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Baseline

Impact of coastal power plant cooling system on planktonic diversity of a polluted creek system

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ABSTRACT

A tropical coastal power plant with a once-through cooling system that pumped sea water along with tiny marine phytoplankton and zooplankton for waste heat discharge recorded reduction in the population density of these organisms by 64% and 93%, respectively, at the discharge site. The depletion of organic carbon is 0.69 tons per annum with loss of 20 to 24 lakhs fish fecundity. The synergistic effect of tropical summer ambiance and waste heat discharge from the power plant considerably reduced the phytoplankton population in the coolant water discharge point during April, June, and July. This resulted in changes in the phytoplankton community structure from Bacillariophyceae > Dyanophyceae > Cyanophyceae to Bacillariophyceae > Cyanophyceae > Dyanophyceae in the Ennore creek system. A unique epibiotic assemblage of the diatoms *Licmophora juergensii* and *Licmophora flabellata* was observed on *Phormidium* sp., a mat-forming Cyanobacterium preharbored along the 4.5-km-long transport channel of the cooling tower blow out of the thermal power plant. These pedunculate fouling diatoms have a symbiotic association with *Phormidium* sp., which grows few microns high above the substrate, thus creating obstructive flow in cooling water channels of the power plant. Further, loss of fish larvae during zooplankton population reduction creates an impact on the local fishery. However, the emerging scenario of global warming predicts that the migration of fish population toward cooler regions shall further aggravate the fishery reduction near the power plant cooling operation along the tropical coasts. The marine organisms living in tropical coastal waters operated at upper limits of thermal tolerance produce a demand for the regulatory bodies in India to enforce a drop in discharge criteria for coolant water, with the pre-existing power stations permitted to discharge up to 10 °C above the ambient temperature and newer power stations permitted to discharge a maximum of 7 °C. It becomes a requisite for power stations to draw additional seawater along with the plankton. Therefore, an emerging technology of subsurface intake systems called beachwell that resolves the issue of coolant water intake without biota was advocated.

The demand for power-generating plants has been increasing regardless of several appeals in energy conservation. Factors such as urbanization and industrialization propel the need for energy production (Major Singh, 2015). Consequently, it increases the need for cooling water at various steps during energy generation procedures. In general, water bodies such as rivers and ocean were often used as key sources to meet the in-satiated demand for cooling water.

Water drawn into power plants usually contains organisms such as phytoplankton, algal propagules, zooplankton, invertebrate larvae, and fish larvae often considered as a representative of local ecological communities (York and Foster, 2005). These traversing communities can be used as a mirror reflection to determine the adverse impacts such as decreased biomass and productivity of phytoplankton and heterotrophic bacteria (Capuzzo, 1980; Choi et al., 2002; Morgan and Stross, 1969; Shiah et al., 2006; Takesue and Tsuruta, 1978), reduction in survival and diversity of zooplankton communities (Taylor, 2006), and reduction in other metazoans (Bamber and Seaby, 2004; Capuzzo, 1980; Carpenter et al., 1974; Evans et al., 1986; Hoffmeyer et al., 2005; Kartasheva et al., 2008) in the aquatic environment.

The damage in the transiting plankton cells often associates with factors such as the type of organisms, conditions of operational systems, temperature, and chlorine residues (Bamber and Seaby, 2004; Capuzzo, 1980; Poornima et al., 2005). Among these factors, thermal stress was reported as a causative factor for transiting plankton mortality (Thorhaug, 1978; Marumo et al., 1992; Taylor, 2006). In general, seasonal variation of Indian coastal water temperature widely varies (maximum of 10 °C), thereby forcing the organisms to live in upper lethal temperature limits (Krishnakumar et al., 1991). Further, mortality of planktonic communities was also strongly related to the discharge of heated waste materials in tropical coastal water (Poornima et al., 2006).

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Table 1
Impact of power plant effluent discharge on plankton reduction – an overview.

S.nos.	Power plant type	Phytoplankton reduction	Zooplankton reduction	Fin fish/larvae mortality	Primary productivity (GPP) reduction	Reference
1	Coal based, Korea	–	20–37%	–	–	Choi et al., 2012
2	Nuclear power plant, Taiwan	10–43%	–	–	–	Wen-Tseng Lo et al., 2016
3	The nuclear power plant, Chennai, India	35–70%	–	–	–	Poornima et al., 2005
4	Nuclear Power Station, USA	–	70%	–	–	Carpenter et al., 1974
5	Nuclear Plant, USA Lake Michigan	–	14–22%	–	–	Evans et al., 1986
6	The nuclear power station, South Africa	42.8–70.6%	6.3–41.9%	–	–	Huggett and Cook, 1991
7	Coal-, oil and gas-fired thermal electricity generating station, Malaysia	–	–	26%	–	Azila and Chong, 2010
8	Nuclear Power Plant, Taiwan	–	–	63%	–	Liao et al., 2004
9	Coal & oil fired thermal power station, USA	–	–	–	53%	Morgan and Stross, 1969
10	Owase-Mita Thermal Power Plant, Japan	–	–	–	11 to 32%	Takesue and Tsuruta., 1978
11	The nuclear power plant in northeastern Long Island Sound, USA	–	70%	–	–	Carpenter et al., 1974
12	Smolensk and Kursk Nuclear power plant, Russia	–	50%	–	–	Kartasheva et al., 2008
13	Tuticorin Thermal Power Station, Tuticorin, India	88%	89%	–	–	Selvin Pitchaikani et al., 2010

It is apparent that power plant intake systems pump seawater along with existing biota into a series of mechanical devices (strainers, screens, tubes, etc.) for filtration. The strainers and screens perform the function of impingement, thus restricting the entry of large marine organisms and debris as well as supplying water with microorganisms (planktonic and nektonic species) to the condenser for heating cause entrainment (Greenwood, 2008; Mayhew et al., 2000; Bamber and Seaby, 2004). This micro marine biota often releases effluents in the same environment. However, the variety of physical and chemical stresses faced by this micro marine biota may reflect on the survival of such organisms varying in biodiversity in the released environment. Our knowledge of the impact of effluents released from power plant cooling systems on planktonic biodiversity is limited (Table 1).

Studies have been conducted worldwide to address the impact of power plant effluent on plankton community (Morgan and Stross, 1969; Takesue and Tsuruta, 1978; Evans et al., 1986; Shiah et al., 2006; Lo et al., 2016). In India, few reports on the thermal impact on planktonic organisms are available from various vicinities (Saravanane et al., 1998, Rajadurai et al., 2005, Poornima et al., 2005 & 2006; Selvin-Pitchaikani et al., 2010; Palanichamy et al., 2002). For instance, reduction in benthic fauna (Kailasam and Sivakami, 2004) and zooplankton species (Easterson et al., 2000) was recorded.

Notably, no attempts were made to address the impact of a coal-based thermal power plant along the coastline of Tamil Nadu. Eccentrically, Ennore creek is the most exploited and polluted water body that is located along this coastline and receives effluent discharges from major industries including fertilizers, rubber factories, steel rolling, motor vehicles, and oil refineries surrounded by thermal power plants. Particularly, studies on understanding the change in planktonic biodiversity of the Ennore creek system after the discharge of heated effluents from the power plant into the polluted aquatic ecosystem are not available.

North Chennai Thermal Power Station (NCTPS), a coal-based thermal power plant operated by Tamil Nadu Generation and Distribution Corporation Limited (TANGEDCO), is located at the confluence point of the Ennore creek with the Bay of Bengal, South India (Fig. 1). The NCTPS Power Plant Unit shares its southern boundary with the Ennore creek (13°13′54.48″ N, 80°19′26.60″ E), northern boundary with Ennore port, eastern boundary with the Bay of Bengal coast, and western boundary with Buckingham canal (Fig. 1).

By 1995, NCTPS was commissioned with a total power production capacity of 630 MW (with three units of 210 MW each) with a cooling water suction capability of 90,000 m^3 per hour through the adjoining Ennore port *through* an open channel along the Bay of Bengal coast (WAPCOS, 2014). By 2013, additionally, two power plants of 600 MW each were installed, and this resulted in an increased cooling water suction volume of 2,00,000 m^3/h through the pre-existing cooling water intake system. A total volume of 2,90,000 m^3/h was discharged through an open precooling channel of width 130 m and length 2.5 km, followed by another warm water channel of length 2 km, which leads to the Ennore creek for discharge (Fig. 1). It measured the hot water release from the heated condenser approximately 8 °C above the ambient temperature (WAPCOS, 2014).

The ecological and economic significance of the Ennore creek system adjoining coastal waters of the Bay of Bengal have been reported (Shanthi and Gajendran, 2009). The glorious past of the creek had flourishing mangrove swamps that later degraded to patches and fringes because of the anthropogenic activities (Chaves and Lakshumanan, 2008). The north–south trending channels of the creek connect with the Pulicat Lake bioreserve in the north to the distributaries of the Kosasthalaiyar River in the south.

The creek situated in the direction of west to east opens into the Bay of Bengal. It receives a large quantity of wastewater from various sources present along the adjoining industrial belt located at Manali (Sreenivasan and Franklin, 1975; Purvaja and Ramesh, 2000; Jayaprakash et al., 2005; Prince Prakash jebakumar et al., 2014; Sachithanandam et al., 2017). Buvaneshwari et al. (2014) studied the thermal dispersion of power plant effluent discharge at the Ennore creek and recorded serious environmental concerns. Thus, the present study conceived to unravel the impact of effluents released from NCTPS on plankton population diversity in the creek waters.

The plankton standing crop assessment is done by collecting monthly samples for a period of one year from July 2014 to June 2015 in the vicinity of NCTPS. The power plant operating conditions were constant throughout the sampling period. Water samples for physico-chemical analysis were collected from various places such as intake point, discharge point, and possible thermal plume dispersion areas inside the Ennore creek. The population density of the residing planktonic communities was analyzed once in a month throughout the study tenure.

The sampling stations were designated as EHE1 to EHE5: EHE1 for intake water collection area at the Bay of Bengal near the approach channel of the Ennore port; EHE2 for hot water discharge point at the Ennore Creek bank; EHE3 for an area that is 300 m away from the