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Eco-Toxicological Study Of Industrial Effluent And Solid Waste Of A Chlor-Alkali Industry On The Aquatic And Terrestrial Environments Of The Contaminated Site At Ganjam, Odisha, India.

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Abstract

Pollution by mercury is one such silent epidemic that affects almost all the biota connected in a food chain and food web of the ecosystem. Once mercury, in any form, enters the food chain, its concentration goes on increasing by many folds from the first trophic level to the last trophic level. The present study was planned to find out the status and extent of mercury pollution in and around the industry, nearer to Rushikulya River and Bay of Bengal. The analysis of the effluent in the past indicated the highly toxic nature of the effluent and its impact on the environmental parameters. The present study indicated that the effluent discharged from the industry, effluent in the effluent canal, solid waste dumping site, effluent soaking pond near the river bank, leaching effluent and sites where effluent joins the river is highly contaminated with mercury contained effluent. Significant level of mercury was detected in all aquatic and terrestrial samples tested. The effluent significantly altered the physico-chemical properties of the water bodies impacting the physico-chemical parameters. The dissolved oxygen was seriously affected which impacted the aquatic animals. Presence of elemental mercury in effluent and solid waste can be methylated by bacteria to ionic and inorganic forms which can pose a serious threat to the environment and available biota at the contaminated site. The effluent needs to be treated physically, chemically and biologically and after proper treatment the effluent can only be discharged in to the natural environment for protection of aquatic and terrestrial flora and fauna and most important is to protect the human beings inhabiting in the contaminated areas.

Keywords: Chlor-alkali industry, Solid waste, Effluent, Mercury, Physico-chemical analysis.

Introduction

Rapid industrialization to meet the demand of human has resulted in the rise of pollution. To encounter this and to preserve the high quality of the environment new concept so called “Cleaner Production” for waste minimization is being introduced, technology designed to prevent waste emission at the source of generation itself (Uwadiae *et al*., 2011). Developing countries like India and some others are now heavily industrialized to meet its own demands with most priorities to supply other financing countries worldwide. M/s. Jayashree chemicals (P) Ltd., a Chlor-alkali Industry producing caustic soda, HCl and liquid chlorine has been using the mercury cell process for decades and was adding mercury along its wastes into the environment continuously up to 2012. In 2012 the mercury electrolytic cell process was replaced by membrane cell process phase wise and the process of replacement was completed in 2014. The earlier discharged / dumped mercury in to the land mass as solid waste and mercury contained effluent into water bodies remained in the environment for years as mercury is a persistent, non degradable, bio accumulative and toxic pollutant. Leakage of mercury and washings from the cell house containing mercury comes out in the effluent canal along with the effluent which is stored in the open stocking pond. This area is meant for the drying of effluent naturally under sun. Chemicals’ leaching from the stocking pond contaminates river water ultimately polluting the estuary and the sea. Solid waste which was dumped

near the bank of the river gets drained and mixed with the river water during rainy season heavily contaminating the water bodies. Reports are available indicating heavy pollution in all most all the river systems by industries in India due to improper management of the discharged chemicals and other materials (Modak *et al.*, 1990 and Lokhande *et al.*, 2011). The effluent of the industry containing significant amount of mercury has been continuously contaminating the river and the sea over the last 45 years and still it showed its effect in the environment even after the change of technology in 2012, from mercury cell process to membrane technology. Mercury pollution is a serious scenario all over the world (Panigrahi, 1980; Shaw *et al.*, 1985 and 1986a,b; Li *et al.* 2009). High pollutant load from the Chlor-alkali industry directly discharged in to aquatic environments contaminate it and the surrounding land mass (Hall *et al.*, 1987; Sahu & Panigrahi, 2002). Percolation and leaching of the waste chemicals along with toxic metals caused ground water pollution thus contaminating the ground water source to a greater extent. According to Mwinyihija (2011), pollutants are the key factors that damage the ecology of the receiving terrestrial and the aquatic system of the vicinity of the discharge point from the industry. The present study was made to investigate the level and extent of pollution in the river Rushikulya and the estuary at Ganjam.

Table-A1: Comparison of Physico-chemical properties of the effluent reported at different time periods.

Sl. No	Parameter	Shaw *et al.*, 1986	Sahu & Panigrahi (2002)	Rauta,2013
1	Temperature (^oC)	31.2±1.6	31.4±1.2	30.2±0.6
2	pH	9.2±0.2	9.3±0.3	9.2±0.4
3	Alkalinity(as $CaCO_3$ mg 1^{-1})	256.2 ± 14.4	212.5±8.8	198.6±11.5
4	Hardness(as $CaCO_3$ mg 1^{-1})	487.6± 22.1	465.2±8.4	368.4±24.6
5	Chlorinity (mg 1^{-1})	1997.6±18.4	1739.2±31.5	1595.6±14.8
6	Dissolved oxygen (mg 1^{-1})	2.8 ±0.4	2.6±0.6	2.24±0.34
7	BOD (mg 1^{-1})	39.3±1.1	22.5±2.6	21.4±3.8
8	COD (mg 1^{-1})	301.4±3.2	326.4±11.4	195.8±29.3
9	Suspended solids (mg 1^{-1})	193.3±14.7	132.8±11.6	105.6±17.4
10	Total nitrogen (mg 1^{-1})	1.4±0.3	2.6±0.5	1.8±0.4
11	Total phosphorus (mg 1^{-1})	0.13±0.02	0.26±0.07	0.19±0.05
12	Total mercury (mg 1^{-1})	3.02±0.23	2.85±0.16	2.65±0.12

The analysis of the data from 1986 to 2013 indicated that the effluent is highly toxic. The comparison indicated that within 28 years of time, little variations were observed. But from toxicological stand point, no significant change had occurred, even though the industry claimed treatment of the effluent and safe disposal of the effluent. Instead of directly discharging the effluent into the river, now for the last eight years (2006-2014), the effluent is discharged into an open field and allowed to soak, very nearer to the river, where, leaching of the effluent was marked as an important issue. Most of the parameters showed a declining trend in 2014 just because of change in technology in 2014. Significant variation in mercury content was noted in the effluent sample. In 1986, the effluent contained 3.02±0.23mg 1^{-1} which decreased to 2.85±0.16 mg 1^{-1} in 1996, which further declined to 2.65±0.12 mg 1^{-1} in 2006 and in 2015 significant decrease to negligible amount of mercury was observed (Table-A1).

The present study aims at understanding the mercury pollution problem and status at Ganjam, in and around the industry and the entire contaminated site including aquatic and terrestrial environments. It was also planned to study the extent and spread of mercury pollution in and around the industry.

Materials & Methods

Location of Contaminated site:


(Google map of the industrial site, solid waste dump site & Effluent collection site)

Effluent, solid waste and plant samples were collected from the contaminated site at Ganjam near the industrial site and brought to the laboratory in plastic containers kept in ice box for analysis. The physico-chemical analysis was carried out following the protocol of APHA (1998) on spot. Samples were brought in glass bottles for analysis of few parameters in the laboratory. Effluent contained solid waste samples were collected from the effluent channel discharge point, where the effluent joins the river in 5litre dark glass bottles, brought to the laboratory and kept in refrigerators for use. The effluent was dry sterilized with the help of UV radiation only to kill if any microorganism present but not by autoclaving to maintain the chemical composition and properties of the chemicals present in the effluent. Quantitative determination of mercury in the digested samples (in Bethge's apparatus) was carried out with the help of Mercury Analyzer, a cold vapor Atomic Absorption Spectrophotometer, (Mercury Analyzer, MA5800, ECIL (1981) India).

Results

Water sample from effluent and river were analyzed for their physico-chemical properties at two different seasons (summer & rain) of 2015 and are presented in Table-A.2 & A.3. Out of these 9 samples, 5 are effluents and 4 are river water. During summer and rain, the effluent sample from Station X1, X2, X3, X4, R3 & R4 were transparent while samples from station X5, R1 & R2 were muddy. All samples were odorless and transparency varied from stations to station as described in tables below.

Table-A.2. Physico-chemical parameters of Effluent and River water during Summer season, 2015.

Site	Transparency	Odor	Temp (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
X1	Transparent	Odorless	32.9	7.82	53.3	40.8	35.4	7.62
X2	Transparent	Odorless	32.5	8.27	33.9	25.9	22.4	8.33
X3	Transparent	Odorless	32.5	8.32	33.5	25.5	22.1	9.52
X4	Transparent	Odorless	33.4	8.47	34.1	26.0	22.5	10.24
X5	Muddy	Odorless	32.9	8.27	34.5	26.3	22.7	8.81
R1	Muddy	Odorless	35.7	8.47	40.8	31.2	27.0	10.24
R2	Muddy	Odorless	36.1	8.29	39.7	29.7	25.8	8.33
R3	Transparent	Odorless	37.2	8.51	41.2	31.5	27.3	7.86
R4	Transparent	Odorless	37.5	8.5	40.3	33.6	28.1	7.14

Table-A. 3. Physico-chemical parameters of Effluent and River water during Rainy Season, 2015.

Site	Transparency	Odor	Temp (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
X1	Transparent	Odorless	33.2	7.72	60.2	51.5	41.0	9.55
X2	Transparent	Odorless	32.5	7.89	41.2	33.6	29.3	9.62
X3	Transparent	Odorless	31.1	8.3	40.2	30.2	27.8	11.34
X4	Transparent	Odorless	31.4	8.23	35.4	36.0	25.6	11.8
X5	Muddy	Odorless	30.1	8.1	33.6	32.8	24.1	11.09
R1	Muddy	Odorless	32	8.5	39.9	31.2	29.9	10.24
R2	Muddy	Odorless	30.9	8.14	42.9	39.7	30.2	9.97
R3	Transparent	Odorless	30.9	8.3	42.1	33.1	30.2	10.35
R4	Transparent	Odorless	31.5	8.5	45.3	34.9	29.2	9.24

Temperature ranged between 32.5 to 33.4ºC in all the 5 stations of the stocking pond in summer season. However, higher temperature was recorded in the river due to less depth. During rainy season, the temperature in all stations showed a lower value when compared to summer season (Fig. A.1). The pH in the water samples from a polluted area is an important parameter. The samples were alkaline showing a very narrow range of difference in all the samples. Similar results were also reported by Mathur and Kumar (2013). During summer pH ranged from 7.82 – 8.51, where as in rainy season, the pH value ranged between 7.72 – 8.5. On an average it was noticed that during summer, the pH was slightly high when compared to the rainy season. During rain conductivity was more as compared to summer. Mixing of rain water with the sample water may help in ionization of compounds thus increase in conductivity. During summer highest conductivity was at Station X1 (53.3µs/cm) and lowest at station X3 (33.5µs/cm). In rain highest value of conductivity was recorded from station X1 (60.2µs/cm) and lowest at station X5 (33.6µs/cm). Salinity

value during summer was maximum at station X1 (40.8 ppt) and minimum at station X3 (25.5 ppt) while in rain the value was more than in summer at station X1 i.e. 51.5 ppt and minimum at station X3 i.e. 30.2 ppt. TDS value in summer was maximum (35.4 ppt) at station X1 and was minimum (22.1 ppt) at station X3. During rain the value of TDS was maximum (41.0 ppt) at station X1 and minimum at station X5 (24.1 ppt). As compared to the values of TDS in summer at each station, higher TDS values were recorded in rain. Samples showed high DO value in rain as mixing of aerated rain water increases the oxygen content. It was found to be more at Station X4 and R1 (10.24 mg/L) due to standing of the effluent for maximum period and least at station X1 (7.62 mg/L) and R4 (7.14 mg/L) during summer. In rain the maximum DO value of 11.8 mg/L (station X4) followed by 11.34 mg/L (station X3) where as minimum value was 9.55 mg/L (station X1) and 9.24 mg/L (station R4). Lesser DO values in the effluents at different stations indicate the level of pollution.

Table 1. Physico chemical characteristic of industrial effluent during summer 2016. Data are the mean of samples ± standard deviation.

Site	Transparency	Odor	Temp (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
X1	Transparent	Odorless	33.1	8.27	61.3	48.8	45.4	6.82
X2	Transparent	Odorless	33.0	8.1	52.7	45.9	32.4	7.86
X3	Transparent	Odorless	32.4	8.11	46.2	45.5	42.1	9.9
X4	Transparent	Odorless	33.0	8.0	45.1	46.0	42.5	9.84
X5	Muddy	Odorless	31.8	7.82	40.8	46.3	42.7	8.87

The effluent was transparent and odorless in all the stations except at station X5 which was muddy and has temperature between 31 to 33 ºC during summer. pH was minimum at X5 (7.82) and maximum at X1 (8.27). Maximum conductivity was 61.3 µs/cm at station X1 and minimum at station X5 (40.8 µs/cm). Salinity value was highest at station X1 (48.8 ppt) and lowest at station X3 (45.5 ppt). 45.4 ppt TDS was recorded at station X1 which was highest and lowest TDS value was recorded at station X2 (32.4 ppt). Dissolve oxygen of effluent at station X3 was 9.9 mg/L which was highest during summer and lowest at station X1 (6.82 mg/L).

Table 2. Physico chemical characteristic of river water during summer 2016.

Site	Transparency	Odor	Temp (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
R1	Muddy	Odorless	34.3	7.6	40.8	41.5	47.0	10.7
R2	Muddy	Odorless	34.1	7.1	42.9	49.7	45.8	9.4
R3	Transparent	Odorless	33.2	7.18	43.8	41.5	47.3	7.1
R4	Transparent	Odorless	33.0	7.41	49.3	48.6	48.6	7.55

Physico chemical parameters of river water were also recorded during summer. Water sample from four stations were analyzed. Water at R1 and R2 were muddy where as station R3 and R4 were transparent. Water samples were odorless at all the stations. Temperature was between 33 ºC to 34.3 ºC and pH ranged between 7.1 (R2) to 7.6 (R1). Maximum conductivity was observed at R4 (49.3 µs/cm) and minimum value at 40.8 µs/cm at R1. Salinity value was highest at R2 (49.7 ppt) and lowest at both R1 and R3 (41.5 ppt). TDS was maximum 48.6 ppt at R4 and minimum 45.8 ppt at station R2. Dissolved Oxygen value was recorded to be highest at R1 (10.7 mg/L) and lowest recorded at station R3 (7.1 mg/L).

Table 3. Physico chemical characteristic of industrial effluent during rain 2016.

Site	Transparency	Odor	Temp (ºC)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
X1	Transparent	Odorless	35.1	7.4	68.2	41.5	40.2	7.55
X2	Transparent	Odorless	32.7	7.42	62.2	43.6	35.3	8.67
X3	Transparent	Odorless	30.1	8.1	52.2	41.2	34.8	10.3
X4	Transparent	Odorless	30.4	7.7	45.4	38.2	35.6	10.8
X5	Muddy	Odorless	34.1	8.2	43.6	33.8	34.3	9.98

During rain, all the physico chemical parameters of the effluent were measured. All the sample effluents were transparent except at station X5 which was muddy. All the samples were odorless. Temperature was highest 35.1 ºC at station X1 and lowest 30.1 ºC at station X3. pH maximum at station X5 (8.2) and minimum at station X1 (7.4). Highest conductivity was recorded at station X1 (68.2 µs/cm) and lowest at station X5 (43.6 µs/cm). Salinity ranges between 33.8 ppt (station X5) to 43.6 ppt (station X2). Maximum

TDS value was recorded at station X1 (40.2 ppt) and minimum at station X5 (34.3 ppt). DO value was highest at station X4 (1.8 mg/L) and lowest at station X1 (7.55 mg/L).

Table 4. Physico chemical characteristic of river water during rain 2016. Data are the mean of five samples.

Site	Transparency	Odor	Temp (°C)	pH	Conductivity (µs/cm)	Salinity (ppt)	TDS (ppt)	DO (mg/L)
R1	Muddy	Odorless	35.6	7.92	43.3	35.2	39.7	9.5
R2	Muddy	Odorless	34.9	7.9	47.8	36.6	34.2	9.73
R3	Transparent	Odorless	34.9	8.2	51.1	37.1	36.2	8.45
R4	Transparent	Odorless	32.5	8.41	55.8	40.9	36.7	8.7

River water during rain analyzed for physico-chemical parameters. Water was muddy from station R1 and R2 where as transparent at station R3 and R4. Temperature ranges between 34.9 °C (R2 and R3) to 35.6 °C (R1). pH of river water during rain was highest at R4 (8.41) and lowest at station R2 (7.9). Conductivity was measured maximum at station R4 (55.8 µs/cm) and minimum at station R1 (43.3 µs/cm). Maximum salinity was recorded at station R4 (40.9 ppt) and minimum at station R1 (35.2 ppt). TDS was highest at station R1 (39.7 ppt) and minimum at station R2 (34.2 ppt). DO value during rain was maximum at station R2 (9.73 mg/L) and minimum at station R3 (8.45 mg/L).

Table 5. Comparison of physico chemical properties of Effluent in stocking pond during summer (S) and winter (W). Data are the mean of samples.

Sl. No.	Site	Temp (°C)		pH		Conductivity (µs/cm)		Salinity (ppt)		TDS (ppt)		DO (mg/L)	
		S	W	S	W	S	W	S	W	S	W	S	W
1	X1	36.4	33.7	7.6	8.2	84.3	70.6	50.8	55.2	80.4	44.3	5.59	7.15
2	X2	36.4	33.2	7.4	8.3	57.4	67.6	50.1	51.2	60.8	45.1	5.88	8.02
3	X3	34.5	30.1	7.6	7.7	50.2	48.5	48.6	50.4	49.1	48.5	6.74	6.95
4	X4	35.2	29.5	7.3	7.6	46.8	49.3	46.5	48.1	46.5	47.2	7.56	6.93
5	X5	31.3	29.4	7.2	7.6	46.9	48.2	46.2	46.0	45.7	47.6	7.57	7.61

Table 5 shows temperature of the effluent in the stocking pond ranges from 31.3 °C (X5) to 36.4 °C (X1 & X2) during summer and 29.4 °C (X5) to 33.7 °C (X1) during winter. pH was recorded minimum at site X5 (7.2) and maximum at X1 & X3 (7.6) during summer. During winter pH was minimum at X4 & X5 (7.6) and maximum at X2 (8.3). Conductivity was 46.8 – 84.3 µs/cm during summer and 48.2 – 70.6 µs/cm in winter. Salinity ranges from 46.2 to 50.8 ppt in summer and 46.0 to 55.2 ppt in winter. Total dissolved solids (TDS) lies between 45.7 to 80.4 ppt in summer and 44.3 to 48.5 ppt in winter. Dissolved oxygen (DO) in the effluent was maximum at X5 (7.57 mg/L) and minimum at X1 (5.59mg/L) during summer. During winter DO value is higher than summer at each site except site X4.

The amount of residual mercury varies according to the distance from the industry. It depends on the distance and the leaching capacity in soil and water to the surroundings. The content of mercury was estimated and tabulated in Table 6.

Table-6: Total mercury (mg/L) content in effluent, river water and estuary water in summer and rainy, 2017-18. Data are the mean of five samples ± standard deviation. X(1-5)- Sites near effluent stocking pond, R- River water, E- Estuary

Sites	Summer	Rainy	Sites	Summer	Rainy
X1	0.012 ± 0.003	0.011 ± 0.09	X5	0.250 ± 0.021	0.233 ± 0.019
X2	0.049 ± 0.003	0.035 ± 0.006	R	0.061 ± 0.04	0.052± 0.08
X3	0.180 ± 0.012	0.188 ± 0.020	E	1.25 ± 0.14	1.67 ± 0.45
X4	0.198 ± 0.027	0.210 ± 0.025			

Total mercury content of effluent at station X1 was 0.012 mg/L during summer which was higher than the value recorded during rain that is 0.011 mg/L. At station X2 Hg content was 0.049 mg/L during summer which was higher than rain 0.035 mg/L. Station- X3 effluent sample showed 0.180 mg/L Hg in summer which was lower than Hg content during rain 0.188 mg/L. Station X4 effluent contained 0.198 mg/L of Hg during summer which was less than the value recorded during rain 0.210 mg/L. In summer the total Hg content was 0.250 mg/L at station -X5 which was higher than value recorded during rain 0.233 mg/L. River water recorded 0.061 mg/L of Hg during summer which was higher than rain 0.052 mg/L. Estuary water had 1.25 mg/L of Hg in summer which was lower than during rain 1.67 mg/L. When compared among effluent, river water and estuary, maximum amount of mercury was recorded in estuary water.

Table-7: Total mercury (mg/L) content around the industry. Data are the mean of samples ± standard

deviation. ND- Not detected

Sites	Upstream River	Downstream River	North Side
0.5 Km	0.072 ± 0.007	0.062 ± 0.004	0.132 ± 0.028
1.0 Km	0.063 ± 0.002	0.064 ± 0.004	0.101 ± 0.013
1.5 Km	0.052 ± 0.004	0.080 ±0.012	0.054 ± 0.007
2.0 Km	0.029 ± 0.001	0.167 ±0.021	ND

The above results show that the amount of mercury in effluent is beyond the permissible limits (0.1 mg/L). Mercury content in river water is more than standard limits (0.001 mg/L) prescribed by Pollution Control Board (Odisha / India).

Discussion

Chlor-alkali industries using mercury cell technology had polluted the environment (Gonzalez, 1991) with most toxic substance mercury which is a neurotoxin (Chang, 1977) and is also referred as 'quicksilver' from the ancient times due to its mobility and unpredictable characteristics. Effluent and solid wastes from the industry are dumped nearer to the river Rushikulya, which finds its way into the river, reaching to the estuary and ultimately Bay of Bengal. Both effluent and solid waste contained Hg beyond the permissible limits prescribed by Pollution Control Boards. Bernaus *et al.*, 2006 also reported discharge and pollution of mercury from chlor alkali industry in Netherlands suggesting the huge concentration of mercury leading to detrimental effects on biota. The discharge of effluent into the soaking pond permits settlement of mercury in the sediments, which can be methylated by bacteria and the product is more than toxic than elemental mercury. Mercury by natural oxidation and reduction followed by its interaction with environmentally available chemicals and in presence of microbes change their status from elemental to ionic than to inorganic and organic forms. All other forms of mercury except elemental mercury can be absorbed by living organisms and can be translocated to different parts of the body and can be retained in different tissues, which will lead to residual accumulation. The transport by way of translocation to fruiting part or edible part of the plant is significant, which may lead to biomagnifications of the toxicant in the ecosystem. This accumulated mercury in life forms may find their way into human body by consumption of .contaminated food, which can be disastrous. Chemical industries in India have grown up notably since independence. These industries discharge their wastes into the environment contaminating air, water and land. Industrial waste is in the form of gases, solids, liquid effluents and slurries containing a range of organic and inorganic chemicals. The chief aspect of land pollution is basically caused by solid and semi-solid waste disposal methods, the presence of hazardous chemicals in the environment and the despoilation and degradation of the land surface. Hazardous wastes are those that could be harmful to the human health, other organisms and the environment. Many inorganic elements as Mercury (Hg), Lead (Pb), Cadmium (Cd), and Arsenic (As) are biological poisons at concentrations in the parts per billion (ppb) ranges. Once the chemicals find their way into the environment, a major portion reaches the soil and sediment, which in turn serve as sink (Haque, 1975). Leaching of chemicals from wastes, pose serious ground water contamination problem (Priyadarsan *et al*., 2016). Plants absorb these toxic leached chemicals along with water and other nutrients and accumulate in different tissues. These store chemicals in their body and these chemicals pass through the food chain from one trophic level to higher trophic level. These toxic chemicals are poorly excreted, hence retained as residual chemicals in the body. A significant build up of the toxic chemicals in different organs / tissues of the organisms are achieved through the process of biological magnification (Mishra *et al.*, 2013 and Priyadarsan *et al*., 2016).

Water temperature ranged between 32.5 to 33.4^{o}C in all the 5 stations of the stocking pond in summer season and in winter the temperature was much less. However, higher temperature was recorded in the river due to less depth in summer. During rainy season, the temperature in all stations showed a lower value when compared to summer season. The pH in the water samples from a polluted area is an important parameter. The samples were alkaline showing a very narrow range of difference in all the samples. Similar results were also reported by Mathur and Kumar (2013). During summer pH ranged from 7.82 – 8.51, where as in rainy season, the pH value ranged from 7.72 to 8.5. On an average it was noticed that during summer, the pH was slightly high when compared to the rainy season. During rain conductivity was more as compared to summer. Mixing of rain water with the sample water may help in ionization of compounds thus increase in conductivity. During summer highest conductivity was at Station X1 (53.3µs/cm) and lowest at station X3 (33.5µs/cm). In rain highest value of conductivity was recorded from station X1 (60.2µs/cm) and lowest at station X5 (33.6µs/cm). During rain high value of conductivity was observed. According to Siyanbola *et al.* (2011), TDS and Conductivity are directly related to each other. As the value of TDS increases, Conductivity of the water sample increases. Salinity value during summer was maximum

at station X1 and minimum at station X3 while in rain the value was more than in summer at station X1 i.e. 51.5 ppt and minimum at station X3 i.e. 30.2 ppt. Presence of chemicals and other metals in the effluent of the stocking pond aids in the increased salinity value mainly during rain. TDS value in summer was high at station X1 and was minimum at station X3. During rain the value of TDS was maximum at station X1 and minimum at station X5. As compared to the values of TDS in summer at each station, higher TDS values were recorded in rain. This may be due to run away water containing mud and other particles from the adjacent land. Similar result was also obtained in the present study. According to Kavitha *et al*. (2012) fluctuation in TDS is due to content collision of colloidal particles of the effluent. One of the most important parameters indicating the level of pollution in water system is the oxygen content of water (Balamurugan and Dheenadayalan, 2012). On average the dissolve oxygen amount was more during rain than summer. Samples showed high DO value in rain as mixing of aerated rain water increases the oxygen content. It was found to be more at Station X4 and R1 (10.24 mg/L) due to standing of the effluent for maximum period and least at station X1 (7.62 mg/L) and R4 (7.14 mg/L) during summer. In rain the maximum DO value of 11.8 mg/L (station X4) followed by 11.34 mg/L (station X3) where as minimum value was 9.55 mg/L (station X1) and 9.24 mg/L (station R4). Lesser DO values in the effluents at different stations indicate the level of pollution). Terrestrial plants showed significant accumulation of mercury. Due to presence of mercury in the water of Rushikulya River beyond the permissible limit, it has been considered as one of the Mercury Hotspots of India among other rivers like Ib River (Odisha), Kalu River (Mumbai), Kodaikanal (Tamilnadu), etc. Mercury content was more nearer to the industry as compared to the water samples in upstream and increases in the downstream. In soil samples around the industry, mercury content decreases to the distant places. The observed results showed the leaching of mercury that was released by the industry in recent past to the neighboring areas contaminating the terrestrial plants and plants growing in crop fields. Significant amount of mercury was detected in plants showing alteration in their physiological outputs (Padhy and Panigrahi, 2016). Prusty and Panigrahi (2017a) reported the impact of environmental mercury discharged from a Chlor-alkali industry on the biodiversity at the contaminated site of Ganjam and indicated disappearance of some species from the area. He authors concluded that the disappearance of species is related to high intensity of mercury pollution. The same authors found significant amount of residual mercury in terrestrial plants collected from the contaminated site. In addition, the authors also indicated that some terrestrial plant species disappeared from the contaminated site due to severe impact of mercury pollution. Verma *et al.* (2018a) reported while working on the reclamation of the effluent of a Chlor-alkali industry by environmental chemicals in presence of cyanobacterium that environmental chemicals could not help to reduce the toxicity of the effluent even in presence of environmental chemicals except that in case of chemicals which were part of the nutrient medium showed some promise. The same authors also indicated that these chemical additions further deteriorated the condition and instead of showing any reclamation showed severe impact on the BGA. Kapahi and Sachdeva (2019) reported that heavy metal pollution creates environmental stress on all plants, animals, human beings & other organisms and indicated that a complete understanding of the events causing the impact is necessary than only an alternative remediation strategy can be planned for bioremediation of heavy metal pollution. This idea looks more relevant and genuine for proposing bioremediation process and we agree with the report pertaining to the adoption of microalgae and microbes for possible phytoremediation of industrial wastes containing mercury as a strong pollutant.

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Conflict of interest statement

The authors declare that they have no conflicts of interest.

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