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IMPACT OF INDUSTRIAL EFFLUENT ON THE BENTHIC BIODIVERSITY OF GIZRI CREEK, KARACHI

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ABSTRACT

The concentrations and spatial distributions of different pollutants, including ammonia, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Cyanide, Dissolved Oxygen (DO), oil and grease (n-Hexane extract), Phenol, and Heavy metals (As, Cd, Cu, Cr, Hg, Pb and Ni) were investigated in water and sediment samples collected from eight stations at Gizri creek. The concentration of many of these pollutants was quite alarming except Cr, Pb and Ni in water and sediment samples. A total of 138 species of flora and fauna were recorded from 7 different sampling sites of Gizri creek. Ecological survey of the benthic communities revealed that the pollutants are responsible for the degradation of natural ecosystem of the creek, which has consequently resulted in reduced biodiversity of the ecosystem.

Keywords: Pollution, Gizri creek, Industrial pollution, ecology, NEQS (National Environmental Quality Standard)

INTRODUCTION

Karachi is situated on the southwestern part of Indus delta. It is the largest and the most industrialized city of Pakistan. Being the industrial hub of the country more than 8000 registered industrial units are in operation which mostly comprises of oil, steel, paints, chemical, fabric, pharmaceuticals, paper and pulp, food and beverages. However, treatment of industrial effluent is virtually non existent. Only few multinational companies have installed waste treatment facilities. Whereas, most of the industrial and domestic wastewater is discharged untreated into the Arabian Sea through Malir and Lyari Rivers that play an important role in the natural drainage of Karachi City. The coastal zone of Karachi is about 135 km long and it is reported that it is one of the most affected areas along the coast of Pakistan (Haq, 1976; Beg, 1997, Beg, *et al.,* 1984; Iqbal and Jilani, 1995; Khan, *et al.,* 1999, Khan *et al.*, 2007; Khan and Shaukat, 2008).

Malir and Lyari rivers having the catchments areas of 2051 and 7045 Km^2 respectively (ACE, 1994). Throughout the year these rivers serve as dumping places for the discharge of liquid and solid waste of industrial and domestic origin. These rivers instead of giving a pleasant look become an eye sore for the population (Beg, 1997).

Malir River topography can be divided in two parts: (1) upper portion that is hilly and undulated and without any vegetation (2) lower portion that consists of a 48 Km strip from confluence of Mol and Khadeji to sea and occupies about 133,333 Km^2 (ACE, 1994). Apart from Mol and Khadeji the other tributaries of Malir River are Thaddo, Sukkan, Turi, and Jarendo nallas. Malir River travels a distance of 18 km approximately within the city limits. Large scale unauthorized agricultural activity is taking place along the Malir River bed causing alteration in the river water flow. There are presently 8 inlets discharging untreated industrial and domestic wastewater into it.

Gizri creek is situated at the south east of Karachi serving as an outfall of Malir River with a catchment area of more than a thousand square miles. The creek is 10.63 km long and approximately on an average 1.29 km wide with varying depth ranges from 1 to 3m. The creek is grossly polluted mainly due to untreated domestic and industrial discharges. During monsoon period Malir River brings fresh water runoff to the Arabian Sea through Gizri Creek. While rest of the year Malir River transport around 141.54 mgd of industrial and municipal effluents to the sea through Gizri creek (Khan, *et al* ., 2007). During low tides only around 60% of the creek area remains inundated therefore, navigation in the channel is extremely difficult. Moreover, biodegradation of waste under anaerobic conditions generate bed smelling compounds which creates odour nuisance. The sizeable addition of various chemicals in the creek of industrial and domestic origin and the waste oil from defective motor boats further aggravates the problem. The heavy pollution load has virtually converted this ecologically important creek in to a sewage drain. The insufficient water circulation accumulates toxic pollutants which jeopardize the marine ecosystems. The creek also undergoes a slow ongoing erosion and accretion process.

The present study was aimed at collection and analysis of water and sediment samples from the creek area so as to determine the extent of pollution load that is a continuous threat to inland and creek ecosystems.

MATERIALS AND METHODS

The study was conducted during 2011-2012. Water and sediment samples were collected from seven different sampling stations along the Gizri creek at a distance of approximately 1.0 km. At different sampling stations the depth of water varied significantly from 1.0 to 3.0 m. From each sampling station three samples were collected to make one composite samples. Samples were collected monthly normally between 11.0 to 13.0 hours and were brought to the laboratory within two hours of collection, processed accordingly and analyzed for the parameters mentioned below. Fig. 1 represents the sites of sample collection of Gizri creek.

Collection of water samples

The samples were collected using Nikson bottle from the surface (approx. 5 cm), mid point and at the bottom of total depth. The samples were mixed in equal proportion (approx. 1 litre) to make one composite sample. For the collection of water samples for physical and chemical parameters white plastic containers of 2-litre capacity were used. The sample was collected in a way to avoid floating materials. Some portion of the sample was appropriately preserved for later studies according to the procedures as mentioned in Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Collection of sediment samples

The sediment samples from the Creek were collected from the locations given in Fig. 1. These samples were collected in sterile plastic bags using Patterson grab. Temperature and pH of the sediment samples were recorded on the spot. These samples were brought to the laboratory within two hours of collection. The samples were analysed in accordance with the procedures outlined in Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Physical parameters

The physical parameters tested were pH, salinity and temperature. pH and salinity of the samples were determined on site using HACH sensation 156 multi parameter dissolved oxygen meter. Temperature (^oC) measurements were conducted using Zeil thermometer by immersing it in the sample.

Biochemical and Chemical Parameters

These parameters include (i) ammonia NH_3-N (ii) Biochemical Oxygen demand BOD_5 (iii) Chemical Oxygen demand COD (iv) cyanide (v) dissolved oxygen (DO) (vi) oil and grease (n-Hexane extract) and (vii) phenol. These parameters were determined according to the methods mentioned in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Metal Analysis

The metal contents in the sample were measured with the help of Merck.

Collection and Processing of Sample for Benthic Communities

Benthic sample were collected using Patterson grab from the designated sampling sites. At each site a quadrate of 1.0 m^2 was placed at random and the sediment along with benthic organisms and were collected and transferred in the plastic bags. Formalin (10%) was added to the sample to ensured adequate fixing of all the material. Rose Bengal (1% solution in distilled water) was also added to the sample so as to stain the benthic organisms, which made sorting much easier.

Sieving and Sorting

In laboratory, each plastic bag containing biotic sample was carefully opened and the contents were transferred on a sieve of 0.5 mm mesh. The bottom of the sieve was gently dipped several times in sink containing water. The sediment remained on the sieve was transferred to Petri plates and the benthic organisms were handpicked, mostly under a stereomicroscope. Care was taken to pick up all the organisms present in the sediment sample. These organisms were put in suitable containers and fresh formalin solution (10%) was added. The containers were properly labeled.

Fig. 1. Map showing Gizri creek in the south of Karachi City.

Identification of biota

Attempts were made to identify all the biota present in the samples up to species level, but it was not always possible to do so. Hence several specimens were identified only up to various taxonomic categories. This was mainly due to the condition of the preserved specimens, which sometimes lacked those parts of the body that bear species specific characters.

The references which were used for the identification of biota include: Wesenberg-Lund (1949), Dance (1974), Oliver (1975), George and George (1979), Bemert and Ormond (1982), Burukovskii (1982), Davaney *et al.* (1987), Campbell (1989), Fish and Fish (1989), Allen (1997), Mustaquim (1997) and Shameel (2001).

Statistical analysis

Among the multivariate analytical methods available we chose cluster analysis as it is free from the assumptions of multivariate normality of continuity (monotonic nature) of the variables (Orloci and Kenkel, 1985). The method developed by Ward (1963) known as minimum variance technique was employed and a computer program developed by one of us was used (Shaukat and Siddiqui, 2005).

RESULTS AND DISCUSSION

The data collected during the course of study is presented, discussed and compared with National Environmental Quality Standards.

Physical parameters

Physical profile of marine water samples from different locations of Gizri creek is shown in Table 1. pH values of Gizri creek water at different sampling stations ranged between 7.5 to 8.1 whereas, the pH of sediment ranged between 7.5 to 8.2. pH of the entire Creek was towards alkaline side which favours the growth of flora especially algae (Smith and Smith 1998). This may also be due to excessive production of ammonia through the biodegradation of organic compounds under anaerobic condition. The salinity of the Creek water ranged from 31.6-36.4 parts per thousand which is normal to the coastal area of Karachi.

Biochemical and Chemical Parameters

The results of above biochemical and chemical parameters are reported in Table 2. NH_3-N is an important parameter in the pollution of marine and terrestrial environments. The average concentration of NH_3-N in Creek water ranged between 2.5-6.6 mg/L. In marine environment NH_3-N is produced as a result deamination activity by microorganisms. Accumulation of NH_3-N beyond 1.5-2.5 mg/L becomes toxic to growth of marine vertebrates and invertebrates (Bond and Straub,1973; Pearson-Le, *et al*.,1995). This could be one of the causes of lower biodiversity in the creek area (Khan and Shaukat, 2008).

Table 1. Physical profile of marine water at different locations of Gizri creek.

Sample No.	Coordinates	Depth (m)	Parameters					
			pH		Salinity ppt		Temperature (^oC)	
			W	S	W	S	W	S
G-S-1	24°48'35.69"N 67° 4'59.56"E	1.5	7.5	7.6	36.4	ND	20.6	ND
G-S-2	24°47'49.04"N 67° 4'59.63"E	1.8	7.9	8.0	31.6	ND	22.1	ND
G-S-3	24°47'19.32"N 67° 5'32.49"E	2.5	7.6	7.8	31.7	ND	19.6	ND
G-S-4	24°46'44.66"N 67° 6'9.52"E	2.7	8.1	8.2	34.2	ND	21.8	ND
G-S-5	24°46'9.18"N 67° 6'29.69"E	3.0	7.9	7.5	33.5	ND	22.6	ND
G-S-6	24°45'31.90"N 67° 6'24.16"E	3.0	7.7	7.8	32.8	ND	20.8	ND
G-S-7	24°45'1.64"N 67° 5'52.78"E	3.5	7.8	7.6	33.8	ND	21.6	ND
Average		2.57	7.78	7.74	33.42	ND	21.3	ND
Min-Max		1.5-3.5	7.5-8.1	7.5-8.2	31.6-36.4	ND	19.6-22.6	ND
Std. Dev		0.70	0.20	0.21	12.42	ND	10.92	ND

The results are mean of 3 replicates, ND=not done, W=Water, S=Sediment, ppt=Parts per thousand

The BOD_5 values of the creek water ranged between 130-180 mg/L whereas the sediment values varied from 200-300 mg/L. The values are significantly greater (P at the most 0.05) compared to the National Environmental quality Standards of Government of Pakistan. High BOD load is an indication of accumulation of organic pollutants susceptible to biological oxidation. High BOD values tend to reduce dissolved oxygen concentration thereby creating anoxious condition detrimental to marine life forms especially benthic flora. BOD_5 generating compounds such as hydrocarbons are toxic to fish beyond 10-20 mg/L (ACE, 1994). Khan and Shaukat, (2008) and Khan, *et al.*, (2003) also reported similar observations on Chinna Creek and Gharo Creek situated in Karachi.

The COD values represent both biologically and chemically oxidizable substances. The COD values of water and sediment samples ranged between 1667-3000 mg/Land and 2334-4000 mg/Kg respectively. These values are significantly greater that that of NEQS ($P<0.001$). The high values of COD represent the heavy influx of industrial effluent entering in the creek through Malir river. Khan and Shaukat (2008) also reported high COD values of Chinna Creek where the industrial effluent is coming through Lyari River. It can be argued that these two rivers are virtually responsible for the degradation of creek system of Karachi.

The concentration of cyanide in Creek water and sediment as compared to NEQS was quite alarming. The values of Creek water ranged between 2.2 to 4.7 mg/L and in sediment ranged between 3.3 to 7.6 mg/Kg. The maximum allowable limit of cyanide as compared to NEQS is 2.0 mg/L. Presence of cyanide indicates contamination due to industrial waste, which is mainly attributed to electroplating industry, metal treating industry, steam electric power plants, etc. Cyanide even at extremely low concentration is toxic to marine life forms.

Although, DO is not considered to be the pollutant parameter however its concentration represents the extent of pollution. The values of DO in Creek water ranged between 2.09-4.11 mg/L. However, this level of oxygen would not be enough to efficiently control the natural purification system of water in the Creek, which would result in reduced biodiversity.

Table 2. Biochemical and chemical profile of Gharo Creek. W-water, S=sediment.

Sample	Parameters (W=mg/L, S=mg/Kg)													
	NH_3-N		BOD_5		COD		Cyanide		DO		Oil and grease		Phenol	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
G-S-1	4.9	ND	170	220	2667	2334	3.6	6.5	3.44	ND	2.41	3.45	0.11	0.16
G-S-2	6.2	ND	160	260	3000	2667	4.7	7.6	2.58	ND	1.84	3.84	0.13	0.18
G-S-3	6.6	ND	130	200	2667	2934	3.4	6.2	4.11	ND	2.11	3.35	0.12	0.16
G-S-4	5.7	ND	140	290	1667	4000	2.3	5.4	2.09	ND	3.53	4.56	0.16	0.12
G-S-5	4.5	ND	170	270	2434	3400	2.3	3.3	3.16	ND	2.22	3.65	0.14	0.10
G-S-6	4.7	ND	180	300	2000	3133	3.2	4.7	2.74	ND	1.32	3.11	0.16	0.18
G-S-7	2.5	ND	145	243	1876	3124	2.2	3.3	2.45	ND	1.65	3.22	0.17	0.18
Average	5.01	ND	156	254	2330	3084	3.1	5.28	2.93	ND	2.15	3.59	0.14	0.15
Min-Max	2.5-6.6	ND	130-180	200-300	1667-3000	2334-4000	2.2-4.7	3.3-7.6	2.09-4.11	ND	1.32-3.53	3.11-4.56	0.11-0.17	0.10-0.18
Std. Dev.	1.35	ND	18.41	58.00	1061.82	1347.03	0.91	1.70	1.54	ND	1.54	0.49	1.82	1.68

The results reported are means of 3 replicates.

Oil and grease in any amount hampers the dissolution of atmospheric oxygen in the water thereby creating anoxious condition detrimental to marine life form. The concentration of oil and grease in water varied between 1.32-3.53 mg/L where as, in sediment ranged 3.11-4.56 mg/Kg. These values represent relatively insignificant extent of oil pollution in the Creek. The values are in fact low when compared with NEQS where the standard value is 10.0mg/L.

Phenols are usually present in the discharges from petroleum refinery, steam and electric power plants, rubber processing, glass and asbestos manufacturing. The concentration of phenol in Creek water ranged between0. 11-0.17 mg/L and that of sediment ranged from 0.10-0.18 mg/ Kg. These values are significantly higher when compared with NEQS and indicates a heavy pollution load entering into the Creek from the industries near by. These results are inconsistent with the findings of Khan, *et al., (*1999a, b) and Khan and Shaukat (2008).
The concentrations of heavy metals (As, Cd, Cu, Cr, Pb, Ni and Zn) are reported in Table 3. From the standpoint of metallic pollution the Creek water is gravely polluted with Industrial effluent ad depicted from heavy metal concentration in water and sediment samples. . All the heavy metals were relatively higher except Cd. In general the concentration of heavy metals is higher in sediment samples. The concentration of As in water and sediment was 0.04mg/l and 0.07 mg/kg respectively. Cd concentration was also low and was absent in sediment samples. The high concentrations of Cr, Cu, Pb,Ni and Zn are mainly attributed to the industrial activities. Cr is reported to be toxic only in hexavalent form (Misra and Mani, 1992). The concentration of Cr in Creek water varied from 0.15-0.19 mg/l where as in sediment raged between 0.19-0.29 mg/Kg. The high concentration of Cr in Creek water and sediment is mainly attributed to tanneries. These tanneries are situated in the south eastern side of Karachi mostly located in Korangi industrial area. The average concentration of Cu in water samples was 0.26 mg/l where as in sediment sample it was 0.40 mg/l. Although, Cu concentration was not significantly higher but its continuous accumulation may be lethal fro benthic fauna. The concentration of Pb ranged between 0.13 to 0.29 mg/l in water and in sediment from 0.18-0.25mg/kg which might come from plumbing material, batteries, and paint manufacturing industries. Lead exhibits low toxicity potential to plants but a high potential fro toxicity to animals including marine life forms (Bushnel and Joeger, 1986).

The concentration of nickel was relatively high in sediment samples (0.28-0.48 mg/Kg). the major source of Ni is also the effluent of industrial origin. The concentration of Zn was also high in sediment samples.

Table 3. Heavy metal profile of Gizri creek.

Sample	Parameters (mg/L)													
	As		Cd		Cr		Cu		Pb		Ni		Zn	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
S-1	0.02	0.03	0.06	BDL	0.19	0.27	0.32	0.47	0.29	0.36	0.26	0.47	0.35	0.67
S-2	0.06	0.08	0.05	BDL	0.18	0.29	0.31	0.48	0.18	0.24	0.31	0.48	0.41	0.73
S-3	0.03	0.05	0.06	BDL	0.18	0.21	0.28	0.41	0.16	0.21	0.28	0.41	0.34	0.69
S-4	0.07	0.15	0.08	BDL	0.17	0.23	0.21	0.38	0.18	0.20	0.21	0.38	0.33	0.71
S-5	0.05	0.11	0.05	BDL	0.16	0.21	0.35	0.46	0.13	0.28	0.23	0.46	0.34	0.82
S-6	0.06	0.04	0.04	BDL	0.17	0213	0.21	0.33	0.18	0.29	0.17	0.33	0.21	0.78
S-7	0.03	0.04	0.04	BDL	0.15	0.19	0.19	0.28	0.16	0.18	0.19	0.28	0.22	0.81
Min-Max	0.02-0.07	0.03-0.15	0.04-0.08	BDL	0.15-0.19	0.19-0.29	0.19-0.35	0.28-0.48	0.13-0.29	0.18-0.36	0.17-0.31	0.28-0.48	0.21-0.41	0.67-0.82
Average	0.04	0.07	0.054	BDL	0.17	0.23	0.26	0.40	0.18	0.25	0.23	0.40	0.31	0.74
Std. Dev.	0.02	0.03	0.03	BDL	0.05	0.08	0.03	0.05	0.05	0.06	0.06	0.10	0.09	0.05

The results reported are mean of 3 replicates.

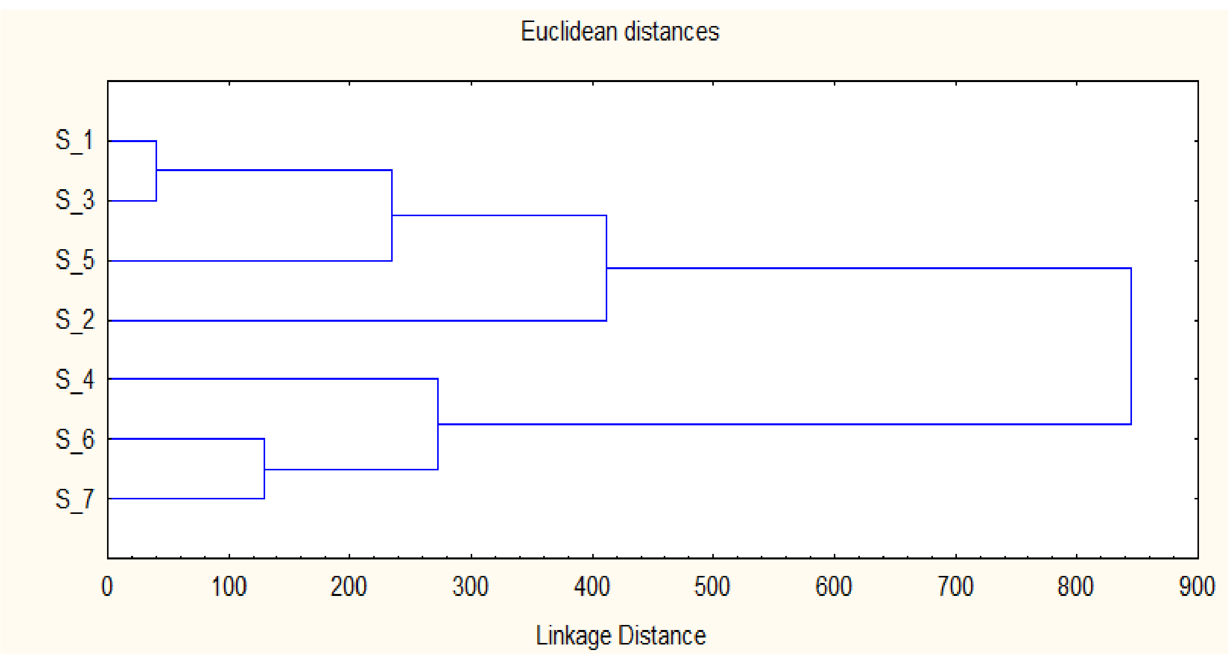

Fig. 2. Dendogram derived from Ward's method of clustering of seven sites based on Gizri creek water characteristics

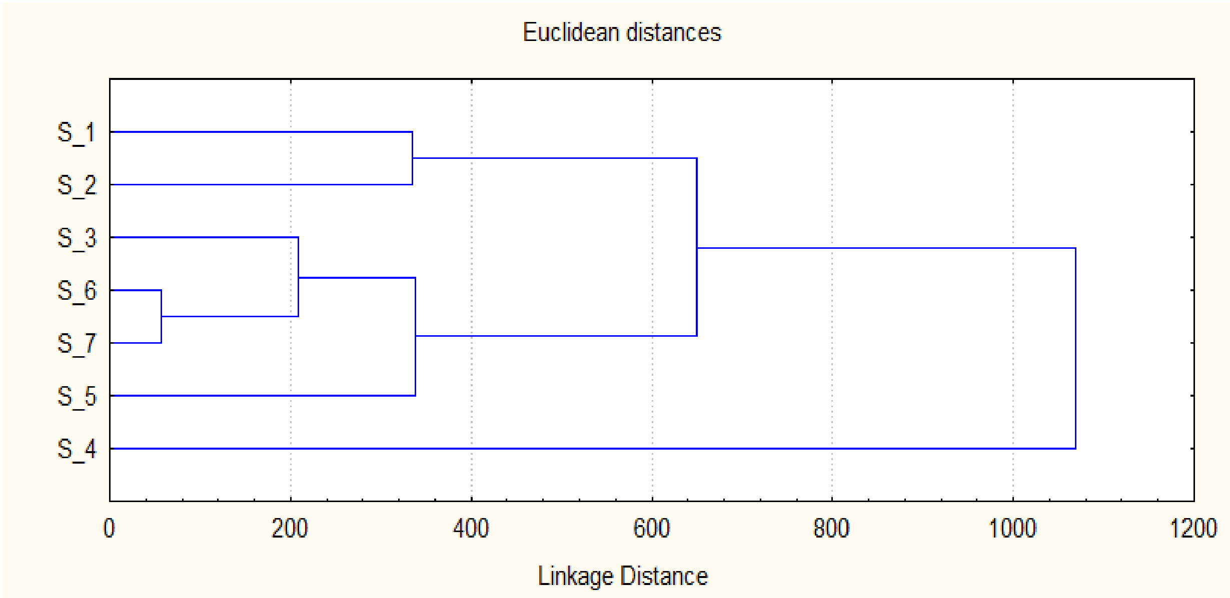

Fig. 3. Dendogram derived from Ward's method of clustering of seven sites based on Gizri creek sediment characteristics

Benthic Communities

During present investigation biota sample from benthic deposits were collected from 7 sampling sites as described above. The number of species of various taxa recorded and the distribution of species across sampling sites are reported in Table 4. A total of 138 species of flora and fauna were recorded from the samples collected at 7 different sampling sites of Gizri creek. The number of angiospermic plant species (monocots and dicots) were low in all the sampling sites because of the saline water at the sites. The number of algal species recorded were substantially higher than the angiosperms recorded at Gizri creek. Among the algae the most abundant species were *Enteromorpha* and *Ulva.* The blue-green algae recorded were *Phormedium* and Nostoc. Like the flora, fauna was also poorly represented. Only one species of sponge (Porifera) was recorded. Marine (benthic) nematodes were found in abundance and represented by 5 species. The most prominent group (phylum) was Nematoda which constituted 23.18 % of the total organisms collected from all the sampling sites. Gastropoda was the second group in abundance that accounts for 13.76%. Within Mollusca, Gastropods were represented by 3 species and bivalves by 2 species. Crustacea had low species richness and constituted 11% %. In Crustacea the most abundant group was Ostrocoda (8.69%). In general, the biodiversity of the creek is low owing to heavy pollution load in the creek.

Cluster analysis

The dendrogram derived from the cluster analysis of water sample basic disclose two groups , one of which comprises of shallow water stations 1-5 which are polluted to greater extent as shown by higher values of BOD and COD. The second group comprises of two sites 6 and 7 where water has greater depth with lesser BOD and COD values. Also the concentrations of most heavy metals is higher in the first five sites. When the dendrogram based of sediment characteristics is compared with that of water quality using a cophenetic metric (see Shaukat and Siddiqui, 2005) a correlation value of 0.367 was obtained indicating some degree of correspondence between water and sediment properties. The dendrogram based on the biota (taxa) of various stations shows two sites namely 1 and 7 to differ considerably from other sites. This is because of greater frequency of nematodes and Gastropods at site 1 while these have low value at site 7. Comparing this dendrogram with that of water quality (cophenetic r= 0.162) and with the sediment (cophenetic r= 0.135) did not reveal significant similarity.

CONCLUSIONS

The study demonstrates that the Creek is continuously receiving industrial discharges. In addition the untreated domestic wastewater further aggravates the situation, by causing organic pollution. The profile of heavy metals shows that most metals are significantly greater than those of NEQS (P at the most 0.05). High BOD and COD of channel water and the accumulation of heavy metals such as chromium, lead and nickel in the sediments are inimical to growth and development of flora and fauna. Thus reduced biodiversity can easily be attributed to increased levels of pollution of the sediments. Heavy metals are being added constantly as a result of the discharge of industrial effluents, their continuous accumulation in marine deposits is a potential threat to aquatic life. It is suggested that a more extensive ecological survey of the creek need to be undertaken to elucidate the impact of above mentioned pollutants on the biotic communities of the Creek.

Table 4. Frequency of occurrence of biota of Gizri creek.

Taxa	Sampling sites							Total number of species	% distribution
	S- 1	S-2	S-3	S-4	S-5	S-6	S-7		
Flora									
Monocot (Graminae)	1	1	2	1	___	___	___	5	3.62
Dicots	1	___	1	1	2	___	___	5	3.62
Algae	3	2	4	2	3	1	___	15	10.86
Total number of plant species	5	3	7	4	5	1	___	25	18.11
Fauna									
Porifera (Sponges)	___	___	___	___	__	__	2	2	1.44
Nematoda (Round worm)	6	9	5	7	2	2	1	32	23.18
Mollusca									
Gastropoda (Snail and Sea slugs)	4	3	5	3	2	1	1	19	13.76
Pelecypoda (Bivalves)	1	2	1	1	1	2	1	9	6.52
Annelida (Polychaeta)	2	2	1	1	1	1	2	10	7.24
Crustacea									
Copepoda	___	___	__	___	1	1	2	4	2.89
Ostracoda	2	2	1	2	1	3	1	12	8.69
Total number of species	25	24	27	22	18	12	10	138	100

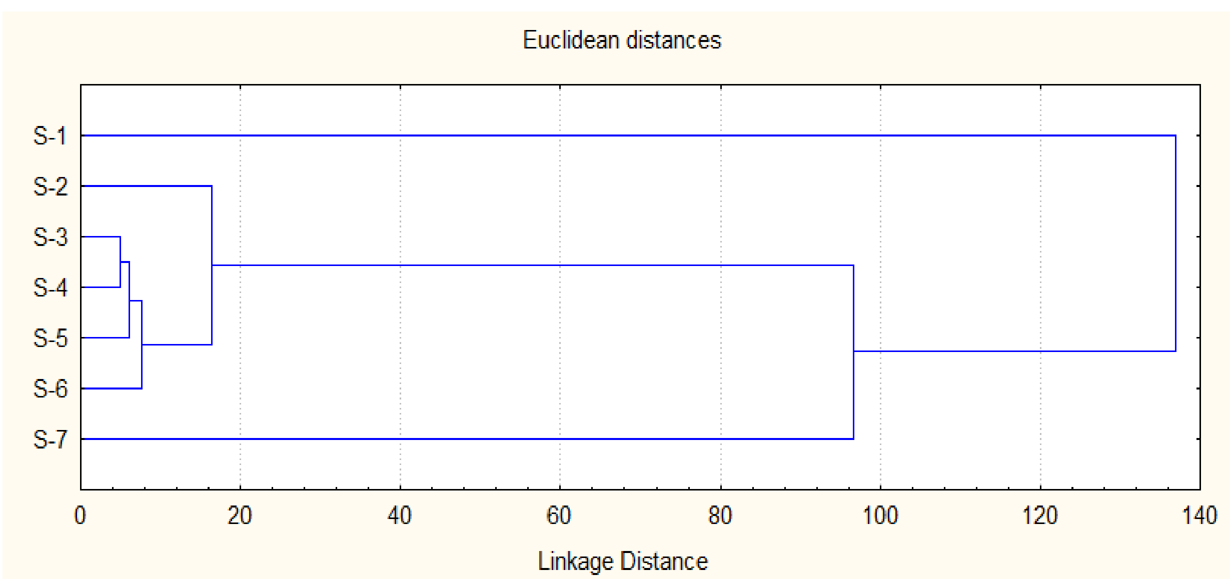

Fig. 3. Dendogram derived from unweighted pair group average clustering of seven sites based benthic communities of Gizri Creek

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