mainly of detritus and phytoplankton which constitute an extremely important part of the marine food chain.

Generally the values of POM for Karachi Harbour ranged from 4.39–7.05mg/l (Figure 7). However, the higher concentrations of organic matter in particulate carbon were detected at Korangi creek and Gizri creek where the values were 11.5 mg/l and 7.15 mg/l respectively.

Increased organic loading of coastal water coupled with nutrient enrichment may result in an increased productivity (algal species) accompanied with oxygen depletion in the upper water column. This anoxic condition coupled with high concentration of organic matter will be harmful

to the planktonic and benthic marine life including shrimps and larval stages of fish (Riley and Chester, 1971).

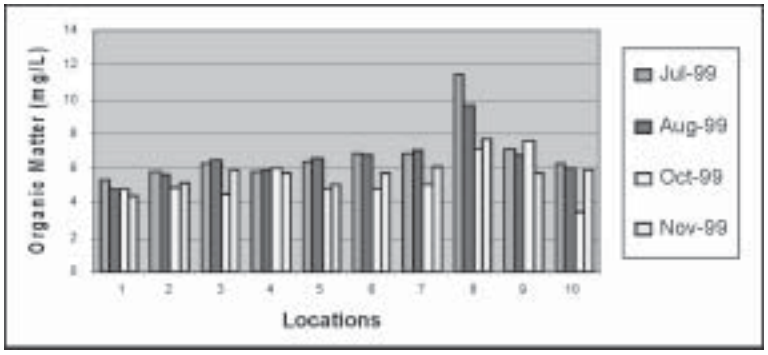

Figure 7: Distribution of POM along Karachi Coast

3.8. Total Oil and Grease in Seawater Surface

The data collected from coastal waters of Karachi clearly show that total oil and grease observed in surface seawater at Manora Channel, Karachi Fish Harbour, and Gizri creek at top end present the highest degree of oil pollution along Karachi coast (Figure 8).

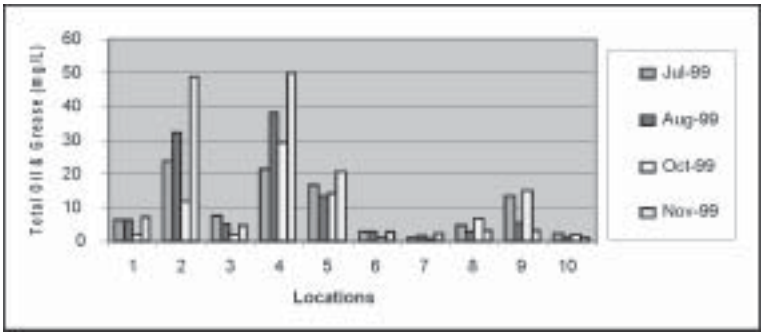

Figure 8: Concentration of Total Oil & Grease Observed in Coastal Waters along Karachi Coast

In addition to oily wastes brought by Lyari River from urban runoff into the Harbour, the Manora channel, which connects Karachi Harbour to the open sea, is polluted by oil resulting mostly from the heavy shipping traffic in the port area, oil discharges from the local mechanized boats and oil terminal points. The highest concentration of total oil and grease in Manora channel water was 49.9 mg/l. It was reported by UNEP (United Nation Environment Programme, 1990) that in Singapore oil and grease in sea water was found in the ranges 1–18 (average 4.2) and 0.1–9.2 (average 1.0) µg/l in 1980 and 1985 respectively, on the west coastal and an average of 2 µg/l in the Straits of Johore (west) in 1980 and 1985. Based on this comparison it appears that Karachi Harbour area is highly polluted with respect to oil pollution.

Karachi Fish Harbour located in the vicinity of upper Harbour was also found to be affected by oil and oily wastes, mostly released from a large number of fishing trawlers. This clearly indicates that higher concentration of oil and grease was found in the locality where ships, fishing boat and trawlers are more operational. The study revealed that the contamination level of oil and grease generally decreased, toward open sea outside Manora channel, indicating a decreased level of oil pollution in the coastal waters of Karachi, out side Karachi Harbour.

The survey along the creeks in eastern side of Karachi revealed that among the creeks Gizri creek was considerably affected by oily wastes mostly released from industrial wastes and Pakistan refinery effluents discharged through drains and Malir River and the concentration of total oil and grease in Gizri creek was 15.2 mg/l. Lower degree of oil pollution was observed in Korangi creek and adjoining areas. The observations show that coastal waters towards eastern of Karachi coast presents lower degree of oil pollution.

3.9. Total Oil and Grease in Marine Sediments

The concentrations obtained for total oil and grease in sediments collected from different localities along Karachi port are presented in Figure 9 which shows the highest values at Manora channel during every month as compared to other localities. Higher values of total oil and grease in sediments have also been obtained at other localities e.g. Karachi Fish Harbour, Lyari River Mouth, Sandspit Backwaters and between the Oil piers which clearly indicate that sediments of Karachi Harbour are generally polluted with oil.

The degree of contamination decreased towards mouth of Manora Channel and outside the channel into open sea. This would be probably a function of textural characteristics of sediments of Manora Channel i.e. clay-rich and more capable of absorbing oil and grease coupled with oil pollution caused by shipping traffic and Lyari River discharges.

The concentration of oil and grease in sediments collected from the creek areas is not as high as observed in Karachi Harbour. The concentration values in creek areas ranged from 16.25 mg/kg to 81.25 mg/kg. The highest value was found in the sediments collected from Gizri creek, which is influenced by run off through Malir River bringing industrial and municipal waste. Korangi creek sediments are also contaminated by oil and grease, which could be attributed to fishing activities at Korangi creek as well as run off from the other adjoining creeks.

The levels of total oil and grease found in the present study are not exceptional and are typical of those which have been measured in other coastal sediments of the world e.g. Buzzards Bay and New York Bight 7–1300 ngg-1 dry wt (Laflamme and Hites, 1978), UK estuaries 60–1510 ngg-1 dry wt (Readman, 1986).

Measurements along the Norwegian, Arctic Coast show that levels of hydrocarbons in sediment vary considerably and the highest level, 7000 mg/kg was found in Hammerfest.

Based on these comparisons, it appears that although total oil and grease level in marine sediments at Karachi Harbour reflects large scale contamination, however, it is not unusual.

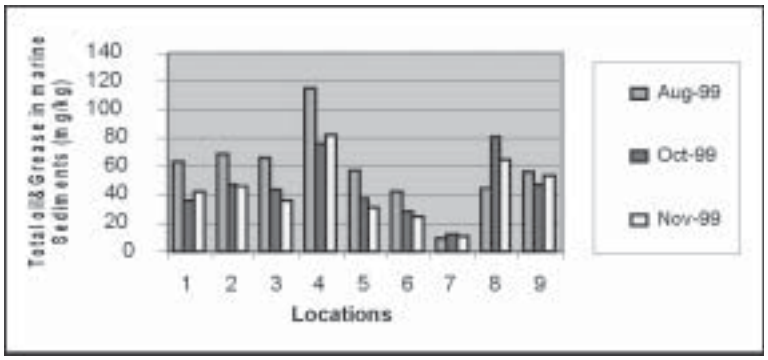

Figure 9: Total Oil& Grease Levels in Marine Sediments along Karachi Coast

Guzzella and De Paolis (1994) in their study of Adriatic Sea along the coast of Italy also found that in the Gulf of Trieste, the most contaminated area was located in the Hrabour of the city which confirms to our results.

It is evident from the foregoing discussion that elevated levels of oil and grease in coastal environment of Karachi is not only due to port activities rather used oil runoff from the city also contributes significantly. In order to bring improvement in the marine environment in the vicinity of Karachi, various measures could be taken by concerned authorities. It is therefore, suggested that apart from implementing various national and international laws and regulations by port authorities it would be a positive step by municipal authorities to develop a programme to minimize the discharge of oily waste or used oil into the sea through sewers or drains. The used oil being discarded at autoworkshops as well as a number of industrial units which would be dispersed in the environment may be collected at throw away prices by the municipality and stored at a central location. This would permit to develop a small business of local recyclers. Under the proposed programme the collected used oil/oil waste could be used as a fuel in metal industries or could be supplied to power plants with air pollution control which will be used for steam generation and ultimately the electricity. The implementation of such as programme will significantly help in improving the deteriorated coastal environment of Karachi (Eslamian, 2009).

4. CONCLUSION

The water quality characteristics found in this study clearly show that in Karachi Hrabour area, the Western Backwaters in the vicinity of Lyari River out fall, area near Karachi Fish Harbour and middle of Manora channel are considerably polluted areas with respect to deteriorated oxygen and oil pollution.

The Gizri creek and Korangi creek towards east of Karachi are less polluted as compared to Karachi Harbour. This increased level of pollution in Karachi Harbour is due to direct discharge of large amount of untreated industrial and domestic wastes from Karachi city in the Harbour through Lyari River, the heavy shipping traffic and discharges from the local mechanized fishing

boats operating from Karachi Harbour through Manora channel and oil leakage from oil terminal points.

In Karachi Harbour area the highest values of total oil and grease in seawater and sediments has been found in Manora channel, and Karachi Fish Harbour which was 49.9 mg/l and 48.9 mg/l for the seawater and 115 mg/kg and 53.6 mg/kg for sediments respectively. The lowest value 0.9 mg/l has been found in water sample collected out side Manora channel in the open sea, which clearly show that open sea area is not polluted with oil.

The increased level of oil, suspended load, organic matter, salinity, temperature and decreased level of dissolved oxygen even up to zero level at certain localities clearly indicate that the coastal environment in the vicinity of Karachi is under the stress of increased level of pollution along the coast.

Lyari and Malir Rivers are two main non perennial rivers passing through Karachi city carrying all the industrial and domestic wastes mostly untreated which are finally discharged into the Arabian Sea. During SW monsoon after heavy rain fall the city experiences flash floods through Lyari and Malir Rivers and the rain water mixed with polluted water spreads into thickly populated areas of the city causing civic problems. The pollution impacted flood water finally enters into the Arabian Sea resulting in adverse socio-economic impacts on the coastal environment and settlements. Karachi the largest industrial and thickly populated city located at the north western boundary of the Arabian Sea is also highly vulnerable to flood damages due to sea level rise as well as storm surge coupled with cyclones passing along the coast of Pakistan.

5. ACKNOWLEDGEMENT

The authors are highly thankful to higher authorities of Mehran University of Engineering and Technology, Jamshoro and Director General, National Institute of Oceanography, Karachi, for facilitating the research work.

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