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Impact of Orangi Nala Industrial Effluents on Sewage Water of Lyari River, Karachi, Pakistan

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Abstract: Industrial and domestic activities generate more than 472 million gallons per day (MGD) wastewater in Karachi (Pakistan). Lyari River is one of the major drains of this effluent and carries pollutants to the Arabian Sea. The Orangi Nala (natural channel) which is a tributary of Lyari River also contains heavy pollution load of industrial wastewater. The present study endeavors to identify contamination problems caused by the wastewater from Orangi Nala and Lyari River in the SITE industrial estate of District West, Karachi, Pakistan. The dense unplanned industrial establishments have negatively affected the wastewater quality in the study area. Wastewater samples from seven different locations in Orangi Nala and Lyari River were collected. Analytical techniques as described under "standard methods for the examination of wastewater" were adopted for physico-chemical and metal analysis of these samples and the results were compared with the National Environmental Quality Standards (2000) of Pakistan Guidelines for wastewater suitability in relation to possible health hazards. The investigations reveal that almost the whole study area is moderate to highly contaminated due to excessive concentrations of water quality parameters such as TSS, COD, BOD, TDS, DO and SAR. From the heavy metal analysis it can be inferred that the concentrations of these metal ions are within permissible limits but on the higher side. Also, for characterization of groundwater of the research area and to evaluate its quality, three groundwater samples were collected from the tube wells located in the study area. These samples were analyzed for the determination of Physico-chemical parameters such as pH, temperature, dissolved solids, salinity and dissolved oxygen.

Key words: Contamination · Industrial effluent · Karachi · Lyari River · Orangi Nala · Pakistan · Sewage Water

INTRODUCTION

The water requirement is widening with growing population. But unfortunately the water assets are being depleted with time and are polluted all over the world. Due to rapid growth in the human population and industries in urban area, pollution in coastal areas has significantly enhanced due to land and marine based activities [1]. Impacts of Pollutants on water quality have rapidly increased which has badly affected the marine environment and surrounding ecosystem. Enormous quantities of untreated municipal and industrial wastes are being drained into the sea resulting in a serious degradation of marine environment and the adjoining coastal areas. Mixing of untreated municipal and industrial effluent with the sea and groundwater not only adversely affects the marine life but also the freshwater assets, human health and agricultural productivity [2].

The trouble accentuates further in metropolitan cities and other trade areas where quick drop in water quality causes different water-associated diseases and degrades the environment. Insufficient municipal structure for dumping and management of wastewater is causing a lot of ecological issues.

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Karachi is a metropolitan city of Pakistan located in the south, on the coast of the Arabian Sea. The city spreads over an area of approximately 3,530 square kilometers comprising 18 Towns with a population density of 4,115 persons / km². Karachi forms a basin and drains into the Arabian Sea by Malir and Lyari rivers. These rivers of Karachi city make a natural drainage [3].

Northwestern part of the Karachi region is dominantly hilly and the ridges are significantly steeper part of the Manghopir anticline. The Manghopir hilly area is thickly populated. Small streams, such as Orangi Nala originate from Manghopir hills [4]. Orangi Nala is an ephemeral stream that flows through Karachi from northeast to the center. It flows through Manghopir, Orangi town and SITE area and drains into Arabian Sea via Lyari River [3].

Karachi has moderate climate with summer and winter. Annual mean maximum temperature is 30.78°C while the minimum is 21.15°C. Annual mean Precipitation is 209.44 millimeters and relative humidity is 64.16%. The humidity and high wind speed prevails all over the year. There are six industrial areas in the city, namely SITE, Korangi, Landhi, Export Processing zone, F.B area and Bin Qasim port industrial area [5].

Non-governmental and international sources report that Karachi's current population is estimated to be 20 million and population is currently growing at the rate of 5% to 6 % per year (mainly on account of rural to urban internal migration), including an estimated 45,000 migrant workers coming to the city every month from different parts of Pakistan [3].

Approximately 70 percent of the population does not have access to clean and safe drinking water and around 80 percent have no access to drainage and sanitation facilities [5].

The present supply of water to Karachi from Indus and Hub sources is approximately 650 MGD. By the year 2015, projected population of Karachi will be 23 Million and @ 54 gallons per capita per day, the demand of water shall be 1242 MGD.

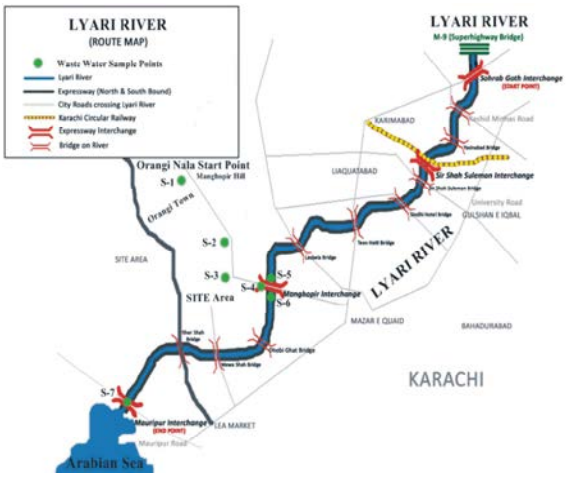
About 8000 industrial units are discharging millions of gallons of effluent per day in the Karachi city. Only 30 to 35% of the industrial and domestic water is treated and the rest is discharged untreated into the Arabian Sea through Malir and Lyari Rivers. Industrial effluents discharged into various surface and ground water bodies cause hydrological inequity and health risk for human beings. Poor water quality has lead to recent outbreaks of infectious diseases, some of which have resulted in mortality. Potable groundwater is available in only 28 percent of the urban land mass [5].

Lyari River is an ephemeral natural stream having substantial catchment area that starts from Badra ranges 100 Km from the city of Karachi and enters the northern end of the city at Super Highway bridges at Sohrab Goth. It flows in the southwest direction towards Maripur Road Bridge. It carries industrial and domestic effluent during the year and the floodwater only for two or three days during the rains [7].

SITE industrial area covers an area of about 16 km^2 having approximately more than 3000 industrial units. Most of them are textile units (about 60%) and others manufacture miscellaneous products and discharge their wastewater into Lyari River via Orangi Nala making it a perennial stream. Over all contribution of SITE area in industrial contamination is 51% [8, 9]. These untreated sewage and industrial wastewater drain into the sea and contaminate the aquatic environment. Consequently large quantities of chemical contamination and effluent as well as sediments are eventually transported to the beaches [4].

Orangi and Gujar nalas are the main tributaries of Lyari River. These tributaries contribute two-third of the runoff within Karachi from the northwest to the Lyari River [10]. Only a few well-known industries have initial treatment facilities, all other industrial units discharge their wastes directly or indirectly into coastal areas of Karachi. Wastewater treatment is a mixture of biological and physiochemical processes. Physical process involves the removal of coarse and suspended matter whereas in biological process microorganisms play a vital role in decomposing biologically degradable organic matter. The chemical process further enhances the treatment quality [11-13, 9]. Three sewage treatment facilities are functioning in Karachi under Karachi water and sewerage board [6]. Only 45 to 55 MGD of the 450 to 472 MGD of wastewater and sewage produced by the city is treated, the rest goes into the sea through natural drains or *nalas*. From total generated effluents, approximately 70% wastewater drains into Arabian Sea without any preliminary and primary treatment which adversely affects marine or aquatic environment [14].

This study was conducted to estimate the physiochemical characteristics of the wastewater / effluents before and after separating suspended solids. This was done in order to evaluate the effectiveness of the simple methods that could be used for the treatment of the wastewater. Also, another purpose of this study



Map Showing Sampling Points of Wastewater [1].

Sampling Points:

S-1 = Manghopeer Shrine
S-2 = Banaras Chowk
S-3 = Habib Bank Chowrangi SITE
S-4 = Before Discharge into Lyari River
S-5 = Before Discharge Orangi Nala into Lyari River
S-6 = After Mixing Orangi Nala into Lyari River
S-7 = Lyari River-Tail of Lyari River under Railway Bridge, Agra Taj

was to characterize groundwater of the research area and evaluate its quality.

MATERIALS AND METHODS

Sampling: Seven wastewater composite samples (one composite samples= 8 samples on hourly basis x every week x up to three months) were collected from Lyari River and Orangi Nala in glass containers and analyzed in the laboratory in order to determine the physico-chemical parameters and metal ions [15].

Three groundwater samples were collected in glass containers from tube wells (after discarding water for the first 5 minutes of flow) located near Lyari River and Orangi Nala and analyzed in the laboratory in order to determine the physico-chemical parameters and metal ions [15].

Analysis: Physico-chemical parameters such as pH, temperature, dissolved solids, salinity and dissolved oxygen were determined at the time of sample collection using HACH Sension 156 USA 2000 [16]. TSS was determined using APHA Method-2540-D, COD by Colorimetric determination method (HACH-8000) at the range of 0 to 15000 mg/l, BOD_5 by Respirometric Method (HACH-10099) for 5 days at 20 ± 1°C and Chloride was determined by Argentometric Method-4500-Cl [15], NEQS [17, 18].

Metals were analyzed using Thermo ice 3000 atomic absorption spectrophotometer. Metals include Cadmium, Chromium, Copper, Nickel, Zinc, Lead, Calcium, Magnesium and Sodium in groundwater and wastewater by standard method (APHA-3111 B, 2005) [15].

Experiment: Study was designed to test the efficacy of treatment system (preliminary and primary) to control TSS, COD and BOD concentrations in wastewater flowing through Orangi Nala and Lyari River to coastal estuary of the Arabian Sea.

Wastewater samples from Orangi Nala and Lyari River (S-1 to S-7) given in Table-1 were subjected to preliminary and primary treatment by removing all floating material by manual filtration through filter paper (42mm). The samples from each site were examined for COD total (before filtration) as well as COD soluble (after filtration); the results are shown in Table-1.

Results show a significant decrease in organic load of pollutants. The approach of this study was also to determine the total and soluble fractions of BOD. After the primary treatment, effluent was tested for COD and BOD concentrations. Reductions observed in COD and BOD concentrations ranged from 42 to 58% and from 68 to 81% respectively.

RESULTS AND DISCUSSION

Seven wastewater samples were drawn from different locations which included sewerage water and industrial effluent and analyzed for physico-chemical parameters including trace and heavy metals. The results of the physico-chemical analyses are presented in Table 2 that shows the critical parameters exceeding the NEQS permissible limits. All samples analyzed for physico-chemical parameters were found to be higher than national standard NEQS [17, 18].

Sampling point S-1 showed high BOD_5 361.5 mg/L; COD 466.0 mg/L; TDS 10128 mg/L; TSS 355.3 mg/L; SAR 25.1; low DO 1.09 and also significant quantity of heavy metals. All parameters are found to be high at this sampling point due to mixing of sewage and industrial effluents.

Table 1: Cod and Bod Concentration Reduction Percentile of Wastewater Samples

		NEQS Limit= 150 mg/l			NEQS Limit= 80 mg/l		
Points	TSS total (mg/L)	COD total Before Filter (mg/L)	COD Soluble After Filter (mg/L)	COD Reduction%	BOD5 Before Filter (mg/L)	BOD5 Soluble After Filter(mg/L)	BOD Reduction%
S-1	355.3	466.3	267.0	42.74	361.5	101.0	72.06
S-2	403.8	1400.5	630.0	55.00	850	161.0	81.05
S-3	375	659.5	284.0	56.94	362.8	86.0	76.29
S-4	348	613.8	263.0	57.15	367	93.0	74.65
S-5	190	511.0	211.0	58.71	282.8	87.0	69.23
S-6	287.3	689.0	308.0	55.30	410	131.0	68.04
S-7	533.5	675.0	326.0	51.70	492.25	148.0	69.93

Table 2: Physico-chemical Parameters Analyses for Wastewater Samples

Parameters	Limit	S#1	S #2	S#3	S#4	S#5	S#6	S#7	Mean
Tmp.	40°C	27.3	27.5	28.5	28.7	27.3	27.5	27.3	27.73
pH	6.5-8.5	8.22	7.45	7.27	7.40	7.29	7.29	7.52	7.49
Salinity	0.01-%	6.93	0.88	0.93	1.0	1.11	0.98	1.50	1.90
DO	4- 6 mg/L	1.2	1.10	1.03	1.76	1.26	1.38	1.19	1.26
BOD5	80 mg/L	362	283	379	492	207	289	392	343.25
COD	150 mg/L	466.3	511.0	689	675	481	535	511	552.58
TDS	< 1000 mg/L	10128	770	971	1040	1015	1060	1545	2360.91
TSS	200 mg/L	356	190	288	534	110	189	270	279.03
Pb	0.01 mg/L	0.36	BDL	0.02	0.02	0.03	0.06	0.91	0.2271
Cd	0.01 mg/L	0.04	0.03	0.02	0.04	0.03	0.04	0.67	0.1179
Ni	0.02 mg/L	0.15	0.13	0.14	0.16	0.15	0.16	0.53	0.1941
Zn	5.0 mg/L	0.12	0.31	0.47	0.25	0.30	0.26	0.64	0.3222
Cr	0.05 mg/L	0.09	0.03	0.03	0.03	0.03	0.02	0.02	0.0286
Cu	2.0 mg/L	0.06	0.14	0.16	0.05	0.15	0.03	0.17	0.1032
SAR	1.5	25.31	2.65	2.61	2.95	3.05	3.03	4.24	6.2629

Tmp = Temperature

Table 3: Ground Water Samples from Manghopeer Karachi (Gw-1).

Sample Details	Units	S#1	S#2	S #3	S#4	Mean ± SD
Tmp.	Acceptable	38.4	37.1	36.8	35.5	36.95 ± 1.19
pH	6.5- 8.5	7.48	7.41	7.39	7.36	7.41 ± 0.05
Turbidity	5.0 NTU	1.0	1.02	1.12	1.05	1.04 ± 0.05
BOD5	6 mg/L	12.0	9.5	13.8	10.5	11.45 ± 1.87
COD	10 mg/L	50.0	40.0	35.5	38.2	40.9 ± 6.32
TDS	<1000 mg/L	1197	1215	1256	1210	1219.5 ± 25.48
TSS	5 mg/L	94.0	85.0	98.0	90.0	91.75 ± 5.56
Pb	0.05 mg/L	0.0085	0.0069	BDL	BDL	0.0077 ± 0.001
Cd	0.01 mg/L	0.0369	0.0251	0.0389	0.0310	0.0329 ± 0.006
Ni	0.02 mg/L	0.1390	0.1210	0.1421	0.1335	0.1339 ± 0.009
Zn	5.0 mg/L	0.0951	0.0824	0.0986	0.0901	0.0915 ± 0.007
Cr	0.05 mg/L	0.0100	0.0091	0.0123	0.0110	0.0106 ± 0.001
Cu	2.0 mg/L	0.5400	0.4850	0.5821	0.4947	0.5254 ± 0.044
SAR	1.5	4.22	4.17	4.13	4.23	4.18 ± 0.046

BDL: Below Detection limits, SAR: Sodium Absorption Ratio Tmp. : Temperature

Table 4: Ground Water Samples from Orangi Town # 7 Karachi (Gw-2)

SampleDetails	Unit	S#1	S #2	S#3	S#4	Mean ± SD
Tmp.	Acceptable	27.3	26.8	26.5	26.8	26.9 ± 0.33
pH Value	6.5- 8.5	7.35	7.30	7.09	7.20	7.24 ± 0.12
Salinity	5.0 NTU	2.5	2.7	2.8	2.5	2.6 ± 0.15
BOD5	6 mg/L	BDL	BDL	BDL	BDL	BDL
COD	10 mg/L	BDL	BDL	BDL	BDL	BDL
TDS	<1000 mg/L	2563.0	2830.0	3198.0	3088.0	2919.8 ± 283.46
TSS	5 mg/L	48.0	54.0	62.0	58.0	55.5 ± 5.97
Pb	0.05 mg/L	BDL	BDL	BDL	BDL	BDL
Cd	0.01 mg/L	BDL	BDL	BDL	BDL	BDL
Ni	0.02 mg/L	BDL	BDL	BDL	BDL	BDL
Zn	5.0 mg/L	BDL	BDL	BDL	BDL	BDL
Cr	0.05 mg/L	BDL	BDL	BDL	BDL	BDL
Cu	2.0 mg/L	BDL	BDL	BDL	BDL	BDL
SAR	1.5	7.30	8.24	9.32	8.75	8.40 ± 0.86

BDL: Below Detection limits, SAR: Sodium Absorption Ratio

Tmp. : Temperature

Table 5: Ground Water Samples from Treatment Plant (Tp-1) Gate Haroonabad Site Karachi (Gw-3)

SampleDetails	Unit	S#1	S #2	S#3	S#4	Mean ± SD
Tmpe - ratue.	Acceptable	22.5	22.0	21.8	21.4	21.9 ± 0.46
pH Value	6.5- 8.5	6.94	6.92	6.91	6.88	6.91 ± 0.03
Salinity	5.0 NTU	2.2	2.1	2.5	2.2	2.3 ± 0.17
BOD5	6 mg/L	18.0	15.0	19.0	12.0	16.0 ± 3.16
COD	10 mg/L	30.0	23.0	32.0	20.0	26.3 ± 5.67
TDS	<1000 mg/L	2163.0	2098.0	2225.0	2130.0	2154.0 ± 54.26
TSS	5 mg/L	42.0	35.0	43.0	38.0	39.5 ± 3.69
Pb	0.05 mg/L	0.0302	0.0145	0.0233	0.0189	0.0217 ± 0.0066
Cd	0.01 mg/L	0.0129	0.0104	0.0189	0.0140	0.0141 ± 0.0036
Ni	0.02 mg/L	BDL	BDL	BDL	BDL	BDL
Zn	5.0 mg/L	0.5321	0.4211	0.9500	0.6120	0.6288 ± 0.2279
Cr	0.05 mg/L	BDL	BDL	BDL	BDL	BDL
Cu	2.0 mg/L	0.0927	0.0758	0.0990	0.0814	0.0872 ± 0.0105
SAR	1.5	9.00	9.08	8.91	8.98	8.99 ± 0.0699

BDL: Below Detection limits, SAR: Sodium Absorption Ratio

At sampling point S-2 high BOD_5 282.8 mg/L; COD 511.0 mg/L; TDS 769.5 mg/L; TSS 190.0 mg/L; SAR 2.65; low DO 1.10 and also heavy metals in significant quantities were encountered. Manghopeer nala, Orangi town sewage nala and SITE industrial effluents nala merge at sampling point S-2. This spot is also the start point of SITE industrial area.

At sampling point S-3 high BOD_5 379.3 mg/L; COD 689.0 mg/L; TDS 970.8 mg/L; TSS 287.3 mg/L; SAR 2.61; low DO 1.03 and also heavy metals in significant quantity were encountered. All parameters were high at this sampling site due to SITE area being close to it. All the industrial effluents from different industries affect this site.

Before discharge into the Lyari River at S-4, Orangi nala shows high BOD_5 492.25 mg/L; COD 675 mg/L; TDS 1039.25 mg/L; TSS 533.5 mg/L; SAR 2.95; low DO 1.76 and also heavy metals in significant because of mixing of the effluents from SITE industrial area, marble factories and sewage water.

Before mixing of the effluents of Orangi Nala with those of the Lyari River at S-5, the analyses of the latter showed high BOD_5 206.8 mg/L; COD 481.0 mg/L; TDS 1014.5 mg/L; TSS 109.5 mg/L; SAR 3.05; low DO 1.26 and also significant quantity of heavy metals. Result show that BOD and TSS loads were much less in Lyari River before Orangi Nala discharged its load into it.

After the mixing of Orangi Nala effluents with those of the Lyari river at S-6, high BOD_5 288.8 mg/L; COD 5.35 mg/L; TDS 1059 mg/L; TSS 188.3 mg/L; SAR 3.03; low DO 1.38 and also heavy metals in significant quantity were analyzed.

Analytical data show that at sampling point S-7 in the Liyari River, high BOD_5 391.3 mg/L; COD 510.8 mg/L;

TDS mg/L; TSS 188.3 mg/L; SAR 3.03; low DO 1.38 and also significant quantity of heavy metals were detected in the effluent.

Sodium Adsorption Ratio (SAR): SAR is an indicator of the sodium hazard of water. Excess sodium in relation to calcium and magnesium concentrations in soils destroys soil structure that reduces permeability of the soil to water and air. Sodium hazard in water is an index that can be used to evaluate the suitability of water for irrigating crops [19].

Monthly mean SAR value at Orangi Nala to Lyari River varies between 2.61 to 25.31 mg/L. SAR mean value is minimum at S-6 and maximum at S-1, shown in Table 2.

According to Canadian Water Quality Guidelines (1999) SAR < 4 is "Safe", 4 – 9 "Possible safe" and > 9 is "Hazardous" for irrigation water standards.

For Characterization of the water from different sampling points SAR was considered critical. Concentration of soluble matter would lead to higher SAR and total dissolved solid (TDS) due to interrelation and mixing of domestic as well as industrial wastewater [20].

Metal Analysis of Ground Water of the Same Areas

Zinc: Zinc concentration in NEQS [18] is 5.0 mg/L for drinking water. Zinc is an important and favorable element in human metabolism, however when it exceeds certain level, it causes renal disorders, diarrhea, respiratory disease, nausea etc [21].

Alvi *et al*. [22] reported that average concentration of zinc in ground water at SITE industrial area varied from 0.037 to 4.30 mg/L, whereas in adjoining residential area its concentration ranged from 0.16 to 0.0948 mg/L.

Cadmium: During present study the monthly mean cadmium concentration of ground water varied from BDL to 0.033 mg/L. Mean cadmium concentration recorded minimum at GW-2 and maximum at GW-1.

NEQS [18] for cadmium concentration is 0.01 mg/L for drinking water. Concentration of cadmium within limit in ground water can be tolerated but concentration in excess is harmful to human health. When cadmium concentration increases beyond the normal range it causes fading effects in liver, bones and kidneys.

Alvi *et al*.[22] reported average cadmium concentration in ground water at SITE industrial area that varied from 0 to 0.64 ppb, whereas in adjoining residential area its values range from 0 to 0.6 ppb.

Copper: Monthly mean copper concentration of ground water ranges from BDL to 0.53 mg/L. Mean copper concentration recorded minimum at GW-2 and maximum at GW-1.

NEQS limit [18] for copper concentration is 2.0 mg/L for drinking water. Copper is important and useful element in human metabolism. However, excessive Copper concentrations cause different diseases like depressions, GIT problems and kidney problems [21].

Alvi *et al*. [22] reported average concentration of copper in ground water at SITE industrial area that varied from 1.3 to 40.05 ppb, whereas in adjoining residential area its values range from 7.86 to 61.6 ppb.

Nickel: During present studies monthly mean nickel concentration of ground water varied from BDL to 0.1339 mg/L. Mean nickel concentration recorded minimum at GW-2 and maximum at GW-1.

Permissible limit of nickel in NEQS [18] is 0.02 mg/L for drinking water. Nickel is essential before birth and is associated with DNA and RNA molecules and enzymes. Excessive concentration in blood and enzymes increased blood sugar level [23].

Alvi *et al*. [22] reported average concentration of nickel in ground water at SITE industrial area that varied from 1.3 to 40.05 ppb, whereas in adjoining residential area its values ranged from 7.86 to 61.6 ppb.

Lead: During the present study monthly mean lead of ground water varied from BDL to 0.022 mg/L. Mean lead concentration recorded minimum at GW-2 and maximum at GW-3.

NEQS limit [18] for lead concentration is 0.05 mg/L for drinking water. Exposure to lead is associated with a wide range of effects, including various neuro effects, mortality, impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes [24].

Alvi *et al*. [22] reported average concentration of lead in ground water at SITE industrial area that varied from 0.72 to 199.25 ppb, whereas in adjoining residential area it values from 2.03 to 45.65 ppb.

Chromium: During present studies monthly mean chromium of ground water varied from BDL to 0.011 mg/L. Mean chromium concentration recorded minimum at GW-2 and maximum at GW-1.

NEQS limit [18] is 0.05 mg/L for drinking water. Excessive chromium is highly toxic causing skin irritation and allergy and lung cancer (Klaason, 2001) [23].

Alvi *et al*. [22] reported average concentration of Cr in ground water at SITE industrial area that varied from 4.2 to 173.5 ppb, whereas in adjoining residential area its values range from 3.2 to 42.7 ppb.

CONCLUSION

Untreated Industrial and domestic wastewater is a source of serious hazard to the coastal area of Karachi, which is a highly polluted coastal belt in the world resulting in an enormous economic loss to the country through decrease in the export potential of fisheries.

The study included testing of a wide range of pollutants at Orangi Nala and Lyari River. Results in comparison with National Environmental Quality Standards (NEQS) limits suggest that TSS, COD, BOD are higher than NEQS limits in all samples, whereas TDS, DO and SAR also fall under moderate to high category in all the samples.

Heavy metals concentrations from the study areas are within NEQS limits and have no adverse effect on coastal areas of Karachi, however chances of' their accumulation in marine life, groundwater, in marine organism and in food may cause serious risk for human health.

Data of the Results of sample analysis of the wastewater from Orangi Nala before mixing into Lyari River show higher values of TSS, TDS, COD, BOD and heavy metals (Cr, Ni, Cd) than those of the Lyari River alone. These values represent high to moderate level of pollution. These data indicate that Orangi Nala has higher quantity of pollutants than Lyari River.

It was observed during experimentation that an effluent containing >50% soluble COD will degrade faster than effluent having <50% unsalable COD. Experimental results showed that the soluble COD fractions are more readily biodegradable.

Research study shows that low cost treatment of municipal sewage and industrial wastewater treatment by using septic or settling tank at individual and small level of industrial facility will provide initial level of preliminary and primary treatment by settling and filtration. This system of treatment can be economically and environmentally feasible for industrial establishments.

Therefore it is recommended that industries and municipal organizations should try to remove total suspended solids (TSS) at their discharge source to reduce the organic load.

To overcome the pollution load in Arabian Sea, there is a need to improve the performance of all treatment plants as they are not working out their proper strength. New treatment plants at other areas should also be installed to treat the domestic and industrial wastewater before its discharge into coastal areas of Karachi.

Proper legislation in this regard needs to be strictly enforced. Rules must be adhered to and damages caused to environment must be recovered from polluters.

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