ORIGINAL ARTICLE

A preliminary pollution appraisal of western backwater at Karachi Coastal area

Aamir Alamgir[1] · Noor Fatima[1] · Moazzam Ali Khan[1] · Muttiur Rehman[2] · Syed Shahid Shaukat[1]

Abstract

This study aims at preliminary analysis of pollution profile of western backwater. The site is very important from the ecological perspective. The mangrove ecosystem of the study area is of prime significance, whilst the study area is receiving heavy pollution load from Lyari River. The water samples were collected from the pre-designated locations and analyzed for physical and biochemical characteristics. The BOD and COD concentrations of the samples were extremely higher from the environmental and ecological viewpoint. The heavy inorganic and organic load is coming from the domestic and industrial effluents coming from Lyari River. Oil and grease concentrations were also extremely higher in all these sites indicating the hampering of natural purification system of water. The concentration of phenol also indicates the emptying of industrial effluent at the Lyari River outfall. The heavy influx of the nutrients in the form of nitrogen and phosphate represents the problem of eutrophication at the study area. Out of all 7 sites, L-7 was most polluted as it was closed to the Lyari River outfall. The extent of pollution is at the following order L-7 > L-5 > L-6 > L-4 > L-3 > L-2 > L-1.

Keywords Untreated effluent · Western backwater · Pollution · Karachi

Introduction

Karachi is the hub of financial and industrial activities situated on the south-west corner of Indus Delta. It is the eighth most populous city of the world having an estimated population of above 180 million. There are more than 10,000 registered industrial units manufacturing food, chemical, textile, paints and paper and pulp products. In addition, to that there are thousands of cottage industries operating in informal sectors.

The industrial units are discharging their waste without any treatment. Although there are few industries who have established waste treatment facilities, but a majority of the industrial units are throwing their waste directly into the Arabian Sea through Malir and Lyari rivers. These are the two major drains carrying the entire waste of Karachi city and discharging into Arabian Sea.

Karachi is industrially divided into six major industrial zones, namely Bin Qasim Industrial Zone in the east near Port Bin Qasim, LITE (Landhi Industrial Trading Estate) in the east, SITE (Sindh Industrial Trading Estate) and North Karachi Industrial Area in the north, Federal B Industrial Area in the centre of the city, HITE (Hub Industrial Trading Estate) between Karachi and Gadiani in the west and West Wharf Industrial Area at the South of the city.

Currently, > 350 MGD of wastewater is generated in the city of both domestic and industrial origins. The city district government claimed that the wastewater is treated at 3 treatment plants operated through Karachi water and Sewerage Board (TP-1 at Sher Shah; TP-2 at Mahmoodabadand TP-3 at Mauripur). But the ground reality is that these treatment plants are not functioning efficiently, and the wastewater only receives the preliminary treatment after which it is discharged in the sea with heavy pollution load (Saleem 2002; Siddique 2006).

Karachi coast is now overwhelmed with heavy pollution load owing to heavy domestic and industrial discharges, port and shipping activities and solid waste dumping (Qari et al. 2005; Rizvi et al. 1988; Saifullah et al. 2002). Without doubts, it can be argued that 135-km-long coastline in Karachi is the most polluted area along the entire Pakistani

✉ Aamir Alamgir
     aamirkhan.ku@gmail.com

1   Institute of Environmental Studies, University of Karachi, Karachi 75270, Pakistan

2   Department of Chemistry, University of Karachi, Karachi 75270, Pakistan

coast (Khan and Khan 2001). Mashiatullah et al. (2009) described that 1500 tons/day of organic load is dumped into the Karachi coast alone from the industries that is much higher in comparison with WHO standards (Khan et al. 1996).

Karachi wastewater is discharged mainly through Malir and Lyari basins having catchment areas of 2051 and 7045 Km^2, respectively (ACE 1993). The fresh water is abandoned from these rivers since long; therefore, these drains are mainly used for dumping of domestic and industrial effluents, solid waste dumping and cattle yard. As there is no more fresh water in these rivers, they are merely used for (1) dumping of garbage and industrial waste, (2) cattle yard waste, (3) laundry effluent, (4) waste from unauthorized factories, (5) agriculture wastes and (6) domestic wastewater from human settlements (Beg 1997). Lyari River that was previously a seasonal river now becomes the eye sore of Karachi and merely serves as sewer for the adjoining industrial establishments and human settlements (Mansoor et al. 2008).

Materials and methods

Study area

Western backwater by the Chinna Creek and Eastern backwater are the two backwaters of Karachi. The western backwater mainly includes the estuary of Lyari River that is situated on the eastern–north-eastern site of the western backwater. Western breakwater also receives untreated wastewater through Manora Channel and Karachi harbour. Geomorphologically, the area is mostly muddy comprises of mud flats with thick mangrove forest. The mangrove area is mostly sandy. The area above the mangroves is somewhat rocky and dry representing a typical habitat entirely different from the mangrove ecosystem.

Collection of samples

During the study, 7 water samples were collected from 7 pre-designated sites using Niskin bottle and are given in Table 1 and Fig. 1. The samples were grabbed and collected during 2014. The western break water samples were collected in pre-sterilized plastic containers. Samples for BOD analysis were collected using amber glass bottles. Separate glass containers were used for the collection of water samples for the analysis of oil and grease. The samples were analyzed using Standard Methods for the Examination of Water and Wastewater (APHA 2005).

Table 1 Sampling sites of the study area

Sampling site	GIS coordinates
L-1	24°51′27.66″N
	66°52′30.23″E
L-2	24°51′18.43″N
	66°52′48.17″E
L-3	24°51′9.55″N
	66°53′5.27″E
L-4	24°50′50.16″N
	66°53′41.37″E
L-5	24°51′14.66″N
	66°54′16.73″E
L-6	24°49′57.74″N
	66°55′32.61″E
L-7	24°51′32.16″N
	66°54′47.84″E

Physical parameters

This includes on-site determination of pH (HANNA portable pH metre), dissolved oxygen (DO; Jenway 630i dissolved oxygen metre) and salinity (inolab WTW series cond 720 m).

Biochemical and chemical parameters

The water samples were analyzed for BOD_5 (biochemical oxygen demand; azide modification method), COD (chemical oxygen demand; dichromate reflux method), oil and grease (n-Hexane extract; gravimetric method), phenol (spectrophotometrically), TKN (total Kjeldahl nitrogen; distillation method), phosphate (ascorbic acid method), TSS (total suspended solids; gravimetric method), TDS (total dissolved solids; gravimetric method) and sulphate (gravimetric method.

Statistical analysis

The data were statistically analyzed using STATISTICA (99 Edition) software. Descriptive and multivariate analyses (cluster analysis) were performed using the above-mentioned software.

Results and discussion

This preliminary investigation was conducted to evaluate the pollution profile of western backwater in the Karachi coastal area. The results of physicochemical analysis of water samples are presented in Table 2. The pH of the samples ranged from 7.5 to 8.1. It means that pH of the samples was towards the alkaline side. Joshi and Ghose (2003) reported pH of

Fig. 1 Sites of sample collection

Table 2 Descriptive statistics of physicochemical analysis western backwater, Karachi

Parameters mg/l	Mean	Min.	Max.	Lower quartile	Upper quartile	SD	NEQS into sea
pH	7.86	7.50	8.10	7.70	8.10	0.22	6–9
Salinity ‰	2.09	1.80	2.50	1.90	2.20	0.23	N/A
TSS	383.43	313	459	364	412	45.05	200
TDS	1269.5	1053	1529	1128	1426	172.99	N/A
DO	2.76	2.15	3.24	2.47	3.11	0.39	N/A
BOD	346.7	240	458.00	275	410	74.89	80
COD	1417.2	894	1667	1283	1621	272.68	400
Oil and grease	9.13	7.55	10.84	7.67	10.36	1.24	10
Phenol	0.15	0.10	0.21	0.13	0.18	0.03	0.3
TKN	157.56	101.1	184.10	154.6	172.3	26.65	N/A
Sulphate	915.14	735	1125	788	1043	141.29	N/A
Phosphate	5.73	4.61	6.81	4.67	6.54	0.86	N/A

7.5 from the mangroves area that was similar to the present findings. High pH values are mostly due to the presence of sea salts.

The area is surrounded by mangroves forest whose development can be correlated with salinity. The growth of *Avicennia* has positive correlation with salinity, and it has been reported that increasing salinity stimulates the growth of *Avicennia* (Lovelock and Ball 2002). The optimum salinity range for *Avicennia* seedling growth is 5–30‰. The functional physiology and reproductive activity of marine biota are also affected by high salinity (Qari et al. 2005). The salinity values of the sampling sites ranged from 1.8 to 2.5‰. Qasim (1982) reported the surface salinity value of Arabian Sea varied from 35.4 to 36.6‰ that declined from north to south.

Municipal SS are mostly organic, of which nearly half are settleable. Such distribution varies which in most of the cases is not homogenous. The variations in TSS are reported in Table 2. The values of TSS and TDS fluctuated between 313 to 459 mg/l and 1053 to 1529 mg/l. The amount of TDS progressively increases near mangroves area, whilst no significant variation was observed among the sites. It would mean that SS were present in soluble form rather than in the suspended form in the domestic and industrial effluents (Khan et al. 1999; Khan and Khan 2001). High suspended solid level precludes the entry of light into the water, which may damage submerged vegetation because of limited photosynthesis due to limited availability of light in the deeper water. The vegetation once dead is biodegraded by the microorganisms during which they consume oxygen thereby creating anaerobic conditions detrimental to marine

life forms. High SS absorbed more heat and thus intensify surface water temperature (Salamone and Newman 1955).

During the study, DO level was greater than 2.0 mg/l at all sites. No significant comparative increase in the DO concentration was observed in all sampling stations. The results are relatively similar with the findings (Khan and Shaukat 2008b). The minimum DO value was observed at L-4 (2.15 mg/l), whilst maximum DO value was found at L-5 (3.24 mg/l). The increased concentration of DO near the mangroves sites is possibly due to the development of flora including halophytic plants near the fringes and algae. Moreover, high temperature and wind velocity are also responsible for the increased DO concentrations. The overall pattern of DO is indicative of heavy pollution load which is detrimental for the useful development and sustenance of biodiversity as well as density of plants and marine animals. Alamgir et al. (2017) reported very low DO values along Lyari River and recorded the nuisance of putrefying smell all along the Lyari River. The putrefaction so exists due to the incoming high organic load that depreciates DO concentration. Khan et al. (1999) also stated comparable values of DO of Lyari River effluent.

The average BOD_5 values ranged between 240 (L-1) and 458 (L-7) mg/l. BOD and COD represent organic and inorganic pollution load present in the wastewater discharges (Liu et al. 2005). High BOD_5 and COD inhibit the marine life forms as they tend to exhaust DO. The BOD_5 values were significantly higher from the pollution viewpoint. Some of the BOD_5 generating compounds particularly found in oil such as total petroleum hydrocarbons are toxic to fishes at a concentration of more than 10 mg/l. The average BOD_5 values of the sampling sites were 346 mg/l. High BOD level was reported along Karachi coast (Khan and Khan 2001) as well as Lyari River (Alamgir et al. 2017). Tariq et al. (2016) and Khan and Shaukat (2008a) also reported high values of BOD at Chinna Creek which is connected to the study area. It should be noted that the area is heavily polluted with the organic load and its uninterrupted accumulation is detrimental for the marine environment. One pertinent reason that could contribute to high BOD levels is the indiscriminate dumping of municipal solid waste, which undergoes bacterial putrefaction and depletes DO appreciably in western breakwater.

COD represents both chemically and biologically oxidizable materials. The COD values of the sampling sites vary from 894 to 1667 mg/land and are presented in Table 2. The highest COD value was observed at L-3. In general, the COD values are higher than NEQS (National Environmental Quality Standards; 200 mg/L). However, according to NEQS (2000) the standard is 400 mg/l if the effluent discharges into the sea. The COD values are considerably higher which may be due to the presence of organic and inorganic pollutants including oil present in the area. Tariq

et al. (2016) and Khan and Shaukat (2008a) already reported high COD concentration closed to the study area. Elevated COD values indicated the existence of high concentration of chemically oxidizable material that may be lethal to aquatic environment.

Oil and grease concentrations of the sampling sites are reported in Table 2. Oil and grease interfere in the dissolution of atmospheric oxygen thereby hampering the natural purification of water. Therefore, their presence in any amount in marine environment is considered disagreeable. The principle constituent that is toxic to marine life forms rather than the oil itself is petroleum hydrocarbons that occur widely in both liquid and gaseous state. The biodegradation of hydrocarbons under anaerobic conditions plays exhaust the DO in seawater. Accidental spillage and disposal of oily wastes has rendered 10 million tons of oil pollutants annually enter into the marine environment. Routine navigation operations also the significant cause of oil pollution in the seas. Once enters in the sea oil is being degraded by marine bacteria particularly in oxygenated environment. Oil also sink and continue to deposit in benthic environment where it undergoes comparatively slow microbial degradation due to lesser availability of DO, thus affecting benthic life. The mean oil and grease concentration of the sampling sites ranged from 7.55 to 10.4 mg/l, respectively. Maximum allowable limit as per NEQS (2000) is 10 mg/l. Highest concentration was found at L-7. Higher oil and grease concentrations indicated that the process of its removal through photo-oxidation, sedimentation and biodegradation is not working proficiently mainly because of lesser DO concentration. Biodegradation rates of oil are hard to foresee due to the intricacy of the environment, whilst rate of biodegradation is also reliant on the oil composition. Distribution of oil in marine environment may cause an augmented toxicity to marine life that is considered lethal (Anderson et al. 2009; Bartoli et al. 2001).

According to NEQS (2000), the maximum desirable limit for phenol is 0.1 mg/l. Phenols were found in all the sampling stations and the average value was 0.15 mg/l (Table 2). Phenols are readily oxidized by aerobic microorganisms to products of no toxicity in the presence of DO. Since DO was only limited in all of these samples, the breakdown of phenols was, therefore, very little. Phenols are usually present in discharges from petroleum refining, steam electric power plants, manufacturing, rubber processing and glass and asbestos manufacturing). Khan et al. (1999) reported higher values of phenol at the western backwater of Karachi coast. Phenol is detrimental to marine life forms even at concentration as low as 5 μg/l (Navarro et al. 2008). Phenols once enter in fish body mainly affect the metabolism, survival, growth and reproductive system (Holmberg et al. 1972; Mukherjee et al. 1991; Verma et al. 1980).

Fig. 2 Dendogram derived from Ward's method of 7 sites based on physicochemical analysis western backwater, Karachi
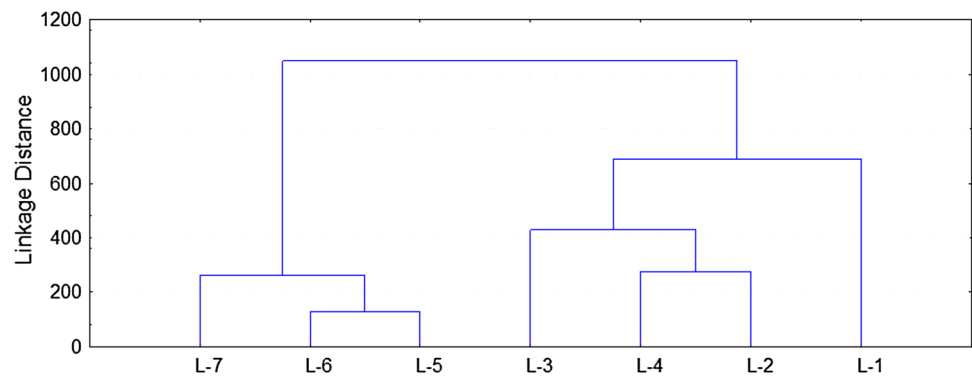
The average of all stations ranged 101.12–184.1 mg/l (Table 2). Comparing the TKN values in all these stations, no temporal or spatial relationship has been found in the distribution and occurrence pattern of TKN. There is no increasing or decreasing pattern of TKN was observed as such. The fluctuations in TKN values only exist at a narrow range. Natural levels of TKN in water bodies are typically less than 2.0 mg/L. However, concentrations above 3 mg/l are considered excessive in natural water (Lee and Jones-Lee 2001).

The results of sulphate analysis are presented in Tables 2. The values of sulphate ranged between 735 and 1125 mg/l. Since the oxygen concentration at all the sampling stations was exceptionally low which leads to the production of H_2S through microbial decomposition of biologically decomposed organic matter. The typical sewage like smell at the sampling sites is also due the massive production of hydrogen sulphide gas.

The environment of coastal lagoon is characterized by high inputs of nutrients responsible for high rates of primary productivity (Castel et al. 1996). Aluminium, calcium and iron phosphates are formed from the weathering of clays or detritus particles. Microorganisms have the capability to solubilize these compounds (Illmer and Schinner 1995). Boto (1982) described that 31 ppb of phosphate is regarded as low. In the present investigation, mean phosphate level was found to be 5.73 mg/l. Phosphate is the main contributor of eutrophication in water bodies. The input of phosphate is also from nearby anthropogenic sources although limited but includes the use of fertilizer and detergents. The mechanism of flow of phosphorus and other nutrients in the seawater and sediments is an intricate phenomenon that is subjective to physical, chemical and biological processes. These processes are under the influence of pH, temperature and redox potential (Carlton and Wetzel 1988). The major problem in the Mediterranean coastal lagoons is the influx of nutrients (i.e. P and N) causing eutrophication in hot months (Mesnage and Picot 1995).

The results of cluster analysis in the form of a dendrogram are presented in Fig. 2. Two main groups can easily be seen. The group of three sites (L-5, L-6 and L-7) on the left represents highly polluted sites, whereas the group on the right that includes four sites (L-1, L-2, L-3 and L4) represents relatively less polluted sites.

Conclusions

The study reveals that western backwater at Karachi coast is that is continuously receiving untreated domestic and industrial discharges from Lyari River, which is affecting marine ecosystem and its biological diversity. The natural purification system of water in the area is seriously hampered. It is suggested that a more extensive ecological survey of the area is conducted to elucidate the impact of above-mentioned pollutants on the ecological communities of the western breakwater.

References

ACE (1993) Lyari and malir rivers pollution study. Associated Consulting Engineers, Karachi, pp 1–24

Alamgir A, Khan MA, Shaukat SS, Kazmi SJH (2017) A quantitative appraisal of Lyari river effluent, Karachi, Pakistan. Desalination Water Treat 62:175–184

Anderson BS, Arenella-Parkerson D, Phillips BM, Tjeerdema RS, Crane D (2009) Preliminary investigation of the effects of

⨂ Springer

dispersed prudhoe bay crude oil on developing tops melt embryos. Atherinops Affinis Environ Pollut 157:1058–1061

APHA (2005) Standard methods for the examination of water and wastewater, 21st edn. American Public Health Association, Washington DC

Bartoli M, Nizzoli D, Viaroli P, Turolla E, Castaldelli G, Fano EA, Rossi R (2001) Impact of tapes philippinarum farming on nutrient dynamics and benthic respiration in the Sacca di Goro. Hydrobiologia 455:203–212

Beg M (1997) Pollution of the Karachi coastal environment. Wildl Environ 5:20–22

Boto KK (1982) Nutrient and organic fluxes in mangroves Mangrove ecosystems in Australia: structure, function and management-pages: 239–258. Australian National University, Canberra

Carlton RG, Wetzel RG (1988) Phosphorus flux from lake sediments: effect of epipelic algal oxygen production. Limnol Oceanogr 33:562–570

Castel J, Caumette P, Herbert R (1996) Eutrophication gradients in coastal lagoons as exemplified by the Bassin d'Arcachon and the Étang du Prévost. Hydrobiologia 329:ix

Holmberg B, Jensen S, Larsson Å, Lewander K, Olsson M (1972) Metabolic effects of technical pentachlorophenol (PCP) on the eel *Anguilla anguilla* L. Comp Biochem Physiol Part B 43:171–183

Illmer P, Schinner F (1995) Phosphate solubilizing microorganisms under non-sterile conditions. BODENKULTUR-WIEN AND MUNCHEN 46:197

Joshi H, Ghose M (2003) Forest structure and species distribution along soil salinity and pH gradient in mangrove swamps of the Sundarbans. Trop Ecol 44:195–204

Khan MA, Khan MA (2001) Impact of Industrial discharge on Karachi coastal environment. Proc Eight Stat Sem 2001 Karachi University, pp 205–216

Khan M, Shaukat S (2008a) Physico-chemical characteristics of water and sediments of Chinna creek and the associated benthic biota on its fringes. Int J Biol Biotechnol (Pakistan)

Khan MA, Shaukat S (2008b) Physico-chemical characteristics of water and sediments of Chinna creek and the associated benthic biota on its fringes. In J Biol Biotechnol (Pakistan) 5(1–2):133–141

Khan MA, Akhtar M, Nazli A, Khan MA (1996) Variation in oxygen production in waste stabilization ponds at the Karachi University. Karachi Univ J Sci 24:161–169

Khan M, Hashmi I, Rashid A, Niaz G, Khan F (1999) Studies on Lyari river effluents. Pak J Sci Ind Res 42:230–235

Lee G, Jones-Lee A (2001) Assessing the water quality impact of phosphorus runoff from agricultural lands. In: Abstracts of papers of the American Chemical Society, 2001. American Chemical Society 1155 16TH ST, NW, Washington, DC 20036 USA, pp U72–U72

Liu L, Ji H, Liu Y, Xin H (2005) Chemical oxygen demand of seawater determined with a microwave heating method. J Ocean Univ China JOUC 4:152–156

Lovelock CE, Ball MC (2002) Influence of salinity on photosynthesis of halophytes. In: Läuchli A, Lüttge U (eds) Salinity: environment - plants - molecules. Springer, Dordrecht, pp 315–339

Mansoor A, Khan N, Jamil N (2008) Quantitative study for exchange of gases from open sewer channel to atmosphere world academy of science, engineering and technology. Int J Math Comput Phys Electr Comput Eng 2:130–132

Mashiatullah A, Qureshi R, Ahmad N, Khalid F, Javed T (2009) Physico-chemical and biological water quality of Karachi coastal water. Nucleus 46:53–59

Mesnage V, Picot B (1995) The distribution of phosphate in sediments and its relation with eutrophication of a Mediterranean coastal lagoon. Hydrobiologia 297:29–41

Mukherjee D, Guha D, Kumar V, Chakrabarty S (1991) Impairment of steroidogenesis and reproduction in sexually mature Cyprinus carpio by phenol sulfide under laboratory conditions. Aquat Toxicol 21:29–39

Navarro AE, Portales RF, Sun-Kou MR, Llanos BP (2008) Effect of pH on phenol biosorption by marine seaweeds. J Hazard Mater 156:405–411

Qari R, Siddiqui SA, Qureshi NA (2005) A comparative study of heavy metal concentrations in surficial sediments from coastal areas of Karachi. Pak Mar Pollut Bull 50:595–599

Qasim S (1982) Oceanography of the northern Arabian sea deep sea research Part A. Oceanogr Res Pap 29:1041–1068

Rizvi S, Saleem M, Baquer J (1988) Steel mill effluents: influence on the Bakran Creek environment. Mar Sci Arab Sea, 549–569

Saifullah S, Khan S, Ismail S (2002) Distribution of nickel in a polluted mangrove habitat of the Indus Delta. Mar Pollut Bull 44:570–576

Salamone JJ, Newman M (1955) Heat transfer design characteristics—water suspensions of solids. Ind Eng Chem 47:283–288

Saleem M (2002) Study of heavy metal pollution level and impact on the fauna and flora of the Karachi and Gawadar Coast. WWF Project Report Project No 50022801: 32

Siddique A (2006) Geographical information system (GIS) linked evaluation of the ground water pollution and its sources effecting environment of Karachi city and its coastal region. University of Karachi, Karachi

Tariq S, Khan MA, Alamgir A (2016) Physico-chemical profile of Malir river and chinna creek. Proced Environ Sci 34:514–524

Verma S, Rani S, Tyagi A, Dalela R (1980) Evaluation of acute toxicity of phenol and its chloro-and nitro-derivatives to certain teleosts. Water Air Soil Pollut 14:95–102