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Integrated study and quality analysis of surface drainage and sewer water for Bhubaneswar Municipal Corporation, India

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***Abstract*— Bhubaneswar city the capital of the state of Odisha is situated in the eastern coast along Bay of Bengal has an undulating ridge and valley topography and is covered by number of natural drainage channels. The leading drainage is controlled by the Kuakhai and Daya rivers, all along the city on the north and the south. A number of open drains also run across west to east spreading throughout the city, some of which finally joins to form Gangua Nallah which in turn meets River Daya, a distributary of River Kuakhai. The city is in the western side of River Kuakhai and to the northern part of River Daya sloping from the north - west of the city area to the Kuakhai River in the east and Daya River in the south. The total consumption of water for Bhubaneswar city is mainly met from River Kuakhai, River Daya, spring tanks and from ground water sources. River Kuakhai and River Daya are the major surface water source, though these rivers receive industrial and domestic discharges, which are the prime source of polluting the rivers. The discharges are through wastewater drains, overflow of the septic tanks and oxidation ponds.**

There are 88 industries and 2 industrial clusters, of which 34 are water pollution potential industries, which discharge their effluent directly into the drains without any basic treatment. Most of the sewage from the city reaches River Kuakhai and River Daya through open drains. There are about 10 open drains in the city of Bhubaneswar discharging wastewater. The drains cover an area of about 103.43 sq km with the drainage length of 37.18 km. The only drain named Patia falls into Kukhai River directly and remaining nine drains outfalls in Gangua Nallah, which is the main drain between Daya West branch canal and Daya River. All the drains cut across the South Eastern Railway line, NH-203& 5 and Daya West Branch Canal without proper planning.

***Index Terms*— Drainage, wastewater, sewerage, water quality, Gangua Nallah, Kuakhai River**

I. INTRODUCTION

Waste water refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources (Arshad et al, 2009; Gulp & Gulp, 1971). Integrated Sewerage system for Bhubaneswar city has been undertaken to improve the infrastructure of the city in an effort to provide basic amenities to people way back in 1950's. Due to massive growth in population and rampant migration population soared to twenty times. This resulted in failure of the conventional disposal of wastewater. In response to the failure of sewerage disposal, the government has decided to modernize the sewerage system with a sound technology. The sewerage system of Bhubaneswar envisages laying of 412km underground gravity sewer for collection of sewage of each household and establishment throughout the city in uncovered area, replacement and renovation of all existing old sewers, construction of main, intermediate and lift pumping stations, construction of sewage treatment plants and construction of low cost sanitation units in the city area. As per government of Odisha, the new sewerage system has been planned by dividing the city into six sewerage zones that shall provide an independent sewerage network, pumping system, sewage treatment and disposal system. An integrated sewerage system has been designed for a projected city population of 2.2 million up to 2041. The project area of 145km^2 includes all wards of Bhubaneswar Municipal Corporation and fringe areas covered under city master plan. The project ensures proper treatment of generated sewage in the city with provision of modern treatment technology like Standard Activates Sludge Process (SASP). The project will provide good and effective sewerage services to the urban population and will reduce non-point sources of pollution which may result with a remarkable improvement of the overall sanitation condition of the city. However, in cities and towns with old sewage systems, treatment stations simply do not exist or they might not be properly equipped for an efficient treatment. The most important consideration in determining the self-purification capacity of a stream is its ability to maintain an adequate DO concentration which among other factors is controlled by atmospheric re-aeration, BOD, nitrification and temperature (Naeem et al, 2011).

Even when all establishments are connected to the sewage system, the designed capacities are often exceeded, resulting in a less efficient sewage system and occasional leaks (Paula et.al, 2012). Changes in land use and cover influence surface water quality and thus are a potential threat to water systems (Isoken et. al, 2013).Odisha Water Supply & Sewerage Board (OWSSB) established in 1991 for rapid development and proper regulation of water supply and sewerage services in the state of Odisha to execute major water supply and sewerage projects and after completion, has to be handed over to Odisha Public Health Engineering Organization (OPHEO) for day to day operation and maintenance. As per OWSSB a master plan has been prepared for present sewerage plan and future development (Fig.1). On the basis of land use and land cover Bhubaneswar city has been divided into six sewerage zones for smooth implementation of the project. Earth excavation and RCC work is in full swing to give a new shape to the old existing sewerage system (Fig.2).

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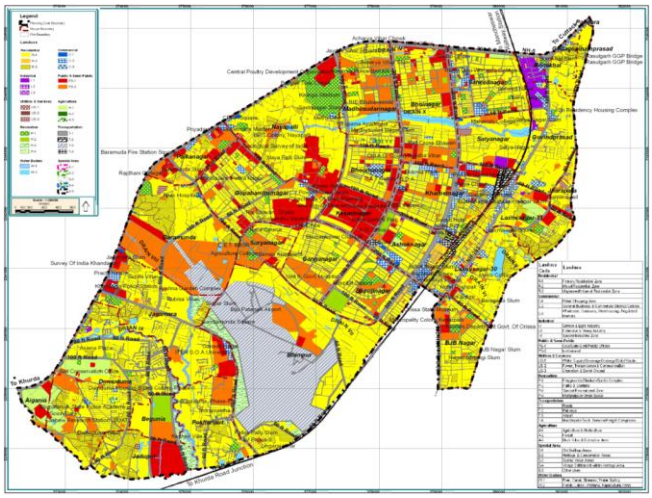


Fig.1 Land use plan of Bhubaneswar city

Fig.2 Integrated Sewerage System

Fig. 3 RCC structure for the natural drainages

Cleaning and de-siltation work in four out of 10 major natural drainage channels in the city has run into problem over land acquisition. The Rs 74crore project requires the Bhubaneswar Municipal Corporation (BMC) to acquire nearly 14 acres along the route of these channels, which has been encroached upon in some places. The project also requires land to widen channel routes at a few places. The water resources department looks after all major drains in the city, while the BMC is only concerned about the smaller drains (EMP, Govt. of Odisha).The renovation work involves erection of concrete walls on both the sides of the drains and a bed made of laterite stones to allow recharge of groundwater (Fig.3). Walls on the sides of the natural drainage channels will also ensure that wastewater, including sewer lines do not get mixed with rainwater flowing through the natural drainage channels. Out of 10 natural drains flowing through the city, five drainages passed through the core city area and were identified as Nallahs having a catchment area of 40km^2. The other five drains had a catchment area of 44.18km^2. However, all the drains were now choked with debris and weeds. The entire storm water of the capital was discharged through these natural drainage channels, and they ultimately fell into Gangua Nallah which flows into the Daya River (The Telegraph, 2011).

II. Observation

The waste water that flows after being used for domestic, industrial and other purposes is known as sewage. Sewage contains water as the main component, while other constituents include organic waste and chemicals (Ram et al, 2011). In most of the places sewage is discharged into open drains without any treatment, which joins to form Gangua Nallah and ultimately discharges to river Daya. The Gangua Nallah joins river Daya around one kilometer downstream of Kukuria Bridge. Gangua Nallah which finally meets River Daya serves as the ultimate for the wastewater discharges of Bhubaneswar city (Fig. 4). River Kuakhai and Gangua receive about 107.25 mld of wastewater out of which 47.6 mld is from domestic sources, 29.3 mld from industrial areas mostly generated from the Patia and Chandaka industrial estate and 30.35 mld from mixed sources (Table 1). The wastewater discharged into Kuakhai and Daya from various drains and the pollution load carried by them are the primary source of pollution for those two rivers. The total organic load (BOD) discharged through these drains is 100.64 t/day and that of solids is127 t/day. The major contributor to the water pollution for BOD load is Patia drain followed by Sainik School. These drains discharge both domestic and industrial wastewater from densely populated old city areas. Out of the 10 drains flowing in the city almost 9 of them meets the Gangua Nallah at different locations.

Drain Patia outfalls into Kuakhai River directly and drain number 2 to 10 outfalls in Gangua. The total BOD load discharged to River Kuakhai is 27.20 t/d and to the Gangua Nallah73.44 t/d. The flow in the river Kuakhai and Daya helps in achieving the required dilutions for wastewater. The flow path of all the ten drainages is shown in Fig.4. River Kuakhai is a tributary of River Mahanadi and water remains throughout the year. The flow in Kuakhai during lean season varies from 85m^3/s to 105m^3/s. River Daya is also a large seasonal river and water remains throughout the river with considerable flow. The flow in Daya river varies from 55m^3/s to 90m^3/s. The flow of the Gangua Nallah ranges from 8m^3/s to 60m^3/s at different locations. The length of the drainage passing through Bharatpur and Sainik School has a maximum stretch of 5.63Km and 1.13Km respectively where as their catchment areas are 13.67Km^2 and 1.44Km^2 (Table 1).

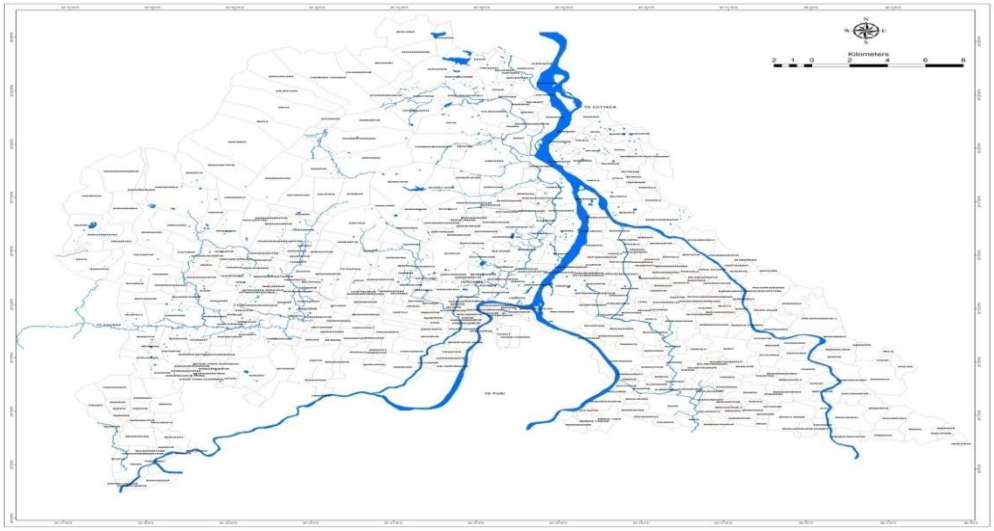


Fig.4 Drainage Map of Bhubaneswar

Drain No.	Drain Name	Starting Point	Terminal Point	Length in km	Drainage Area in sq. Km.
1	Patia	Forest lake Chandrashekharpur	Daya West Canal Crossing to River Kuakhai	4.32	16.93
2	Sainik School	Sainik School Road Culvert	Railway Bridges (Confluence with Drain no 3) to Gangua Nallah	1.13	1.44
3	OAP Area	Near Sainik School	Railway Bridges (Confluence with Drain no 2) to Gangua Nallah	2.42	3.31
4	Culvert near Reserve Forest, Bharatpur	Culvert near Reserve Forest, Bharatpur	Daya West Canal Crossing to Gangua Nallah	5.63	13.67
5	Culvert in Janpath Road	Culvert in Janpath Road	Gangua Nallah	3.13	3.66
6	Railway Bridges	Railway Bridges	Gangua Nallah	2.16	2.89
7	Culvert in Airport Road	Culvert in Airport Road	Gangua Nallah	4.34	9.46
8	Joklandi Road	Joklandi Road	Confluence with Drain no 8 to Gangua Nallah	4.33	12.99
9	Culvert on NH-5	Culvert on NH-5	Pokhariput Railway Bridge to Gangua Nallah	4.24	12.55
10	Lake near CRP Colony	Lake near CRP Colony	Gangua Nallah	5.48	10.28
Total				**37.18**	**103.23**

Table 1 Geographic detail of the drainages (Source: GoO)

The average discharge of different drainages has been presented in Table 2. This table also shows the major areas and their respective municipal wards through which each drain passes through.

Drain No	Nomenclature	Major Areas	Ward No	Average Discharge MLD
1	Patia	Chandersekharpur, Damana,Garkana, Patia, Rokata, Mancheswar.	1	17
2	Sainik School	Gadakan.	2	1.55
3	OAP Area	Samanta Vihar, Vani Vihar, Garkana.	2, 3, 5, 6, 7, 8	3.55
4	Vanivihar	Nayapalli, Madhusudan Nagar, VaniVihar, Pandara, Gadakan, Bhoi Nagar.	4, 6, 7, 17	16.4
5	Laxmisagar Area	Kesari Nagar, Charbatia, East Bargada.	24, 23,	4.45
6	Baragada Area	East Bargada, Laxmisagar, Ashok Nagar.	25, 26, 10	3.45
7	Kedargouri	Goutam Nagar, West Bargada, Nuagaon.	26, 23	5.45
8	Airport Area	Baramunda, Jokolandi, Jagmara.	13,14, 15, 16, 17	14.3
9	Ghatikia	Aiginia, Dumduma, Jagamara, Begunia, Kochilaput, Ransinghpur, Ebaranga, Pokhariput, Ghatika, Sankarpur.	18, 19, 20, 15,16	28.8
10	Nicco Park	Madhusudan Nagar, Bhoinagar, Satyanagar, Govindprasad, Kardakanta, Jharpada, Nilkanthanagar, Madhusudan Nagar.	9, 12, 11, 10, 21,22	12.3

Table 2 Details of the drainage paths and their movement through different municipal wards (Source: GoO)

As per the earlier discussion it has already been described that all the drainages excluding one, meet Gangua Nallah and the lone Patia drain meets Kuakhai river. Since the drainages are not pre-treated before they mix with the rivers, there is a huge change in their quality. But as per the data presented in Fig. 5 it is confirmed that except temperature and COD there is hardly any distinct variation in the other properties. The COD and TSS too remain high as compared to their standards.

Apart from the rivers, Gangua Nallah receives the maximum discharges from the City. Gangua Nallah is a natural stream that emanates from Gadakan village and flows between Kuakhai and Daya River and confluence with Daya near Kanti village. Length of the Nallah is 35.7 km. The bed width is 30mts and the bed level at the mouth level at the mouth is 2.62 m. Its independent catchment area is 75.6km^2 in the city. It discharges approximately 652 cusecs of water into Daya (Fig.5).

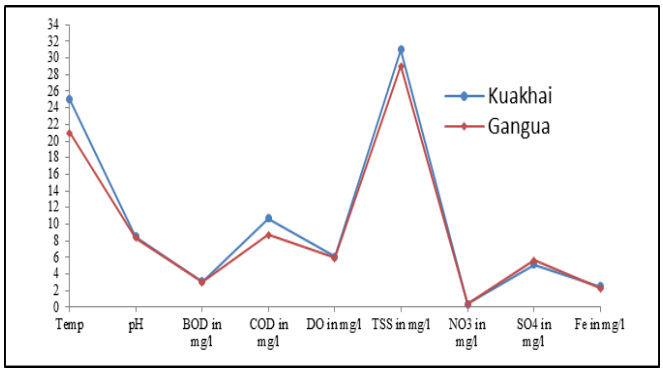


Fig.5 Water quality analysis of Kuakhai River and Gangua Nallah

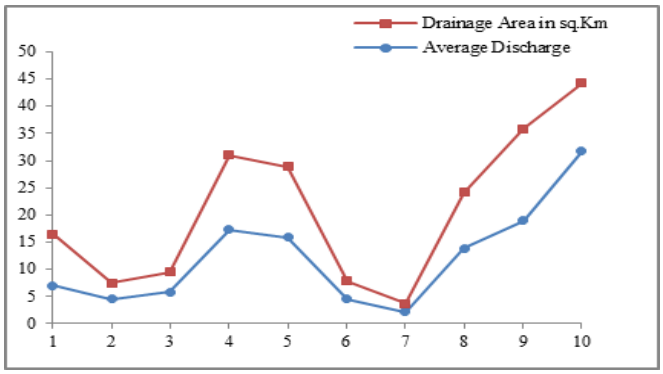


Fig.5 Area Vs. Discharge graph

Parameters	Monitoring Sites									
Drain no.	AcharyaVihar	Saheed Nagar	KedarGouri	Chandra sekharpur	Nayapalli	Unit-II	Satya Nagar	Mancheswar	Baragada	Laxmisagar
pH	7.4	6.1	7.5	7.6	6.9	7.2	7.2	5.9	6.9	6.9
SS (mg/l)	120	20	160	100	140	180	60	160	200	200
TDS (mg/l)	180	200	200	200	400	300	400	200	400	400
BOD (mg/l)	100	160	120	60	140	120	140	24	100	100
COD (mg/l)	130	208	160	120	208	176	176	52	160	160
Cl^-(mg/l)	36	50	66	34	72	64	88	28	72	72

Table 3 Quality analysis of sewage water at different monitoring sites.

The pollution level of different areas all along Bhubaneswar have been calculated and presented in Table 3. In Saheed Nagar and Mancheswar the sewerage water is more acidic whereas in the other areas the pH is neutral. Similarly the suspended solids (SS) is too high in Baragada and Laxmisagar region. COD level in Nayapalli is maximum whereas at Mancheswar it is minimum. Table 4 shows the quality of drainage water presented through histogram.

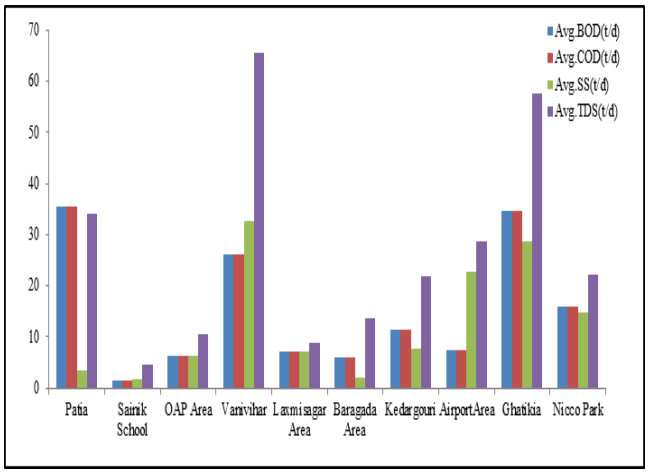
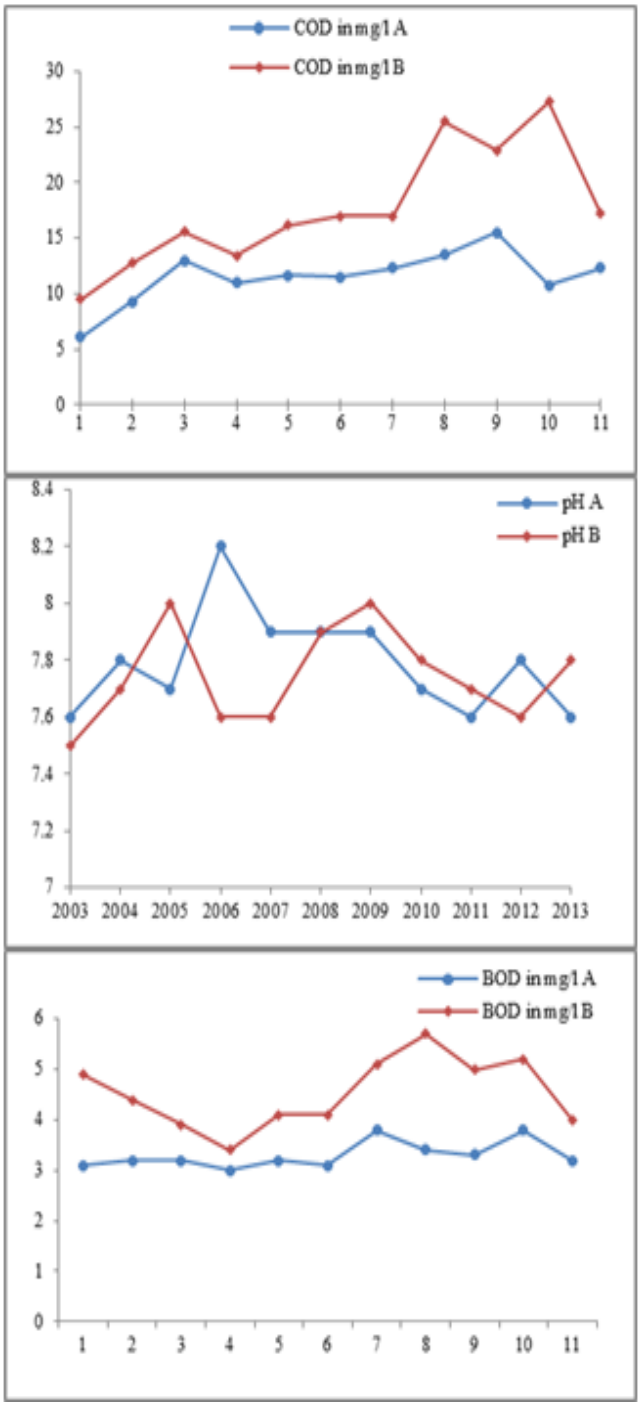


Table 4 Pollution Load Discharges through Surface Drains in Bhubaneswar City

III. Results

Rains are likely to wash off indiscriminately disposed excreta into shallow wells particularly if the wells are not protected. Therefore, this may have also contributed to the contamination of the generally open shallow wells with fecal matter (Elizabeth and Augustine, 2007). At present only the main city district is sewered. Several areas in the city are not covered by sewerage system and these areas are severely affected due to stagnation of sewage on the roads and open plots adjoining the building blocks. Open drains carrying sewage across the city pose severe threat to health in addition to causing nuisance of bad odour and over flow during monsoon. In absence of sewerage system, people are using septic tanks and soak pits. In most of the places sewage is discharged in to open drains without any treatment, which ultimately discharge to Gangua Nallah. Gangua Nallah in its course of 12 km in the city of Bhubaneswar receives wastewater discharges at 9 drains. River Kuakhai receives about27.22 mld of wastewater from Patia drain. Also, the old sewerage system is prone to frequent choking of sewerage lines leading to overflow of sewage into roads and creating bad sanitary conditions. Lack of periodic maintenance and renovation of old sewerage system is yet another problem. The total organic load (BOD) discharged through these drains is 100.64 t/day and that of solids is 127 t/day. The major contributor to the water pollution for BOD Load is Patia drain followed by Sainik School. These drains discharge both domestic and industrial wastewater from densely populated old city areas. The existing water quality in river Kuakhai is 'acceptable'. Over the year the trends shows that the water quality has deteriorated from the 'excellent' category to the 'desirable' category at the upstream of Bhubaneswar. But due the discharges from the city the water quality has deteriorated although not alarming. The present water quality in River Kuakhai can be categorized under 'C' class and falls under the 'Acceptable' category of the Water Quality Criteria. The water quality in almost all the lakes and ponds is not suitable for bathing. The high levels of BOD, chloride, nitrate, TC and FC counts recorded in all these water bodies indicate their polluted nature. However, in view of the socio-economic considerations added with religious sentiments, bathing in these public ponds is likely to continue for time to come. The existing water pollution levels, poor sanitation, lack of sewerage system, polluted drains and river, overflowing sewage are highly deterrent to the tourism activity and for the health of the local people. A set of figures representing the comparison of different quality parameters for the upstream and downstream of Kuakhai river reflecting the deterioration of quality of water of the river due to massive discharge of untreated sewerage water to the river directly (Fig.6).



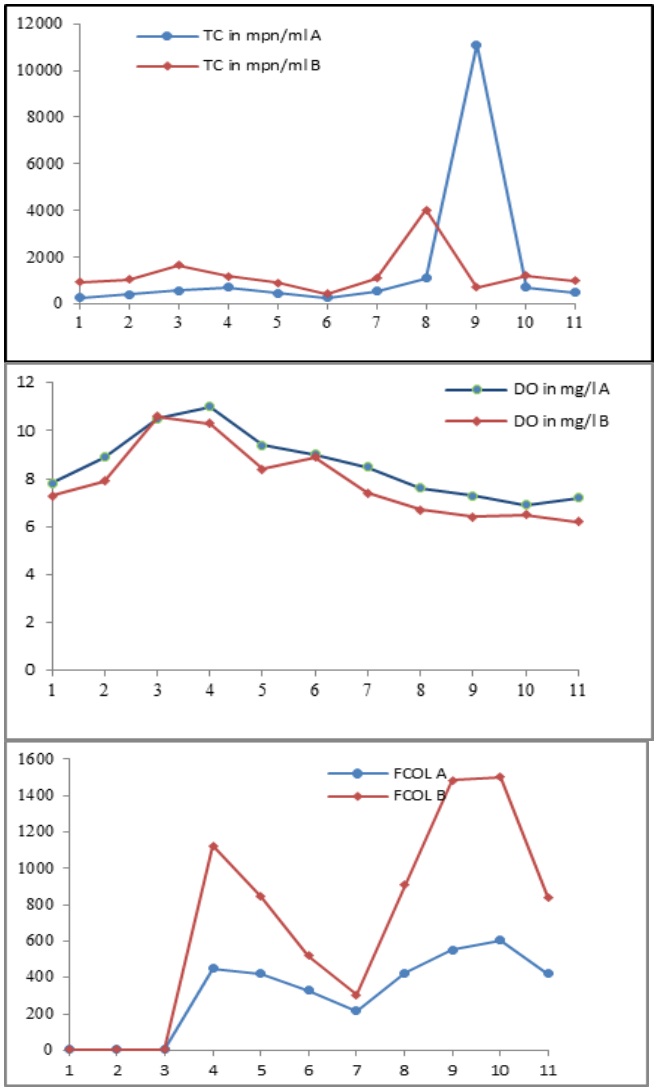


Fig. 6 Comparison of water quality of Kuakhai Upstream (A) & Kuakhai Downstream (B)

IV. Discussion

At present only the main city district is facilitated by sewers. Several areas adjacent to the city are not covered by sewerage system and these areas are severely affected due to stagnation of sewage on the roads and open plots adjoining the building blocks. Open drains carrying sewage across the city pose severe threat to health in addition to causing nuisance of bad odour and over flow during monsoon period. In absence of sewerage system, people are using septic tanks and soak pits. In most of the places sewage is discharged in to open drains without any treatment, which ultimately discharge to Gangua Nallah. Gangua Nallah in its course of 12 km in the city of Bhubaneswar receives wastewater discharges at 9 drains. River Kuakhai receives about 27.22 mld of wastewater from Patia drain. The old sewerage system is prone to frequent choking of sewerage lines leading to overflow of sewage into roads and creating bad sanitary conditions. Lack of periodic maintenance and renovation of old sewerage system is yet another problem. The total organic load (BOD) discharged through these drains is 100.64 t/day and that of solids is 127 t/day. The major contributor to the water pollution for BOD load is Patia drain followed by Sainik School. These drains discharge both domestic and industrial wastewater from densely populated old city areas. The existing water quality in river Kuakhai is 'acceptable'. Over the year the trends shows that the water quality has deteriorated from the 'excellent' category to the 'desirable' category at the upstream of Bhubaneswar. But due the discharges from the city the water quality has deteriorated although not alarming. The present water quality in River Kuakhai can be categorized under 'C' class and falls under the 'Acceptable' category of the Water Quality Criteria. The water quality in all most all the lakes and ponds is not suitable for bathing. The high level of BOD, chloride, nitrate, TC and FC counts recorded in all these water bodies indicate their polluted nature. However, in view of the socio-economic considerations added with religious sentiments, bathing in these public ponds is likely to continue for time to come. The existing water pollution levels, poor sanitation, lack of sewerage system, polluted drains and river, over flowing sewage are highly deterrent to the tourism activity and for the health of the local people.

Conclusion

Most of the area under the Municipal boundary is covered by the drains (103.23km^2), but the waste water falling under the wards 17, 18, 19, 29 do not have easy access to the drains and they spill out in the nearby roads. The total BOD load discharged from the drains is 103.23 t/d out of which 47.6 mld is from domestic sources, 29.3 mld from industrial areas and 30.35 mld from mixed sources. The Gangua Nallah servers as the ultimate discharge for the wastewater of the city receiving73.44 t/d of BOD. Out of the 10 drains flowing in the city almost 9 of them meets the Gangua Nallah at different locations. River Kuakhai receives 27.20 t/d of BOD. The major contributor to the water pollution for BOD load is Patia drain followed by Sainik School. These drains discharge both domestic and industrial wastewater from densely populated old city areas. There is sufficient flow in the River Kuakhai and Gangua Nallah, which helps in achieving the required dilutions for the wastewater. The continuous water velocity through these two channels after diluting the pollutants reduces their polluting characters. Kuakhai and Daya both the rivers have been used to uplift water for drinking purpose. This water has been treated in treatment plants established by government organizations before they are pumped out for supply to households in order to meet the domestic and drinking requirements.

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