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Pre- and Post-Flood Water Quality of National Water Way 3, Near Industrial Effluent Discharge Zone, Kollam, Kerala

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Abstract

Kerala state experienced a severe flood in 2018 after of its kind in 1924. Flood fetches a lot of negative and few positive impacts on the ecology, biodiversity and habitat. National Water Way No.3 (NWW3) in Kerala, running parallel to the Arabian sea, is a coastal inland water body that receives effluents and wastes from different factories and industries apart from municipal and household sewage waste of its course of passage. Due to effluent discharge from Kerala Minerals and Metals Limited (KMML) and Indian Rare Earths (IRE) Limited, water pollution is very high at the Chavara region of the Kollam district, Kerala. Monthly water quality assessment before and after Kerala flood 2018 showed a significant ($P < 0.05$) reduction in pollution level due to flood wash off. A total of 26 water quality parameters, including nutrients and heavy metal concentrations, were assessed following standard procedures from two different locations of NWW3 and statistically evaluated for the pre-and post-flood difference. Results suggest that flood wash-off reduces aquatic bodies' pollution status regarding its water quality and recommends that the effluent discharge pose a severe threat to ecology even beyond the flood wash off effect.

Keywords: Flood wash-off, Kerala Flood 2018, Pollution, Chavara, Heavy metal, NWW3

1. Introduction

Natural hazards pose severe threat and loss to economy, property, human lives, agriculture, livestock and cause severe damage to the habitat, biodiversity and ecology of a region. Kerala flood 2018 was a man fostered natural hazard, which affected the state of Kerala during July – September 2018 after its kind in 1924. Flood being a disaster results in several negative impacts but have very few positive impacts in the form of surface solid and liquid waste wash-off, pollution reduction or dilution, aquifer and dam recharge, re-colonization of flora and fauna and dispersal of organisms. Since anthropogenic pollution level goes beyond the carrying capacity, the flood may act as a natural and self-abatement technique. There are two monsoons, southwest and northwest monsoon prevails in Kerala, of which southwest monsoon during June-September is the prominent one to which the climate, agriculture and other anthropogenic activities are synchronized (Abraham, 2002), but the monsoon 2018 resulted in massive floods in Kerala. The monsoon affects the terrestrial and aquatic ecosystems in many ways and the polluted aquatic ecosystems are 'cleaned' by flood wash off during the period. Zhang *et al.* (2013) developed a model explaining the agricultural pollution dynamics by flood flow impact on water quality, especially on chemical oxygen demand and total nitrogen in Yuqiao reservoir in China during the 2009 floods. Baborowski *et al.* (2012) assessed the water quality of the Elbe river during the flood conditions and reported the transport of contamination, including heavy metals. Several other studies reported the effect of floods on the water quality of aquatic bodies, especially rivers and drinking water sources (Hart *et al*., 1988; Hrdinka *et al.*, 2012; Lyubimova *et al.*, 2016; Eccles *et al.*, 2017; Rui *et al.*, 2018; Kamalanandhini *et al.*, 2019).

Kerala Minerals and Metals Limited (KMML, located at Chavara, Kollam district of Kerala) is one of the leading public sector company producing Titanium sponge, which expels 40,000 MT waste products (sludge) per annum during the production of titanium dioxide pigment. One more industry, Indian Rare Earths Limited (IREL), a Government of India enterprise, is also located adjacent to the KMML and discharge effluents to the National Water Way No.3 (NWW 3) and Arabian sea (Jayasree *et al.*, 2009). The effect of titanium dioxide industrial effluent discharge on aquatic ecology and biota was reported by many authors (Madhupratap *et al.*, 1979; Menon *et al.*, 1979; D'Cruz, 1998; Koshy 2013) and Haridas *et al.* (1980) studied the effect of Titanium factory effluent on marine animals. Sivan and Abraham (2018) reported the water quality, including physical, chemical and biological parameters of NWW 3 with respect to seasonal fluctuations from the Chavara region.

NWW 3 connects Kollam and Kottappuaram (205 km), having 24hrs navigation facilities is a biodiversity-rich backwater river that joins several estuaries during its course. It is one of the most navigable and tourism potential aquatic ecosystems, and its tourism potential is utilized to a good extend at Kollam, Alappuzha and Ernakulam districts. It opens to the Arabian Sea at Munambam, Kayamkulam, and Neenadakara, through which the industrial/urban/domestic waste from the ecosystem complex is expelled to the ocean. Zoppini *et al.* (2019) reported the impact of a river flood on marine water quality and planktonic microbial communities. Greenpeace (2003) documented the presence of more than 240 industrial units operating in Eloor, Kalamassery industrial belt alone with an average release of about 2.6 million litres of untreated effluents per day into the

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backwater system, including the NWW3 and hence the system is polluted due to industrial, urban, domestic and sewage, agricultural and other waste disposals especially along Ernakulam and Chavara region as industries discharge effluents at these regions. Since natural hazards like massive floods are rare events, flood wash-off effect and dilution of pollution thereby clearance or the water quality parameters were understudied, and an assessment has been undertaken in the present study to evaluate the monsoonal flood wash-off effect on water quality parameters of NWW 3 at Chavara region by assessing the water quality prior and after the Kerala flood during 2018 monsoon period.

2. Materials and Methods

2.1. Study Site and Collection Methods

The anthropogenic activity through natural resource tapping and industrial exhaust/effluent discharge has threatened the ecological status of the backwaters and nearby land area especially by the industries, KMML (Kerala Minerals and Metals Limited) and adjacent Indian Rare Earths Limited (IREL), both are engaged in coastal sand mining and processing of minerals like titanium and other rare earth elements. The present investigation was carried out in the National Water Way No.3 near Chavara industrial area ($76^{0}33'0"$E and $8^{0}59'0"$N), Kollam district, Kerala, The NWW 3 joins Vattakayal backwater at its north and the Ashtamudi backwater system at its south. Two sampling stations were selected for the study (Fig. 1). Site 1 (*IRE Kadavu*) was selected near the industrial effluent discharge area, and site 2 (*Kottarathin Kadavu*) was designated near the Vattakayal estuarine area, a less polluted area compared to site 1. Surface water sampling was done monthly from March to September 2018, in which February to May collection data were pooled to form pre-flood period and June to September month data were pooled to form as post-flood period as the state of Kerala experienced a severe flood during June-July 2018. The water quality parameters that warrant *in situ* estimations were done at respective locations themselves during morning hours. Water samples were brought to the laboratory for further chemical analysis following standard procedure.

2.2. Physico-chemical analysis

Physico-chemical analysis of about 26 parameters was carried out using standard procedures. Physical parameters like Temperature (^{0}C) atmospheric and water temperature, flow rate (m/sec), conductivity (ms/cm; Eutech instrument PCD 650), Total dissolved solids (TDS, g/L; Eutech instrument PCD 650), Total suspended solids (TSS, g/L) and total solids (TS; g/L) were estimated using APHA, (2012) methods. Chemical parameters like pH (Eutech instrument PCD 650), Salinity (ppt), dissolved oxygen (mg/L), dissolved carbon dioxide (mg/L), alkalinity (mg/L), Calcium (Ca), Magnesium (Mg) and total hardness (mg/L) were also analysed following APHA (2012) methods. Nutrients (mg/L) like phosphate, nitrite, nitrate, silicate and sulphate were also estimated using the spectrophotometric method (Grasshoff *et al*., 1999). Heavy metal such as cadmium (Cd), chromium (Cr), iron (Fe) and zinc (Zn) were analysed using atomic absorption spectrophotometer (AAS GBC Avantaver 1.33). Gross primary (GPP) and net primary productivity (NPP) were measured using the light and dark bottle method (Grasshoff *et al*., 1999).

2.3. Statistical Analysis

All water quality parameters were analysed using Student's t-test (Zar, 1996) to compare the pre-and post-flood period in two sites separately. A probability value < 0.05 was considered significant.

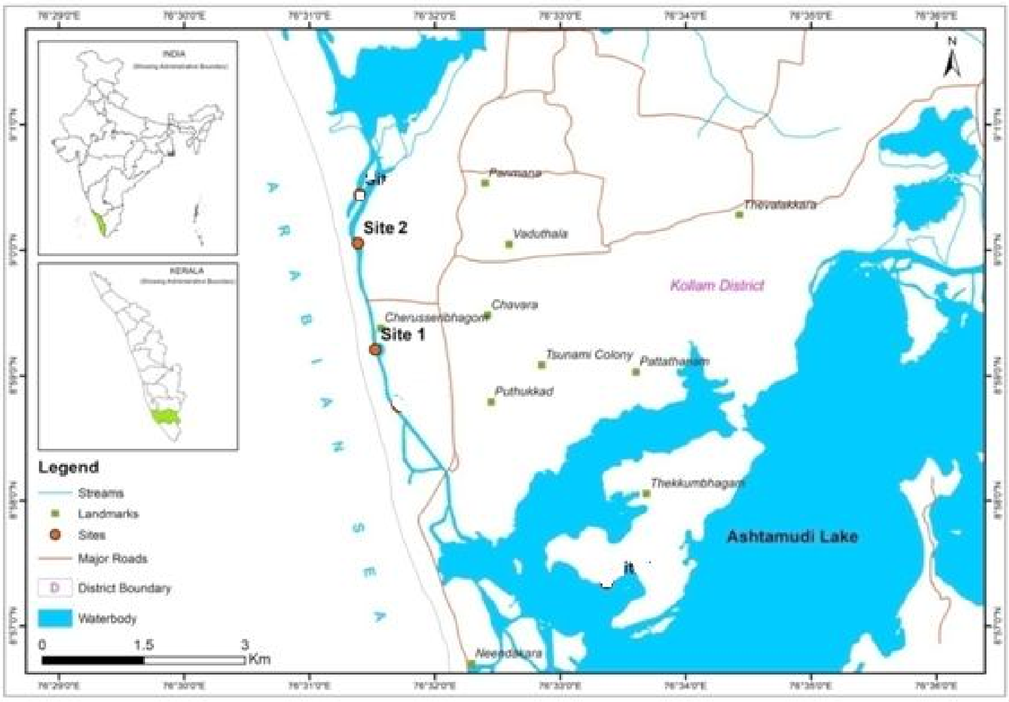

Fig. 1. Two study sites in NWW 3 at Chavara region (Kollam, Kerala)

3. Results and Discussion

Floods affect human, livestock and wildlife sustenance in many ways and lead to mass mortality if the disaster becomes more severe and even mild disaster may result in epidemics and other health problems. Netpae (2014) reported significant water quality difference before and after the flood in three rivers of Thailand during the floods in 2011. Sun *et al*. (2016) reported the impacts of a flash flood on drinking water quality during the Beijing flood in 2012. Effect of a flood event on water quality and comparison with drinking water quality standards were made by Kamalanandhini *et al*. (2019). Monthly pooled average results of water quality analysis for the two locations of the present study are given in table 1 and 2 for sites 1 and 2, respectively. The water quality parameters tested were grouped into physical, chemical, nutrient, heavy metals and biological parameters to compare the flooding effect at two sites separately as the sites represent a polluted and comparatively less polluted area of the backwater system. Among the 26 parameters tested, many showed a significant difference between the pre-flood and post-flood period due to the flood wash-off effect along with the aquatic ecosystem. Temperature, flow rate, conductivity, TDS, TSS and total solids were categorized as physical parameters. In contrast, pH, salinity, dissolved gases, alkalinity and hardness were categorized as chemical parameters. In addition, nutrients, heavy metals and productivity of the ecosystem were also estimated monthly to assess the flood wash-off effect. Except for a few nutrients and productivity, all parameters showed a highly significant ($P < 0.01$) difference after the flood in both the sites. Several studies reported seasonal difference and flood impact in water quality parameters from the same water stretch of NWW3 (Geetha, 1997; Koshy, 2013; Sivan and Abraham, 2018). The surface water temperature reduced to 25.5^{0}C in the post-flood period from 28.5^{0}C at the pre-flood period at site 1. Similarly, atmospheric temperature also registered a significant reduction after the flood period. Temperature showed a similar pattern at site 2 also. The mean value of temperature showed that in both the stations, the highest value of water temperature and the atmospheric temperature were noticed during the pre-flood period, and the lowest was obtained during the post-flood period. The torrential rain during the monsoon period might have reduced both the atmospheric and water temperature. Nair *et al*. (1983) studied the physico-chemical characteristics of the waters of the mudbank region, situated south of Cochin, observed the lowest temperature (29°C) in monsoon and highest in post-monsoon season (33°C). The high value during pre-flood, especially summer could be attributed to high solar radiation (Govindasamy *et al*., 2000). The flow rate was significantly ($P < 0.01$) high during and after flood along both the study stations, which may be due to torrential rainfall and local flooding, which wash-off the pollution due to effluent discharge. The flow rate at site 1 near effluent discharge was comparatively low during pre-flood season, which might be due to water canal blockage due to waste discharge and high density due to effluent discharge. The mean electrical conductivity was ranged from 22.65ms/cm pre-flood time to 82.92ms/cm in post-flood season at site 1 and a little bit lower values at site 2. The high value of electrical conductivity may be due to the flood flow of effluent water from the factory to the waterway. Electrical conductivity can be used to check the accuracy and purity of water and explain the ionic status of all waters. Netpae (2014) reported a significant difference in conductivity before and after the flood in three rivers of Thailand. Sivan and Abraham (2018) reported similar conductivity ranges in the same locality with seasonal monsoon fluctuations. Results of the TDS, TSS and TS from the two sites showed the highest values in the post-flood and the lowest in the pre-flood seasons in both the stations, which might be due to the surface water runoff mixed with soil reaches the estuarine system. At site 1, the TDS registered no significant difference, as the pre-and post- flood remain almost nearer values with pre-flood season registered high TDS due to effluent discharge. The turbulent water flow during monsoon carries sand and silt from terrestrial runoff, and leaching results in a significant rise in suspended and dissolved solids in estuarine waters. The high TDS level in the NWW3 may be due to the accumulation of effluents discharged from the industrial complex (Rani *et al*., 2003; Regina and Nabi, 2004).

All the chemical parameters showed a highly significant ($P < 0.01$) difference between pre-and post-flood readings in both the sites except in the case of total hardness in site 2, away from the effluent discharge zone. The significant change during post-flood time at site 1 may be due to the wash-off effect of effluents from industrial discharge and replacing the polluted water with flood or rainwater. In the present work ,the pH value was near the neutral side in pre-flood and became more acidic ($P < 0.01$) during the post-flood season. 7.03 reduced to 6.58 at site 1 and 6.30 reduced to 5.66 at site 2, the lower value of pH in the post-flood season was mainly due to the monsoon wash-off of effluent mixed water near the surrounding of the industry to the waterway. As per Lokhande (2013)**,** the pH registered varied fluctuations during the pre-andmonsoonal period (7.0 to 8.6). The salinity of the estuarine system was also registered highly significant ($P<0.01$) reduction in the post-flood season as the saline water was replaced by rainwater. The salinity was almost similar during pre-flood season in both the sites as the estuarine system connects with the Arabian Sea at its southern and northern side of the sampling sites. The dissolved oxygen of pre-flood ranged between 2.8gm/L at site 1 to 3.50 mg/L at site 2, which was increased to 7.60 and 8.65 mg/l at site 1 and 2 respectively during post-flood, which showed a significant increment of oxygen content during flooding seasons, which was a good sign for ecosystem restoration due to flooding wash-off. The high dissolved oxygen content in the flooding season may be due to the influx of rainwater runoff, turbulence, mixing with air and fast flow into the estuarine system and heavy rainfall (Zindge and Desai, 1980; Anilakumari *et al*., 2007; Netpae, 2014). Free CO_2 in the present study varied from 1.8 to 12.2 mg/L in both seasons. The lowest mean value of free carbon dioxide was recorded in the post-

Table 1. Effect of Kerala flood wash-off on mean water quality parameters at site 1

	Parameter		Season	Mean	+ SD	t value
Physical Parameters	Atmospheric Temperature	(°C)	Pre-Flood	29	1.16	4.823**
			Post-Flood	26.5	0.68	
	Water Temperature	(°C)	Pre-Flood	28.5	0.58	5.899**
			Post-Flood	25.5	0.58	
	Flow Rate	m/sec	Pre-Flood	8	2.31	4.873**
			Post-Flood	23	1.15	
	Conductivity	ms/cm	Pre-Flood	22.65	2.6	-40.665**
			Post-Flood	82.92	1.1	
	TDS	g/L	Pre-Flood	22.78	1.02	0.886
			Post-Flood	28.92	9.83	
	TSS	g/L	Pre-Flood	7.63	0.04	8.551**
			Post-Flood	14.28	1.02	
	Total Solids	g/L	Pre-Flood	39.57	4.98	3.539*
			Post-Flood	43.19	8.81	
Chemical Parameters	pH		Pre-Flood	7.03	0.08	-5.755**
			Post-Flood	6.58	0.17	
	Salinity	ppt	Pre-Flood	20	2.1	12.557**
			Post-Flood	1.6	2.77	
	Dissolved Oxygen	mg/L	Pre-Flood	2.8	1.69	-2.661*
			Post-Flood	7.6	2.77	
	Dissolved CO_2	mg/L	Pre-Flood	12.2	2.7	12.425**
			Post-Flood	2.8	0.9	
	Alkalinity	mg/L	Pre-Flood	57.5	8.66	-148.379**
			Post-Flood	500	0	
	Ca Hardness	mg/L	Pre-Flood	77.75	6.48	14.194**
			Post-Flood	31.66	0.46	
	Mg Hardness	mg/L	Pre-Flood	1058.6	431.07	2.824*
			Post-Flood	430.47	110.29	
	Total Hardness	mg/L	Pre-Flood	295	81.98	4.109**
			Post-Flood	120	23.09	
Nutrients	Phosphate	mg/L	Pre-Flood	3.34	0.53	-2.453*
			Post-Flood	11.97	7.02	
	Nitrite	mg/L	Pre-Flood	0.88	0.16	-1.48
			Post-Flood	1.71	0.27	
	Nitrate	mg/L	Pre-Flood	0.98	0.16	-1.86
			Post-Flood	1.84	0.44	
	Silicate	mg/L	Pre-Flood	3.16	0.18	-3.108*
			Post-Flood	8.76	1.66	
	Sulphate	mg/L	Pre-Flood	0.06	0.01	-0.624
			Post-Flood	0.31	0.03	
Heavy Metals	Iron	ppm	Pre-Flood	1.2	0	2.568**
			Post-Flood	0.7	0	
	Chromium	ppm	Pre-Flood	0.46	0	2.887**
			Post-Flood	0	0	
	Zinc	ppm	Pre-Flood	0.11	0	1.987*
			Post-Flood	0.02	0	
	Cadmium	ppm	Pre-Flood	0.49	0	1.358*
			Post-Flood	0.14	0	
Biological Parameters	GPP	mg/L	Pre-Flood	2.3	0.23	-2.324*
			Post-Flood	1.6	0.46	
	NPP	mg/L	Pre-Flood	2.33	0.92	-0.48
			Post-Flood	1.8	1.39	

* $P < 0.05$; ** $P < 0.01$

flood season. The highest values were in the pre-flood season, which may be due to the stagnant or slow-moving and pollution rich water during the pre-flood period. Similar observations on the chemical quality of lotic systems were recorded by Ishaq and Khan (2013), and Whitworth *et al*. (2012) explored the dissolved gases and organic carbon content of a major river system (Murray-Darling Basin, Australia) during flooding and explained the hypoxic black-water event with respect to its driving factors. Alkalinity ranged from 57.5mg/l and 61.5mg/l at site 1 and 2 respectively during the pre-flood season, which rose to 500 and 300mg/l in site 1 and 2 respectively during the post-flood season. Alkalinity measures the capacity of water to neutralize acids and is influenced by the presence of alkaline compounds in the water, such as bicarbonates, carbonates and hydroxides. A minimum level of alkalinity is desirable because it is considered as a ‘buffer’ that prevents large variations in pH (Lawson, 2011). High

Table 2. Effect of Kerala flood wash-off on mean water quality parameters at site 2

	Parameter		Season	Mean	± SD	t value
Physical Parameters	Atmospheric Temperature	(^{0}C)	Pre-Flood	28.5	0.5	4.899**
			Post-Flood	26	0.5	
	Water Temperature	(^{0}C)	Pre-Flood	28	0.5	17.472**
			Post-Flood	26.5	0.5	
	Flow Rate	m/sec	Pre-Flood	15	2.5	- 30.327**
			Post-Flood	19	1.55	
	Conductivity	ms/cm	Pre-Flood	23.57	2.62	2.221*
			Post-Flood	75.62	1.79	
	TDS	g/L	Pre-Flood	21.84	2.02	5.608**
			Post-Flood	25.29	5.64	
	TSS	g/L	Pre-Flood	11.98	1.46	2.290*
			Post-Flood	16.41	2.68	
	Total Solids	g/L	Pre-Flood	37.57	4.57	3.309*
			Post-Flood	47.59	8.33	
Chemical Parameters	pH		Pre-Flood	6.3	0	84.437**
			Post-Flood	5.66	0.55	
	Salinity	ppt	Pre-Flood	20	0	- 26.696**
			Post-Flood	0.5	0.46	
	Dissolved Oxygen	mg/L	Pre-Flood	3.5	1.12	5.179*
			Post-Flood	8.65	1.29	
	Dissolved CO2	mg/L	Pre-Flood	6.4	2.39	-11.318**
			Post-Flood	1.8	0.82	
	Alkalinity	mg/L	Pre-Flood	61.5	42.15	31.852**
			Post-Flood	300	0	
	Ca Hardness	mg/L	Pre-Flood	80.56	3.24	24.779**
			Post-Flood	28.45	0.46	
	Mg Hardness	mg/L	Pre-Flood	1992.8	136.76	32.206**
			Post-Flood	290.16	13.52	
	Total Hardness	mg/L	Pre-Flood	489.5	24.83	-1.796
			Post-Flood	88	2.31	
Nutrients	Phosphate	mg/L	Pre-Flood	2.66	0.53	- 7.637**
			Post-Flood	12	10.39	
	Nitrite	mg/L	Pre-Flood	0.3	0.1	-1.765
			Post-Flood	1.83	0.1	
	Nitrate	mg/L	Pre-Flood	0.38	0.03	-2.092
			Post-Flood	1.43	1.18	
	Silicate	mg/L	Pre-Flood	0.46	0.16	- 4.066*
			Post-Flood	7.08	6.33	
	Sulphate	mg/L	Pre-Flood	0.1	0	0.041
			Post-Flood	0.21	0.01	
Heavy Metals	Iron	ppm	Pre-Flood	0.97	0.02	3.568**
			Post-Flood	0.77	0.01	
	Chromium	ppm	Pre-Flood	0.36	0.01	2.814*
			Post-Flood	0.21	0.01	
	Zinc	ppm	Pre-Flood	0.04	0.01	1.025
			Post-Flood	0.01	0	
	Cadmium	ppm	Pre-Flood	0.08	0	3.368*
			Post-Flood	0.02	0	
Biological Parameters	GPP	mg/L	Pre-Flood	1.2	0.82	-1.596
			Post-Flood	2.15	0.75	
	NPP	mg/L	Pre-Flood	1.7	0.12	3.286*
			Post-Flood	1.1	0.65	

* $P < 0.05$; ** $P < 0.01$

alkalinity in the ecosystem may be due to the flushing of household and sanitary waste from surrounding surface water runoff into the backwater system. The Ca, Mg, and total hardness of the water at both the site registered a high rate in pre-flood and low value in post-flood observations with a significant difference. The Ca and Mg hardness reduction may be attributed to dilution of water with floodwater and washing-off of detergents and soaps used for laundry. The monsoonal water dilutes and washes off hard water from the system and hence reduced the hardness during flooding. Similar reports or reduced hardness during monsoon and post-monsoon period was reported by Jayaraman *et al*. (2003). Sivan and Abraham (2018) reported the water quality of NWW 3 along different seasons and reported the impact of monsoon on the chemical parameters of the ecosystem. Singh *et al*. (1999) reported that high hardness indicates pollution due to domestic and industrial effluents.

Results of nutrients like phosphate, nitrite, nitrate, silicate and sulphate analyses indicate that in both the stations, the content was high during post-flood season, which may be due to terrestrial runoff taken by the rainwater to the backwater system. Nitrate and nitrite showed no significant difference between the pre-and post-flood period. Phosphate showed higher concentration during flooding season ranging from 11.97 to 12.00mg/l at site 1 and 2, respectively. A very high concentration of phosphate usually is the result of the industrial discharge. Sulphate also showed high concentration in post-flood season and low concentration in pre-flood season. Abraham (2002) reported a similar seasonal variation pattern in monsoon and post-monsoon nutrient content and its dynamics along the Poonthura river estuary. Nutrient load transport and flood water quality of Tully and Murray catchments in north Queensland, Australia, was modelled by Wallace *et al*. (2009). Netpay (2014) reported nitrate and phosphate content of three rivers of Thailand before and after the 2011 flood. Praveena and Santhosh (2019) reported nutrient cycling and its loadings on the productivity of Kappil estuary, an estuary located south of the present location. Considering the near-normal values of all water quality parameters, the flood wash-off effect reduced the pollution level near the industrial complex area of the Titanium sponge factory in the Chavara region, Kollam district.

Analysis of heavy metals showed that the concentration of heavy metals was high in the pre-flood season, which was significantly reduced in the post-flood period and during the flooding season, the values were going down below the detectable level, which may be due to dilution with flood water or wash-off to the oceans. Generally, the major source of Cr and other trace elements in water is industrial effluents (Kamal *et al*., 2007; Verma *et al*., 2015). Exposure of man to a high concentration of Cr may cause dermatitis, ulcer, destruction of mucus of nose and cancer of the stomach. Fe shows a high range in the pre-flood season, and during the pre-flood season, it ranged from 0.97ppm to 1.20ppm at site 1 and 2, respectively. Seasonal variation showed high iron content in the pre-flood season, and the present study results were in tune with the reports of heavy metal pollution in the Ganga River (Kar *et al*., 2008). Similarly, cadmium and zinc also showed a similar pattern in pre-flood season (0.286ppm) along the NWW3. Zonta *et al.* (2019) assessed the heavy metal concentrations and their deposition distribution of sediments of Po river lagoons of Italy with respect to tidal fluctuations. The prolonged consumption of Zn and Cd in high quantity can result in health complications such as fatigue, dizziness and Neutropenia (Hess and Schmid, 2002) in aquatic and other animals. The heavy metal wash-off by flood water can be regarded as one of the positive impacts of flooding. Still, on the other hand, the flood may bring in trace elements and can be accumulated in surface sediments of estuaries and coastal areas (Baborowski *et al*., 2012; Gopal *et al*., 2017). Both primary productivities, gross and net productivity values were estimated for the two sites and compared for the flood wash-off effect. GPP at site 2 and NPP at site 1 registered no significant difference between the pre- and post-flood period, which might be due to low productivity due to high pollution/effluent discharge during the pre-flood season at site 1. Sivan and Abraham (2018) reported the productivity of NWW 3 along different seasons and reported the impact of monsoon on the water quality parameters, including the ecosystem's productivity. The Gross and net productivity of the Kappil backwater system has been recently reported by Praveena and Santhosh (2019) along with the influence of nutrients on productivity, and the reports corroborate with the present investigation results.

4. Conclusion

The state of Kerala experienced the natural hazard, flooding during July-September 2018, which fetched both large scale negative and small scale positive impact. Washing off wastes/contaminants and dilution and/or reduction in pollution level and nutrient enrichment of aquatic ecosystems were the significant impacts due to flood. The flood wash-off effect was evident from the present study near the industrial effluent discharge zone and the Chavara (Kollam district of Kerala) region of National Water Way No.3. However, the downstream impacts of such wash-off remain to be studied.

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