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IMPACT OF REFINERY EFFLUENT ON WATER QUALITY AND PLANKTON COMPOSITIONS OF KALIANI AND DHANSIRI RIVERS OF ASSAM, INDIA

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ABSTRACT

An ecological health assessment was carried out for two years in the two rivers –Dhansiri and Kaliani of Golaghat district of Assam affected by effluent of the Numaligarh refinery. The river sections were divided into two areas- control area and contaminated area. Some of the selected physiochemical parameters were water temperature, Conductivity, pH, TDS, Turbidity, Total alkalinity, Dissolved Oxygen (DO), Calcium hardness etc. The abundance and density of phytoplankton and zooplankton were calculated and compared between the control area and contaminated area. In the study, a distinct fluctuation was observed in both physiochemical parameters and bio-community structures of the two rivers.

KEY WORDS: Ecological health, Effluent, Numaligarh refinery, Plankton, Pollution

INTRODUCTION

Oil pollution is a serious problem altering the aquatic biota. The wastes are released to the environment in the form of gases, particles and liquid effluent (liquid consisting of surface runoff water, sanitary wastewater, solid waste and sludge) (World Bank, 1998). The waste water released from the refineries are characterized by the presence of large quantity of crude oil products, polycyclic and aromatic hydrocarbon, phenols, metal derivatives, surface active substances, sulfides, naphthalene acids and other chemicals (Suleimanov, 1995). As a result of ineffectiveness of purification systems, waste water may become seriously dangerous, leading to the accumulation of toxic products in the receiving waster bodies with potentially serious consequences on the ecosystem (Aghalino and Eyinla, 2009). The physical and chemical characteristics of water can be used as direct measures of health (e.g. to meet human drinking water or amenity values), as well as indicators of pressures on other ecological values (Bunn and Arthington, 2010). As a part of sustainable regulatory measure, the aim of the study was to determine the effect of effluent discharge on water quality of two rivers Dhansiri and Kaliani by evaluating the ecological health conditions through water quality and plankton density.

MATERIALS AND METHODS

The 3 MMTPA Numaligarh Refinery Limited (NRL) is located at latitude of $26^0 37'30''$ N and longitude of $93^0 43'30''$ E, at elevation of about 90m above MSL that was set up at Numaligarh in the district of Golaghat of Assam (Fig. 1) in accordance with the provisions made in the historic Assam Accord signed on 15th August 1985. Two study areas were used for comparisons, both with similar environmental but are different gradient level. To know the changes in water physicochemical variables and biological community structures, one area located upstream of River Kaliani was considered as control area (S1, S2, S3, S4 and S5) where there was no contamination from refinery effluent; the S6 was the point of effluent discharge and the following S7 was located on River Kaliani and the S8, S9 and S10 were located on Dhansiri (Fig 2). The physicochemical parameters and Plankton

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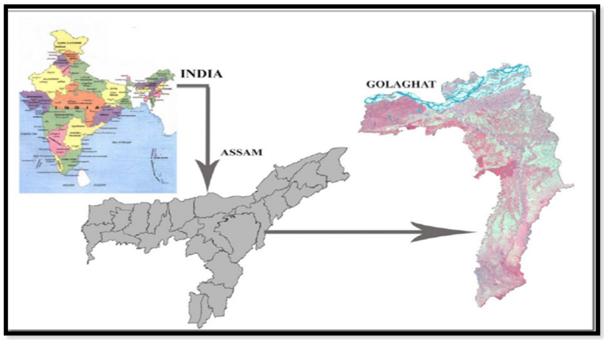

Fig. 1. Location map of Golaghat district of Assam

(Phytoplankton and Zooplankton) samples were collected monthly over a period of two years for March 2012- February 2014.

The physicochemical parameters selected for the study were - water temperature, Conductivity, pH, TDS, Turbidity, Total alkalinity, Dissolved Oxygen (DO), Calcium hardness, Chloride, Free carbon dioxide (FCO_2) and Total hardness.

Plankton was collected with a No. 25 ì plankton net up to the depth of 0.5 meter. A known volume (25 L) of water was strained through plankton net to assess the quantity of the plankton. The samples were fixed in 4% formalin. Qualitative study of the plankton was made following Desikachary (1959); Davis (1955); Ward and Whipple (1959) and Lackey (1983). The density (no./l) of the plankton was calculated using the following formula-

$$N = \frac{A \times C}{L}$$

Where, A = Average number of plankton counted per mL of concentrated sample, C =Volume of concentrated sample in mL, L = Volume of original water in liter passed through the plankton net, N = Total no. of plankton per liter of original water (no./l).

Linear regression analysis was also carried out for the selected physicochemical parameters and bio-communities.

RESULTS AND DISCUSSION

The monthly and seasonal readings of fluctuations of different parameters were carried out for the ten sampling stations are presented in the Table in an annual form (Table 1). The monthly mean water temperature was the highest in June (32.60±0.42 ^{0}C) at S10, while lowest in winter in January (14.00±0.00 ^{0}C) at S1. The annual mean at different stations have shown fluctuations, being the lowest at S1 and the

Table 1. Annual mean values of different parameters of Rivers Dhansiri and Kaliani

Seasons	Control area					Contaminated area				
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Air temperature	24.91±6.18	25.13±6.13	25.35±6.11	25.46±6.06	25.69±6.06	26.14±6.18	26.26±6.12	26.38±6.12	26.45±6.17	26.65±6.16
Water temperature	23.23±5.72	23.45±5.67	23.63±5.68	23.78±5.64	24.05±5.59	24.46±5.67	24.63±5.56	24.72±5.59	24.78±5.65	25.03±5.61
Conductivity	61.21±7.93	62.42±7.03	62.04±6.97	63.25±6.84	61.38±7.34	446.21±29.00	215.29±31.82	153.04±32.23	115.67±21.83	88.04±6.68
pH	6.79±0.27	6.84±0.27	6.87±0.29	6.89±0.25	6.89±0.30	7.01±0.31	6.95±0.28	6.95±0.26	6.92±0.28	6.89±0.29
TDS	25.69±5.82	26.70±5.52	28.32±4.22	30.32±3.32	30.91±3.00	135.90±75.77	84.88±12.09	73.38±11.90	59.45±15.79	52.46±11.78
Turbidity	7.79±3.28	8.07±3.35	8.20±3.10	8.35±3.13	8.58±3.03	22.55±3.40	19.80±2.95	18.29±2.89	17.48±2.93	16.48±2.92
Total alkalinity	23.55±2.95	23.62±3.08	23.80±2.97	24.01±2.99	25.30±6.45	69.03±29.78	49.53±20.30	42.89±17.01	31.69±10.39	29.80±9.31
DO	8.74±1.06	8.55±1.07	8.42±1.04	8.18±0.97	7.84±0.91	4.24±0.21	5.88±0.44	6.69±0.60	7.13±0.71	7.51±0.87
Calcium hardness	13.68±3.02	13.33±2.63	13.63±2.32	14.03±4.06	14.68±4.15	43.41±15.16	31.35±11.68	24.74±7.24	20.89±6.46	20.34±6.33
Chloride	0.98±0.22	0.96±0.27	0.91±0.41	1.23±0.41	1.19±0.49	24.19±14.38	12.37±5.42	3.00±1.63	1.95±0.78	1.37±0.42
FCO2	4.16±0.39	4.34±0.29	4.41±0.31	4.44±0.30	4.51±0.32	5.21±0.38	5.00±0.34	4.83±0.36	4.79±0.34	4.78±0.33
Total hardness	19.67±2.44	19.60±2.36	20.45±3.09	19.55±2.67	21.26±9.57	68.26±36.05	46.89±24.83	38.63±18.91	27.99±11.57	26.05±9.88

highest at S10, which might be due to their altitudinal differences. 25 °C is the recommended limit for no risk according to the FEPA water quality guidelines for domestic use (DWAF, 1995), while 40 °C is recommended limit according to WHO (1993). Based on these guidelines, the temperature of the effluent does not appear to pose any threat to the homeostatic balance of the receiving water bodies, in conformity with the report of Jaji *et al.* (2007).

Conductivity value is a good measure of the relative difference in water quality between different aquifers (Dee, 1989). Seasonal maximum value was recorded in monsoon season with a 481.17±38.72 µS/cm (at S6) which is in conformity with Junk *et al.* (1989), who reported that large amount of ionic substances from the runoff water of the river catchment areas enhance the conductivity in monsoon season and the lowest in winter season with a 55.33±3.93µS/cm (at S1) might be due to minimum rainfall coupled with low temperature, as temperature influences positively on conductivity (Hassan *et al.,* 2008). The maximum annual value was recorded at S6 (446.21±29.00 µS/cm) and minimum at S1 (61.21±7.93µS/cm). The monthly variations of mean conductivity was lowest at S1 (55.00±4.24µS/cm), whereas the maximum value at S6 with 511.00±0.00µS/cm that was slightly above of the WHO (1993) permissible limit of 500µS/cm which might be attributed to the refinery effluent discharged at that point, while in the subsequent downstream of the contaminated area the conductivity became lower indicating recovery from organic load.

The highest value of pH in winter with a 7.44±0.09 (at S6) and the lowest value in monsoon period with a 6.54±0.01 (at S1) were in conformity with Riddhi *et al*. (2011). According to Kaul and Handoo (1980), the increased surface water pH is due to increased metabolic activities of autotrophs, which utilize CO_2, consequently liberating O_2 and reducing H+ ions. The annual mean of highest pH value was recorded at S6 (7.54±0.01) of contaminated area. Waters of both the rivers were found to be slightly acidic in most of the months of the study period, except the S6. This is in agreement with earlier findings of Mukhopadhyay (1996), who reported that in NE region the pH of water was found to be slightly acidic in relatively high altitude system. The monthly mean of pH at S6 with a 7.44±0.09 in February was found maximum than all the other sampling stations. This value could be attributed to the effluent entering the river from NRL, as Jhingran and Pathak (1988) reported that the increase of the pH of the surface water due to industrial effluent. Overall, the pH was within the range of 6.5–8.5 stipulated for drinking and domestic purposes (WHO, 1993). Based on these guidelines, the pH of the river water would not adversely affect its use for domestic as well as recreational purposes and the aquatic ecosystem.

Again the highest value of TDS recorded during monsoon period with a 256.72±54.63 mg/L (at S6) could be related to increase in the load of soluble salts, mud, increase in the surface runoff and erosion of river banks; whereas the lowest value recorded in winter season with a 19.43±0.69 mg/L (at S1) might be due to sedimentation of suspended solids and slow rate of decomposition. Similar results were also reported by Thirumala *et al.* (2011). The annual fluctuation at different sampling stations was recorded maximum at S6 (135.90±75.77 mg/L) and minimum at S1 (25.69±5.82mg/L) indicating an impact on the river section due to contamination of pollutant from NRL discharge. FAO recommendation, the acceptable concentration of TDS for livestock drinking is required to be between 100-150 mg/L, but at the point of effluent discharge the monthly mean value was beyond the required limit of FAO. The high amount of TDS inhibits the photosynthetic activity of aquatic plants and consequently leading to ecological imbalance influencing the food chain and food web (Dallas *et al.,* 1998).

The highest value of turbidity was recorded in monsoon season with a 26.43±2.29 NTU (at S6) and was in conformity with Thirumala *et al.* (2006), who reported that the high turbidity during summer season might also be responsible for the higher water temperature absorbing heat from the sun ray thus making the water warm, whereas the lowest value in winter season with a 2.45±0.24NTU (at S1) was in conformity with Onyema and Ojo (2008) and according to them, most of the suspended particles settle to the bottom causing the water less turbid. The maximum annual value was recorded at S6 (22.55±3.40NTU) and minimum at S1 (7.79±3.28NTU). The S6 has shown the maximum value with a 29.05±0.21 NTU in July, which is beyond the permissible limit of 5 NTU of WHO (2004). On the other hand, the value were gradually ceasing in the further downstream. This reduction might be due to several physiochemical reactions such as sedimentation, coagulation, fixation, amongst other factors like oxidation and precipitation (Wasserman *et al.,* 2006). On the other hand, the control area has shown minimum values throughout the sampling period. Turbidity causes decrease in photosynthetic activity as turbidity precludes deep penetration of light in water and ultimately, the water receiving body is disqualified as source of water for domestic use in the community (Muoghalu and Omocho, 2000).

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Sverdrap *et al.,* 1942). The winter season has shown the maximum value of 99.17±40.86mg/l which might be due to concentration of water in the absence of heavy rainfall, whereas the minimum value of total alkalinity with a 19.88±0.75 mg/L in monsoon season might be due to dilution by rain-water. Similar observations were shown by Singh *et al.* (2009); Latha and Mohan (2010). Annual fluctuation was maximum at S6 (69.03±29.78 mg/L) and minimum at S1 (23.55±2.95 mg/L). The S6 had shown the maximum value in all the months with the peak value in February with an 113.50±53.03 mg/L, while the further downstream has experienced a decrease in values.

The maximum DO with a 9.85±0.18 mg/L (at S1) might be due to the reduced rate of decomposition by decreased microbial activity at low temperature (Prasad and Singh, 2003); while monsoon season has shown minimum value of 3.98±0.17mg/L (at S6) which might be due to increase in temperature as well, as both have shown strong negative correlations ($p<0.01$) in the study and in conformity with Tiwari and Ranga (2012).

In the study, the minimum monthly mean value of DO with a 3.95±0.35mg/L and 3.95±0.07 mg/L were observed at S6 in June and July respectively, while S1 has shown the maximum DO (10.00±0.00 mg/L) in December. Moundiotiya *et al.* (2004) reported that addition of a variety of biodegradable pollutants from domestic and industrial sources stimulate the growth of micro-organisms that consume the dissolved oxygen.

The highest mean value of calcium hardness was recorded in winter with a 54.32±16.46 mg/L at S6, while the lowest was recorded in monsoon with a 10.72±0.40mg/L at S1 indicating a pollution-free status. Monthly maximum values were shown by the S6 with a 69.8510.11 mg/L in March, while minimum at S3 (10.05±1.48mg/L) in July. The maximum values at S6 might be attributed to the refinery effluents (Rai, 1974) and was within the permissible limit of WHO (1993).

The lowest value in monsoon season with a 0.52±0.37mg/L (at S5) and highest value in winter season with a 40.75±23.98mg/L (at S6) confirmed the findings of Mishra and Tripathi (2003) who also reported low chloride during the rainy, but high during winter season.

The maximum value of chloride was recorded in winter (40.75±23.98mg/L) at S6 minimum in monsoon (0.52±0.37mg/L) at S5. The annual lowest value of chloride was recorded at S3 (0.91±0.41 mg/L) while the highest at S6 (24.19±14.38 mg/L) can be regarded as polluted state of the river segment. This can supported with the facts that NRL releases refinery effluent in this point. According to Hasalam (1991), the sewage water and industrial effluent are rich in Cl- and hence the discharge of these wastes result in high chloride level in fresh water. Similar results were reported by Swarnalatha and Nasing Rao (1998) showing that higher concentration of chloride is association with increased level of pollution.

The maximum FCO_2 in monsoon season with a 5.70±0.14 mg/L (at S6) and minimum in winter season with a 3.63±0.38 mg/L (at S1) were in conformity with many of the authors investigations including Biswas and Baruah (2000). The annual mean variations at different stations were found maximum at the S6 and minimum at S1. The maximum value of monthly mean of FCO_2 was recorded in June with a 5.85±0.07mg/L at S6 and minimum of 3.30±0.14 mg/L was recorded at S1 in December. The highest values of FCO_2 at S6 throughout the study period indicated the pollution load from the refinery effluent.

The maximum value of total hardness was recorded in winter with a 103.02±34.30 mg/L (at S6), which might be due to natural accumulation of salts and decrease in water volume, whereas minimum with a 16.67±0.50 mg/L (at S1) in monsoon could be due to the high rate of precipitation during the period which diluted the salt content of the water. Similar trend in total hardness of the riverine water was also observed by several workers (Singh *et al.,* 2009).

The S6 has shown the maximum values of calcium hardness in all the months being highest in February with an 116.00±45.25 mg/L. On the other hand, in the further downstream it had shown a decreasing tendency. The control area had the lowest value than all of the stations of contaminated area. Mohanta and Patra (2000) also reported that addition of sewage, detergents and large scale human use might be the cause of elevation of hardness. However, all the values were within the range of WHO (1989) permissible limit for total hardness of 150 mg/L.

Phytoplankter are the most sensitive biological component of aquatic environment signaling environmental disturbances (Carle, 1979). They were used as indicators of water quality (APHA, 2005). Hambright and Zohary (2000) also stated that phytoplankton is one of the most essential characteristics of the aquatic ecosystem for maintaining its stability and a means of coping with any environmental change. So, phytoplankton population observation may be used as a reliable tool for bio-monitoring studies to assess the pollution status of aquatic bodies.

In the control area of Kaliani all the 25 genera were recorded at S5 *viz. Asterionella, Fragillaria, Diatoma, Ankistrodesmus, Chlorella, Closterium, Cosmarium, Eudorina, Desmidium, Haematococcus, Mougeotia, Odogonium, Pediastrum, Selenastrum, Spirogyra, Ulothrix, Volvox, Zygnema, Anabaena, Gloeotrichia, Nostoc, Oscillatoria, Cryptomonus, Rodomonus* and *Euglena* (Table 2). On the other hand, both the S1 and S4 harbored 21 genera; S2 and S3 harbored 24 genera. The presence of maximum genera indicated a comparatively healthy ecosystem of the control area of Kaliani. Among the all genera, *Asterionella* was an indicator of clean water (Round *et al.*, 1990) and it was not recorded at any station in the contaminated area. A distinct fluctuation was observed in the occurrences of phytoplankton taxa at different sampling stations of the two rivers. Only six genera out of 25 genera of phytoplankton were recorded at S6 and they were *Fragillaria* of Bacillariophyta; *Odogonium, Ulothrix* and *Volvox* of Chlorophyta; *Oscillatoria* of Cyanophyta and *Euglena* of Euglenophyta. According to Palmer (1969), these taxa were tolerant to organic pollution.

A total of 51 phytoplankter were recorded from the S6 and the genus *Odogonium* was the most dominant genus with a 35.29 % and the *Fragillaria* was the least available genus with a 7.84 %. On the other hand, *Oscillatoria* comprised of 19.61%, *Euglena* comprised of 17.65%, whereas both the

Table 2. Annual abundance of phytoplankton of Rivers Dhansiri and Kaliani

Taxa	Control area					Contaminated area					Total	Mean±STD
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10		
1. *Asterionella*	12	8	4	4	5	0	0	0	0	0	33	6.60± 3.44
2. *Fragillaria*	2	4	3	2	4	4	4	4	10	5	42	4.20± 2.25
3. *Diatoma*	6	7	6	6	3	0	3	7	2	6	46	5.11± 1.90
4. *Ankistrodesmus*	7	2	0	0	3	0	0	0	0	2	14	3.50± 2.38
5. *Chlorella*	0	2	2	2	2	0	5	1	4	2	20	2.50± 1.31
6. *Closterium*	2	5	4	3	2	0	0	0	0	3	19	3.17± 1.17
7. *Cosmarium*	1	10	3	6	1	0	2	4	3	0	30	3.75± 3.01
8. *Eudorina*	8	5	2	2	1	0	1	0	2	1	22	2.44± 2.51
9. *Desmidium*	0	2	1	14	3	0	3	3	1	2	29	3.63± 4.27
10. *Haematococcus*	11	4	7	0	3	0	0	0	0	0	25	6.25± 3.59
11. *Mougeotia*	4	0	4	9	2	0	2	5	3	2	31	3.88± 2.36
12. *Odogonium*	0	1	1	5	3	18	10	9	9	8	64	7.11± 5.37
13. *Pediastrum*	1	1	1	0	1	0	0	1	0	2	7	1.17± 0.41
14. *Selenastrum*	2	6	3	6	12	0	2	5	1	2	39	4.33± 3.43
15. *Spirogyra*	6	6	7	6	5	0	0	3	0	1	34	4.86± 2.12
16. *Ulothrix*	2	1	2	0	5	5	6	9	7	7	44	4.89± 2.71
17. *Volvox*	2	9	4	2	3	5	12	1	6	3	47	4.70± 3.47
18. *Zygonema*	6	3	8	11	8	0	1	2	4	3	46	5.11± 3.33
19. *Anabaena*	1	6	4	4	2	0	1	2	3	5	28	3.11± 1.76
20. *Gloeotrichia*	15	7	11	2	6	0	0	2	2	2	47	5.88± 4.94
21. *Nostoc*	2	2	3	7	3	0	1	2	1	1	22	2.44± 1.88
22. *Oscillatoria*	0	1	5	5	3	10	8	3	9	10	54	6.00± 3.35
23. *Cryptomonus*	7	5	10	2	6	0	1	4	6	4	45	5.00± 2.69
24. *Rodomonus*	8	7	8	7	8	0	2	2	1	1	44	4.89± 3.26
25. *Euglena*	12	11	12	12	13	9	10	14	13	14	120	12.00± 1.63
Total	117	115	115	117	107	51	74	83	87	86	952	95.20±22.55

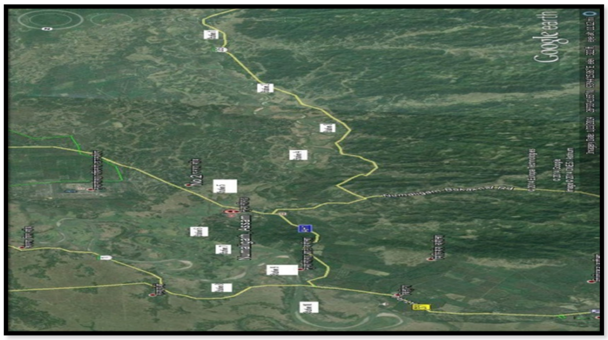

Fig. 2. Satellite imagery of sampling stations of Rivers Dhansiri and Kaliani (Source: Google earth)

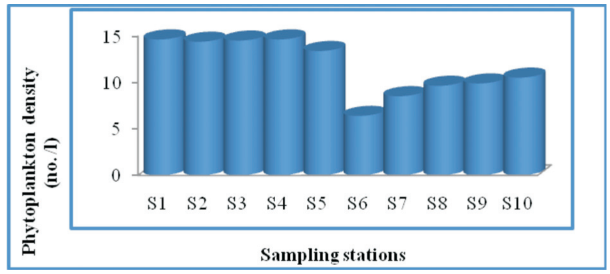

Fig. 3. Mean density of phytoplankton (no./L) of Rivers Dhansiri and Kaliani

genera *Ulothrix* and *Volvox* comprised of 9.80% of the total composition of phytoplankton at S6 of Kaliani. At that point of effluent discharge the phylum Chlorophyta (green algae) was the most dominant with a 55%, followed by Cyanophyta (blue green algae) with a 19%, Euglenophyta with an 18% and Bacillariophyta with an 8% of the total phyla. According to Graham and Wilcox (2000), the green algae are the most diverse group of algae with about 17,000 known species, this diversity of which is reflected by the varied of morphology, with organisms being grouped into a range of growth forms – depending on whether they are unicellular, colonial or filamentous.

The S6 contained the minimum annual mean density with a 6.38±2.02 no./L., which might be due to the adverse effect of refinery effluents, whereas the further downstream (S7, S8, S9 and S10) of S6 have shown a gradual increase in density from S7 with a 8.50±2.80 no./L to 10.50±3.34 no./L at S10 (Fig.3) indicating the decrease effect of organic pollution from NRL. On the other hand, the sampling stations of control area have shown the maximum densities being highest at S1 (14.63±5.57 no./L) and S4 (14.63±6.76 no./L), indicating healthy ecosystems. The phytoplankton community has shown strong positive correlation with DO ($p<0.01$) and depicted with the regression line in Fig.4.

The freshwater zooplankter are primary consumers, feeding on an array of items, typically

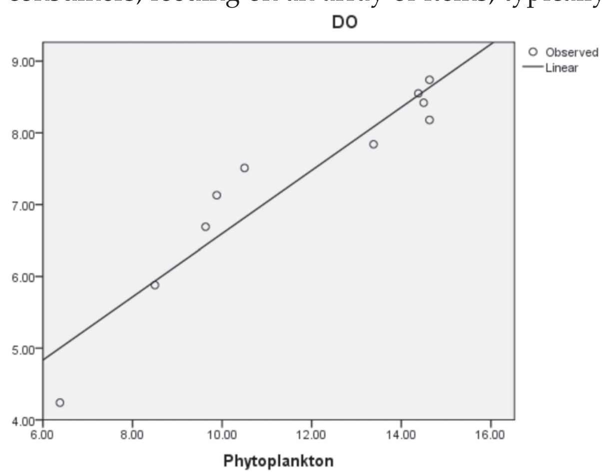

Fig.4. Linear regression line (R^2=0.900) showing relationship between phytoplankton and DO

Table 3. Annual abundance of zooplankton of Rivers Dhansiri and Kaliani

Taxa	Control area					Contaminated area					Total	Mean±STD
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10		
1. *Bosmina*	12	13	10	12	13	0	0	3	6	8	77	9.63±3.66
2. *Pleuroxus*	10	11	12	12	10	4	10	10	8	7	94	9.40±2.46
3. *Cyclops*	9	8	9	8	9	8	6	9	8	11	85	8.50±1.27
4. *Diaptomus*	9	11	13	15	12	0	3	2	7	5	77	8.56±4.59
5. *Cypris*	24	22	22	21	25	1	9	9	15	13	161	16.10±7.99
6. *Paramecium*	34	38	43	40	43	15	25	35	39	34	346	34.60±8.68
7. *Brachionus*	5	6	11	10	10	11	11	12	17	10	103	10.30±3.27
8. *Conochilus*	7	7	11	6	8	7	7	11	9	11	84	8.40±1.96
9. *Kellicotiia*	9	9	5	11	8	0	5	6	7	6	66	7.33±2.06
10. *Lecane*	9	9	9	8	8	0	0	0	0	0	43	8.60±0.55
11. *Trichocera*	8	6	10	10	11	4	5	6	6	7	73	7.30±2.36
Total	136	140	155	153	157	50	81	103	122	112	1209	120.90±35.13

bacteria, detritus, phytoplankton, and other small zooplankters and are in turn consumed by predaceous zooplankton, other invertebrates, ichthyoplankton and adult zooplanktivorous fishes (Wetzel, 2001). All the sampling stations of control area harbored all the eleven recorded genera showing a comparatively healthy ecosystem (Table 3). At the S6 only seven genera out of eleven genera have been recorded and they were *Pleuroxus*, *Cyclops, Cypris, Paramecium, Brachionus, Conochilus* and *Trichocerca.*

Presence of the pollution tolerant genera *viz. Brachionus* and *Trichocerca* abundantly at S6 indicated heavy pollution (Pennak, 1989). At S6 Rotifer was the most dominant group with a 44%, followed by Protozoa with a 30%, Copepoda with a 16%, Cladocera with an 8% of the total group. Rotifers are globally known as indicators of water quality since long time by a number of workers including Sladecek (1983). Ostracoda was the least available group only with a 2% at the S6 that was in conformity with Verma *et al.* (1984), who observed that Ostracods generally decrease with an increase in pollution.

The downstream (S7, S8, S9 and S10) of S6 was comprised of ten genera, excluding the genus *Lecane*, which was recorded only from control area of Kaliani. Annual mean abundance were fluctuated at different sections, the S6 of contaminated area had shown the minimum abundance only with a 4% of the total zooplankton or 6.25 no./L which might be due to the adverse effect from the refinery effluent discharge from NRL with (Fig.5). The S5 harbored the maximum abundance with a 13% or 19.63 no./L and among the contaminated area the S9 has harbored the maximum with a10% indicating a subsequent recovery from the effect of organic load from NRL. The zooplanktons have shown negative correlation with turbidity (Fig. 6).

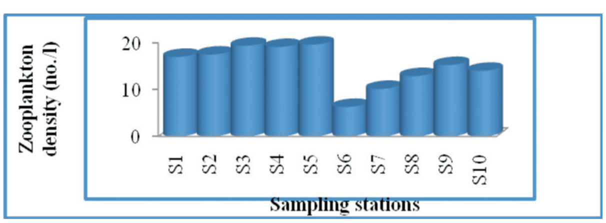

Fig. 5. Mean density of zooplankton (no./L) of Rivers Dhansiri and Kaliani

CONCLUSION

Thus effluent of oil and petroleum industries and release of refinery effluent in particular creates pollution to freshwater environment. Refinery effluent released from NRL has drastically changed some of the physicochemical water variables as well as simplified the structure and complexity of biological assemblages by reducing the number of phytoplankton, zooplankton, especially at the point of effluent discharge (S6) of contaminated area of the river Kaliani. Based on the findings of this study, it can be recommended that NRL petrochemical refinery company should ensure that effluent is properly treated before discharge into the river. Government agencies responsible for proper discharge of this effluent must monitor them properly without compromise in order to ensure the protection of water resources from further degradation.

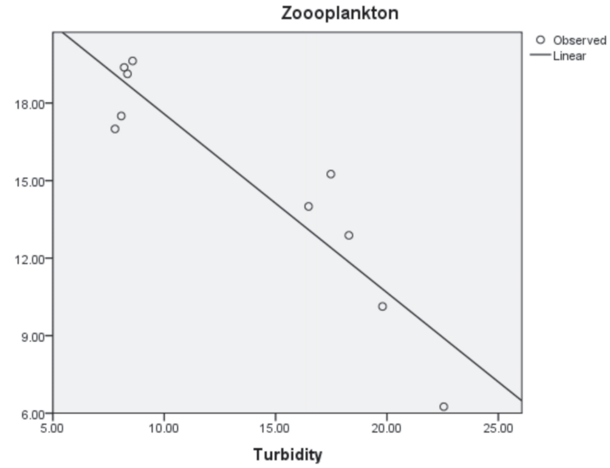

Fig. 6. Linear regression line (R^2=0.853) showing relationship between zooplankton and turbidity

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