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Assessment of Pollution Load in Terms of Water Quality Index and Modelling of Taladanda Canal and Mahanadi River in Paradip Area, Odisha, India

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Abstract: The modelling of water quality is an integrated source of good management, which benefits the environment and its people. In the present study, the quality of water was measured in terms of physicochemical analysis and WQI. This analysis facilitates the eco-management study of the water. In this article, we have measured the quality of the water in Taladanda canal and river Mahanadi nearby Paradip area in terms of WQI for the year 2017. Five different sampling stations were selected from Taladanda canal and nine sampling points were selected from river Mahanadi. It was found that the water quality index in most of the areas was much higher, however, the water is of poor quality. But in PPL site areas, the quality of water was found to be very poor and not suitable for human use. The pollution load was found to be much higher in the Taladanda canal and moderate in Mahanadi River near the Paradip area.

Key words: Water quality index, DO, BOD, modelling, water parameters.

Introduction

Water and air are essential components for the survival of life on the earth. The present study talks about the importance of water. The water molecules join in chains of hydrogen bonds formed by electrostatic interaction between two hydrogens and an oxygen atom. As a result, it forms a tetrahedral network generating a series of larger molecules. The structure of water also contributes to the relative solubility of electrolyte and insolubility of non-electrolyte in aqueous solution. Rivers are the main sources of human consumption water resources which are used in many ways such as domestic, industrial and agricultural purposes (Doetterl et al., 2012). Due to rapid industrialisation, urbanisation and increasing demand for water in various sectors, the utility of water has vastly increased, which has led to scarcity of water. From different industrial belts and urban areas, a huge amount of industrial solid waste, industrial effluents, urban waste, urban effluents along with the statues of different god and goddesses are dumped into the nearest sources of the river, canal water or any other water bodies which are the major cause of increasing pollution load of the river and the canal water and other water resources which are consumed or utilised by humans (Ewa et al., 2011). In rural areas, the agriculture waste along with unused fertilisers and pesticides are finally mixed with the river water which is another cause of heavy contamination of surface water (Serpil, 2012). This also causes an increase in plant nutrients as compared to other water resources, which facilitates eutrophication. Water is highly important for

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the development of both natural environment and human beings. It is one of the most abundantly occurring useful substance found in our globe. A healthy and suitable ecosystem mainly depends upon the quality of the water available. The quality of water can be studied easily in terms of physicochemical, bacteriological parameters and also water quality index (Serpil et al., 2012). It was estimated that our globe is covered by 70% water.

Water pollution was not worrisome a few decades ago, however, due to recent industrial and urban developments, huge tonnes of solid contaminants along with liquid effluents are flown not only into the river water but also the marine water. This causes marine water pollution which threatens the biological community. Paradip port is one of the major ports in India, which is situated in Jagasinghpur district of Odisha. Three directions (east, north and south) of the port city Paradip is covered by water bodies. The South Eastern direction is covered by the Bay of Bengal whereas River Mahanadi flows on its northern side and finally merges from west to east. In the study of surface water pollution, Atharabanki River plays an important role because it shows heavy emission of solid waste materials and sewage water from PPL plants and residential township area, waste from IFFCO fertiliser plants, effluents of the breweries, SKOL. The effluents of the Paradip Port Trust town areas are finally dumped into the Taladanda canal and then mixes with the river Mahanadi very nearer to the point where it merges with the Bay of Bengal. Because of the addition of a huge amount of both solid wastes and liquid effluents into the Taladanda canal and also in river Mahanadi, the water quality of human consumption surface water is gradually degrading rapidly. It is forming a great threat to the survival of flora and fauna in Paradip area and nearby areas.

Our study aims on assessing the water quality in terms of water quality index in river Mahanadi and also the Taladanda canal in the command area of Paradip town. Paradip Port is one of the important ports of India and is considered as the gateway of the coastal trading of the national and many international countries throughout the world. This port transports coal, mining products and other materials throughout the world, which contributes to the economic and industrial development of India. Huge varieties and quantities of different kinds of materials along with processed food products are exported or imported to various countries through Paradip Port. The minerals exported through Paradip Port are mainly the ores of Fe, Mg, Al, Cr, steel materials. In addition to this, coal, scrap iron, crude and purified petroleum products, ammoniacal fertilisers, phosphatic rock, H_2SO_4, H_3PO_4 along with some other different sea food waste processing materials and some machinery parts (Khan et al., 2017) are also transported through this port. Some refined Al from NALCO, refined steel materials of RSP and TISCO, some important alloys mainly ferrochrome, ferromanganese alloy, charge chrome alloy, etc are also traded from the Paradip port.

Recently, Paradip port has also grown up as one of the major sea fishing areas of Odisha, where 700 small and 80 large fishing trawlers are engaged for fishery everyday. The Parade port area which is located nearby is a thriving fishing sector, however, presently it is not controlled by the port authorities. The fishing harbour is directly connected with the Bay of Bengal via the river Mahanadi. The fishes harvested, processing of the fishes into seafood products is the cause of the production of huge quantities of waste every day and its biodegradation increases the pollution load of air, soil and water in and around the Paradip area. The fuel loading, maintenance of such a large number of trawlers along with local fishing boat contributes as a major cause of coastal marine pollution. For public awareness the water quality of Taladanda canal should have to be acknowledged periodically to the local people. Also, water quality improvement programmes should be conducted periodically to aware the people of the losses. The water quality index can give us a better idea about the quality of water in a single value. It is mainly used for the verification and evaluation of the pollution load of water and may be defined as a replication of the combined influence of different water quality parameters on the measurement of overall quality of water. It is mainly divided into two categories i.e., physico-chemical and bacteriological or biological indices. Physico-chemical indices are calculated on the basis of the values of different physico-chemical parameters of the sample water whereas bacteriological indices are calculated by using the biological and bacterial information of the water samples analysed (Krishna et al., 2007).

This study attempts to evaluate the water quality index of the area under study based on hydro-chemical data. The modelling in the water quality showed the change in pollutant concentration and its movement throughout the environment. Contaminating substance entering into the environment may cause an increase or decrease in its concentration because of different kinds of mechanisms. The fate of the pollutants in our environment is the result of interactions between the mass transfer and kinetic data. The water quality modelling is due to all these changes and data. Water quality modelling is an uninterrupted process of improving the models with time because of the information available in the study. It is an adequate technique to describe the actual process. This article focuses on the primary knowledge of water quality modelling through quality, types, structure, physical, chemical, biological parameters. It also studies the application of the water quality models and to know about the unsuitability of water of Taladanda canal, Mahanadi river of Paradip area and nearby areas (Fan et al., 2010). The assessment of water quality in terms of water quality index is a modern method to determine the quality, ranking and suitability of the water.

Materials and Methods

Study Area

Mahanadi River

The water of this river is mostly used for fishing, prawn culture, irrigation, supplying to industry, etc. The river Mahanadi at this section is identified as "Class-D" on the basis of the use of the water in terms of water quality. Nine samples of water from River Mahanadi and its distributaries nearby Paradip area are considered as our study area and water samples are collected from these sampling stations in clean polythene bottles (Ganie et.al., 2012). The different locations of sampling of River Mahanadi are given in Table 1.

Table 1: Mahanadi and its distributaries

River	*Site*	*Code*
Mahanadi	Nilachal Bazar	A1
Nuna	Kusunpur	A2
Mahanadi	Musadia	A3
Mahanadi	Ramnagar	A4
Mahanadi	Karnasi	A5
Mahanadi	Atharabanki Confluence Fishery Harbour	A6
Mahanadi	Sea Confluence Nehru Bungalow	A7
Gobari	Jambu	A8
Chitrotpala	Patakura	A9

Taladanda Canal

The starting point of Taladanda canal Jobra, Cuttack originates from river Mahanadi, which flows towards the Cuttack city and finally the Parade port. This canal is a water source for agricultural activities, domestic water supply to the local people and industrial use. The samples of water are collected from different suitable locations of Taladanda canal (Bharti et al., 2011). These sampling locations are given in Table 2.

Table 2: Sampling Site – Taladanda Canal

Sl No.	*Site*	*Code*
1	TIRTOL	B1
2	CHOUMUHANI	B2
3	BHUTMUNDAI	B3
4	NEAR PPL	B4
5	ATHARABANKI	B5

Sampling Procedure and Sample Analysis

Water samples were collected from nine sampling stations of the river Mahanadi and five sampling stations of Taladanda canal near the Paradip area in a clean plastic bottle at three different seasons (monsoon, pre-monsoon, post-monsoon). The physico-chemical parameters of these samples are studied in the environmental laboratory in the Department of Chemistry and Civil Engineering VSSUT, Burla. The average value of the physico-chemical parameters was calculated (Bharti et al., 2010). From the analysed average data, the WQI of the water samples is calculated by using a proper formula. This WQI data indicates the range of pollution of Mahanadi River and Taladanda canal for the year 2017.

Calculation of WQI in terms of Weighted Arithmetic Water Quality Index Method

This method is a modern method which was developed by Brown et al. in 1972. It is considered as the combined effect of all the important physico-chemical parameters and depicts the quality of water of any water body. In this experiment, WQI has been employed preferably due to the following reasons to determine the water quality of Taladanda canal and river Mahanadi (Akkaraboyina et al., 2012). It determines the quality of the water of any water bodies of both surface and ground water and clarifies the % of purity of water. It is also commonly used by many scientists and researchers to determine the pollution load of any water by using a single calculated value.

(i) It determines the overall aspects of pollution load by using different water parameters and gives better assessments of the quality of water and also its management in a better and more scientific way (Karmas et al., 2011).

(ii) For assessment of pollution load in terms of WQI minimum number of parameters are required in comparison to other methods of assessment.

(iii) It also determines the usability of both surface and underground water for human consumption.

The following steps are adopted in order to determine WQI of the collected sample of water (Rown et al., 1972).

(1) To calculate the quality rate (Q_i) the formula used is given below in equation (1).

$$(Q_i) = [(V_o - V_i)/V_s - V_i] \times 100 \quad (1)$$

V_o = Weighted mean of different parameters

V_i = Optimal acceptable value

V_i = 0, for all of the water parameters except pH & DO (Brown et al., 1970)

V_i for pH = 7 whereas V_i for DO = 14.6 mg/L (Chauhan et al., 2010)

V_s = Standard acceptable limit of particular parameter

(2) Calculation of relative unit weight (W_i) is given as follows:

(W_i) α $1/S_i$ or $W_i = K/S_i$

$K = 1/1/S_i$

where S_i = Standard value of a particular parameter

(3) Water Quality Index (WQI) = $\frac{\Sigma W_i Q_i}{\Sigma W_i}$ (Rao et al., 2010)

i. 0 < WQI < 100 fit for human use (Choudhury et al., 2012)

ii. 0 >WQI > 100 unfit for human use. The Water Quality Index rating has been given below in Table 3.

Table 3: Weighted Arithmetic WQI Method

WQI value	*Water quality*	*Grade*
0 – 25	Excellent	A
26 – 50	Good	B
51 – 75	Poor	C
76 – 100	Very poor	D
Above 100	Very poor & unfit for drinking purpose	E

The water quality index of Taladanda canal for five monitoring stations and river Mahanadi for nine monitoring stations is calculated by weighted arithmetic method for the year 2017, which has been presented in Table 3 (Balan et al., 2012).

Tables 4, 5, 6, 7 and 8 provide the WQI of the water of Taladanda canal in Tirtol, Choumuhani, Bhutamundai, near PPL side area, Atharabanki area respectively and Tables 9, 10, 11, 12, 13, 14, 15, 16 and 17 provide WQI of river Mahanadi in different areas such as Nilachala Vihar area, Kusunpur area, Musadia, Ramnagar area, Karnasi, Fishery Harbour, Nehru Bungalow side area, Jambua and Patakura area respectively.

Figure 1 shows graphical representation of the WQI of Taladanda Canal of five different monitoring stations and found that WQI is maximum near PPL side area because of addition of excessive industrial effluents from PPL and Figure 2 shows the WQI of different monitoring stations of River Mahanadi near the Paradip area.

Water Quality Modelling

The natural structures and systems are God gift which is very complicated as well as highly organised. The models of water quality formed by us tries to measure the different changes happening due to change in the concentration of the pollutants, which are generally moving periodically within our environment. The different categories of pollutants are entering into our environment from various sources in different mechanisms and their concentration may increase or decrease with time and activity of human being. However, in the last few decades, it was found that the concentration of pollutants are increasing very rapidly and it is alarming to the human civilisation (Farnandez et al., 2012). The effect of different pollutants is mainly because of the interaction between kinetic data mass transfer. The modelling of water quality is due to the interaction mechanism and all the datas. The modelling of river water quality and its use in water management is being done since ancient times, but mainly due to the revolutionary work of Streeter and Phelps that its significance has been realised. Both of the scientist explained the degradation of organic material through microbes, which is identified by the change in BOD values and DO. Subsequently, the measurement of the kinetics of bacterial decomposition by simple kinetic data is further modified by using three major steps. The first step was the improvement of the two-state-variable model by introducing the settling rate of particulate matter in addition to the rate of decay called sediment oxygen demand. This model was also modified by using the research result to work on the rate of surface reiteration. Then finally, an extension of this model was made by distinguishing between CBOD and NBOD which may have led to a third state variable (Panigrahi et al., 2013). The simplified nitrogen cycle was incorporated in the second step: NH_3, nitrate,

Table 4: Water Quality Index, Tirtol, Taladanda canal

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.15	8.5	0.117	10	1.17	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	99.6	500	0.002	19.92	0.039	
3	TH	87.2	300	0.003	29.066	0.087	
4	SO_4^{2-}	12	150	0.006	8	0.048	$= \frac{1115.522}{25.8526}$
5	NO_3^-	4.7	45	0.022	10.444	0.229	
6	PO_4^{3-}	3.65	5	0.20	73	14.6	= 43.16
7	Cl^-	22	250	0.004	8.8	0.0352	(GOOD)
8	Fe	0.419	0.30	3.333	139.666	456.506	
9	F^-	0.735	0.60	1.666	122.5	204.085	
10	Cr^{6+}	0.0095	0.05	20	19	380	
11	DO	5.9	6.0	0.1666	101.162	16.853	
12	BOD	3	3.0	0.333	100	33.3	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 1115.9522$	

Table 5: Water Quality Index, Choumuhani, Taladanda canal

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.04	8.5	0.117	2.666	0.31192	
2	TDS	98.6	500	0.002	19.72	0.03944	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
3	TH	81.0	300	0.003	27.666	0.082998	$= \frac{2541.485406}{25.8526}$
4	SO_4^{2-}	11.2	150	0.006	7.466	0.44796	
5	NO_3^-	4.74	45	0.022	10.533	0.23176	= 98.3067 (VERY POOR)
6	PO_4^{3-}	3.5	5	0.20	70.0	14	
7	Cl^-	21.0	250	0.004	8.4	0.0336	
8	Fe	0.48	0.30	3.333	160	533.28	
9	F^-	0.87	0.60	1.666	145	241.57	
10	Cr^{6+}	0.042	0.05	20	84	168	
11	DO	6.92	6.0	0.1666	89.3023	14.87776	
12	BOD	5.1	3.0	0.333	170	56.61	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 2541.485406$	

and nitrite and also appears as new components in the model. The extension of this model appears in as QUAL-1 (TWDB-1971), which is the first model of the QUAL family. Ten years later, the third step of this model was further extended by the incorporation of phosphorus cycling and algae, which may be resulted in organic nitrogen, organic phosphorus, dissolved phosphorus, and the biomass algae (in terms of chlorophyll) as the additional state variables. This new model of water quality is known now-a-days as QUAL-2E and is widely

Table 6: Water Quality Index, Bhutamundai, Taladanda canal

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.08	8.5	0.117	5.333	0.623961	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	90.2	500	0.002	18.04	0.03608	$= \frac{2811.386731}{25.8526}$
3	TH	72.8	300	0.003	24.266	0.072798	=108.7467
4	SO_4^{2-}	10.2	150	0.006	6.8	0.0408	(Very poor and unfit for drinking purpose)
5	NO_3^-	4.6	45	0.022	10.222	0.224884	
6	PO_4^{3-}	3.3	5	0.20	66.0	13.2	
7	Cl^-	22.0	250	0.004	8.8	0.0352	
8	Fe	0.396	0.30	3.333	132	439.956	
9	F^-	0.746	0.60	1.666	127.333	212.136778	
10	Cr^{6+}	0.052	0.05	20	104	2080	
11	DO	6.8	6.0	0.1666	90.6976	15.11023	
12	BOD	4.5	3.0	0.333	150	49.95	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 2811.386731$	

Table 7: Water Quality Index, PPL, Taladanda canal

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.12	8.5	0.117	8.0	0.31192	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	91.8	500	0.002	18.36	0.03944	$= \frac{3802.475087}{25.8526}$
3	TH	80.8	300	0.003	26.933	0.082998	= 147.0829
4	SO_4^{2-}	11.4	150	0.006	7.6	0.44796	(VERY POOR AND UNFIT FOR DRINKING)
5	NO_3^-	5.06	45	0.022	11.244	0.23176	
6	PO_4^{3-}	3.2	5	0.20	70.0	14	
7	Cl^-	19.6	250	0.004	7.84	0.0336	
8	Fe	0.35	0.30	3.333	116.666	533.28	
9	F^-	0.76	0.60	1.666	126.666	241.57	
10	Cr^{6+}	0.08	0.05	20	160	168	
11	DO	6.6	6.0	0.1666	93.02325	14.87776	
12	BOD	4.66	3.0	0.333	155.333	56.61	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 3802.475087$	

used for water management in different sectors. It has also been adopted as practically untouched from various simulation software and decision support systems (DSS). The water quality modelling is a continuous process of improving models with times and is parallel with the increase of the information available and the basic knowledge regarding the simulation system, which is much more adequate to describe the real process of water distribution and manegement (Wani et al., 2016). The focus is to receive the basic knowledge about water quality modelling and its applicability in water distribution, management, treatment and finally save water resources from an excess of pollution load. Figure 3 reflects a general layout of the water quality model.

Table 8: Water Quality Index, Atharabanki, Taladanda canal

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.10	8.5	0.117	6.666	0.7799	WQI = $\frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	89.4	500	0.002	17.88	0.03576	
3	TH	75.2	300	0.003	25.066	0.075198	= $\frac{2792.209080}{25.8526}$
4	SO_4^{2-}	11.2	150	0.006	7.466	0.044796	
5	NO_3^-	4.86	45	0.022	10.8	2.376	= 108.0049
6	PO_4^{3-}	3.24	5	0.20	64.8	12.96	(VERY POOR AND UNFIT FOR
7	Cl^-	21.0	250	0.004	8.4	0.0336	DRINKING)
8	Fe	0.326	0.30	3.333	108.666	362.1838	
9	F^-	0.692	0.60	1.666	115.333	192.14478	
10	Cr^{6+}	0.054	0.05	20	108	2160	
11	DO	6.88	6.0	0.1666	89.76744	14.95525	
12	BOD	4.2	3.0	0.333	140	46.62	
				$\sum W_i$ = 25.8526		$\sum W_i Q_i$ = 2792.209084	

Table 9: Water Quality Index, NilachalaVihar, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	6.96	8.5	0.117	-2.6666	-0.3119922	WQI = $\frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	93.4	500	0.002	18.68	0.3736	
3	TH	74.0	300	0.003	24.6666	0.0739998	= $\frac{1434.4858202}{25.8526}$
4	SO_4^{2-}	11.8	150	0.006	7.8666	0.0471996	
5	NO_3^-	4.8	45	0.022	10.6666	0.2346652	= 55.4871
6	PO_4^{3-}	3.44	5	0.20	68.8	13.76	Poor (Class – C)
7	Cl^-	22.0	250	0.004	8.8	0.0352	
8	Fe	0.344	0.30	3.333	114.6666	382.18377	
9	F^-	0.87	0.60	1.666	145.0	241.57	
10	Cr^{6+}	0.018	0.05	20	36	720.0	
11	DO	6.5	6.0	0.1666	94.186	15.6914	
12	BOD	5.48	3.0	0.333	182.6666	60.8279778	
				$\sum W_i$ = 25.8526		$\sum W_i Q_i$ = 1434.4858202	

Mathematical equation

$$\partial C/\partial t + Vx\,\partial C/\partial x + Vy\,\partial C/\partial y + Vz\,\partial C/\partial z = \partial/\partial x\left(Dx\,\partial C/\partial x\right) + \partial/\partial y\left(Dy\,\partial C/\partial y\right) + \partial/\partial z\left(Dz\,\partial C/\partial z\right) + S(x, y.z) \pm \text{Sinternal} \quad (2)$$

The basis of all water quality models is calculated by using Eq 2. This equation of water quality modelling describes the concentration variations of quality of the constituent C with respect to space and time. Besides the adjectives and the dispersive transport terms, the internal source or sink terms, or internal reaction term, have been included in the equation. This process is also called transformation processes which

Table 10: Water Quality Index, Kusunpur, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values(V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.0	8.5	0.117	0.0	0.0	
2	TDS	93.4	500	0.002	18.68	0.03736	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
3	TH	89.00	300	0.003	29.6666	0.0889998	$= \frac{1434.30689}{25.8526}$
4	SO_4^{2-}	10.6	150	0.006	7.0666	0.0423996	= 40.3559
5	NO_3^-	4.76	45	0.022	10.5777	0.2327094	Poor
6	PO_4^{3-}	3.42	5	0.20	68.4	13.68	Good
7	Cl^-	20.00	250	0.004	8.0	0.032	(Class – B)
8	Fe	0.308	0.30	3.333	102.6666	342.18777	
9	F^-	0.838	0.60	1.666	139.6666	232.68455	
10	Cr^{6+}	0.0096	0.05	20	19.2	384.4	
11	DO	6.72	6.0	0.1666	91.6279	15.2652	
12	BOD	4.96	3.0	0.333	165.3333	55.0559	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 1434.30689$	

Table 11: Water Quality Index, Musadia, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values(V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.04	8.5	0.117	2.6666	0.31199	
2	TDS	92.8	500	0.002	18.56	0.03712	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
3	TH	91.2	300	0.003	30.4	0.0912	
4	SO_4^{2-}	10.8	150	0.006	7.2	0.0432	$= \frac{1015.74158}{25.8526}$
5	NO_3^-	4.88	45	0.022	10.8444	0.23857	= 40.3559
6	PO_4^{3-}	3.36	5	0.20	67.2	13.44	Good
7	Cl^-	21.0	250	0.004	8.4	0.0336	(Class – B)
8	Fe	0.316	0.30	3.333	105.3333	351.0758	
9	F^-	0.772	0.60	1.666	128.6666	214.3585	
10	Cr^{6+}	0.0092	0.05	20	18.4	368.0	
11	DO	6.6	6.0	0.1666	93.0232	15.4976	
12	BOD	4.74	3.0	0.333	158.0	52.614	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 1015.74158$	

means that the concerned substance is transformed by different physical, chemical, biochemical and biological processes that cause changes in the quantity of the substance in an elemental water resource (Padmanav et al., 2005). This change is either a “loss” or sink that is caused by different processes mainly settling, chemical-biochemical decomposition, uptake by living organisms, or a “gain”, a source term, such as scouring from the stream bed, product of chemical-biochemical reactions, biological growth, that is the “build-up “

Table 12: Water Quality Index, Ramnagar, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.2	8.5	0.117	13.3333	1.5599	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	680.0	500	0.002	136.00	0.272	
3	TH	443.0	300	0.003	147.3333	0.4419	$= \frac{2184.3578}{25.8526}$
4	SO_4^{2-}	13.6	150	0.006	9.0666	0.0544	
5	NO_3^-	5.22	45	0.022	11.6	0.0232	= 84.49277
6	PO_4^{3-}	4.12	5	0.20	82.4	16.48	Very Poor and
7	Cl^-	1418	250	0.004	567.2	2.2688	unfit for drinking purposes
8	Fe	1.35	0.30	3.333	450.0	1499.85	(Class – E)
9	F^-	0.562	0.60	1.666	93.6666	156.0485	
10	Cr^{6+}	0.0112	0.05	20	22.4	448.0	
11	DO	7.02	6.0	0.1666	87.1264	14.5152	
12	BOD	4.04	3.0	0.333	134.6666	44.8439	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 2184.3578$	

Table 13: Water Quality Index, Karnasi, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	6.972	8.5	0.117	-1.866	-0.2183	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	99.09	500	0.002	18.018	0.0361	
3	TH	85.09	300	0.003	28.363	0.0851	$= \frac{3063.6353}{25.8526}$
4	SO_4^{2-}	12.36	150	0.006	8.24	0.0494	
5	NO_3^-	4.83	45	0.022	10.733	0.2361	= 71.8753
6	PO_4^{3-}	3.59	5	0.20	71.8	14.36	(Class –C)
7	Cl^-	22.27	250	0.004	8.908	0.0356	Poor Quality
8	Fe	1.09	0.30	3.333	363.333	1210.9888	
9	F^-	0.72	0.60	1.666	120	199.92	
10	Cr^{6+}	0.0093	0.05	20	18.6	372	
11	DO	7.06	6.0	0.1666	87.674	14.6065	
12	BOD	4.15	3.0	0.333	138.333	46.0648	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 1858.141$	

of the substance in concern on the expense of other substances present in the system. The real form of the transformation processes may be represented in relation to concrete model equations like BOD-DO models, the models of the oxygen household and the lake models of the plant nutrient (phosphorus and nitrogen) transformation processes.

C = The concentration, the mass of the quality constituent in a unit volume of water (mass per volume, M L-3); Dx, Dy, Dz - are the coefficients of dispersion in the direction of spatial co-ordinates x, y, and z, (surface area per time, L2T-1); Vx, Vy, Vz - are the components of the flow velocity in spatial directions

Table 14: Water Quality Index, Fishary Harbour, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.081	8.5	0.117	5.4	0.6318	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$ $= \frac{3063.635378}{25.8526}$ =118.502 (Class – E) (Very poor and unfit for drinking purpose)
2	TDS	98.81	500	0.002	19.762	0.0395	
3	TH	80.45	300	0.003	26.816	0.0805	
4	SO_4^{2-}	11.36	150	0.006	7.573	0.0455	
5	NO_3^-	4.73	45	0.022	10.511	0.2312	
6	PO_4^{3-}	3.51	5	0.20	70.2	14.04	
7	Cl^-	21.36	250	0.004	8.544	0.0342	
8	Fe	1.06	0.30	3.333	353.333	1177.6588	
9	F^-	0.86	0.60	1.666	143.333	238.7928	
10	Cr^{6+}	0.039	0.05	20	78.0	1560.0	
11	DO	6.9	6.0	0.1666	89.534	14.9163	
12	BOD	5.15	3.0	0.333	171.666	57.164	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 3063.635378$	

Table 15: Water Quality Index, Nehru Bungalow, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.09	8.5	0.117	6.0	0.720	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$ $= \frac{3119.8817}{25.8526}$ = 120.67 (Class – E) (Very poor and unfit for drinking purposes)
2	TDS	90.18	500	0.002	18.036	0.0361	
3	TH	72.54	300	0.003	24.18	0.0725	
4	SO_4^{2-}	10.36	150	0.006	6.9	0.0414	
5	NO_3^-	4.6	45	0.022	10.223	0.2249	
6	PO_4^{3-}	3.29	5	0.20	65.8	13.16	
7	Cl^-	21.18	250	0.004	8.472	0.0339	
8	Fe	0.92	0.30	3.333	306.666	1022.2098	
9	F^-	0.77	0.60	1.666	128.333	213.8028	
10	Cr^{6+}	0.045	0.05	20	90.0	1800	
11	DO	6.79	6.0	0.1666	113.166	18.8534	
12	BOD	4.57	3.0	0.333	152.333	50.7269	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 3119.8817$	

x, y, and z, (length per time, L T-1); t - is the time (T); S(x,y,z,t) - denotes external sources and sinks of the substance in concern that may vary in both time and space(mass per volume per time, M L-3 T-1); Sinternal - denotes the internal sources and sinks of the substance, (M L-3 T-1); The model designed for water quality are mainly utilised for many different problems and purposes (Khan et al., 2003). The water quality model presented here is termed as River Water Quality Model (RIWAQ). The applications of this model were described below.

(1) Conservative pollution (trace metal ions and inorganic components) modelling using mass balance model and generic water quality model.

Table 16: Water Quality Index, Jambua, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.127	8.5	0.117	8.466	0.9905	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	92.18	500	0.002	18.436	0.0368	$= \frac{4553.59}{25.8526}$
3	TH	80.45	300	0.003	26.816	0.0805	= 176.13
4	SO_4^{2-}	11.36	150	0.006	7.573	0.0454	(Class – E)
5	NO_3^-	5.0	45	0.022	11.111	0.2444	(Very poor and unfit for drinking purposes)
6	PO_4^{3-}	3.2	5	0.20	64.0	12.80	
7	Cl^-	21.63	250	0.004	8.652	0.0346	
8	Fe	0.99	0.30	3.333	330	1099.89	
9	F^-	0.76	0.60	1.666	126.666	211.0255	
10	Cr^{6+}	0.079	0.05	20	158	3160	
11	DO	6.54	6.0	0.1666	93.720	15.6137	
12	BOD	4.76	3.0	0.333	158.666	52.8357	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 4553.59$	

Table 17: Water Quality Index, Patakura, Mahanadi River

Sl No.	*Name of parameters*	*Mean observed values (V_0)*	*Standard values (V_S)*	*Unit weight (W_i)*	*Quality rating (Q_i)*	*$W_i Q_i$*	*Remarks*
1	pH	7.10	8.5	0.117	6.666	0.7799	$WQI = \frac{\Sigma W_i Q_i}{\Sigma W_i}$
2	TDS	92.09	500	0.002	18.418	0.0368	$= \frac{3450.5114}{25.8526}$
3	TH	75.36	300	0.003	25.12	0.753	= 133.4686
4	SO_4^{2-}	10.90	150	0.006	7.066	0.423	(Class – E)
5	NO_3^-	4.81	45	0.022	10.688	0.2351	(Very poor and unfit for drinking purposes)
6	PO_4^{3-}	3.2	5	0.20	64.0	12.8	
7	Cl^-	20.45	250	0.004	8.18	0.0727	
8	Fe	0.95	0.30	3.333	316.666	1055.4477	
9	F^-	0.71	0.60	1.666	118.333	197.1427	
10	Cr^{6+}	0.053	0.05	20	106.0	2120.0	
11	DO	6.81	6.0	0.1666	90.581	15.0907	
12	BOD	4.3	3.0	0.333	143.333	47.7298	
				$\sum W_i = 25.8526$		$\sum W_i Q_i = 3450.5114$	

(2) Modelling of BOD and DO by using dispersion, dilution, diffusion and reaction kinetics.

(3) Nutrient modelling of water by using the export function and the distributed modelling approach.

Objectives of Water Quality Modelling

The objectives of water quality modelling should be very clear and also well-defined, which achieves maximum simplicity consistency with the required degree of accuracy and detail in the process of descriptions of

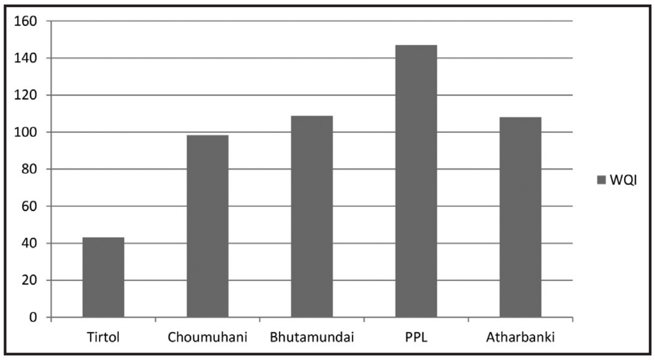

Figure 1: Graphical Representation of WQI in the Taladanda Canal.

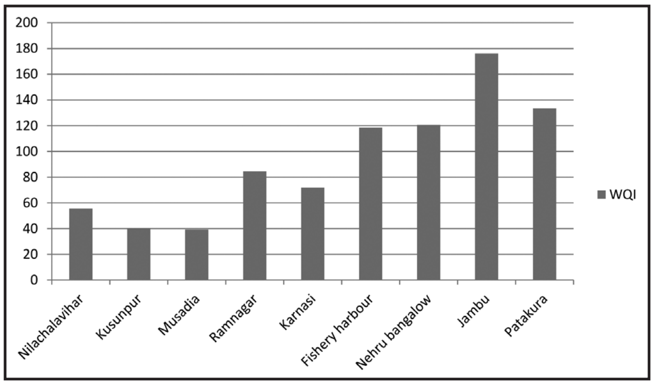

Figure 2: Graphical representation of WQI in Mahanadi river.

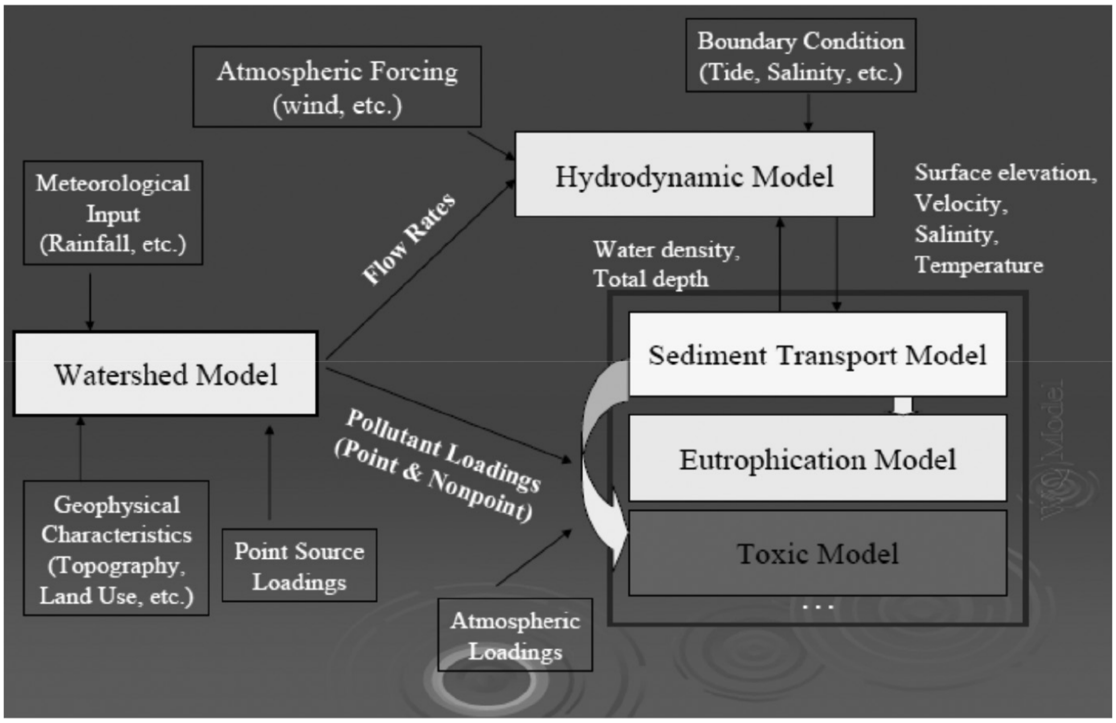

Figure 3: General layout of water quality model.

the complex natural system. Mainly the purpose of modelling falls into one of the following categories (Kumar et al., 2009).

- In the scientific logic, it is used to develop a clear conceptual model based on all available information as well as to understand more fully the transport regime of the pollutants to test hypotheses, to ensure consistent governing principals and observations, and again to quantify the dominant controlling processes. A stimulation code may also be used for clear understanding of the model. The black-box used is the intelligent application of this model.
- This water quality model can bring the responsibility or assess to exposures, and to reconstruct the history of the transportation of the pollutants and also establishes the time ranges within which an occurrence could have begun, or within which polluting substances could have reached in a specified level to certain areas.
- Future contaminant distribution may be calculated, either under existing conditions or with engineering intervention and to control the source or alter the flow regime. These include the choice of code used in the computer, the way of discretisation, the level of effort required in model calibration, and

the analysis of the appropriated assumptions. By definition, a model is a simplified approximation to the real system. A simple model is always preferred to a complex model, as long as it captures the essence of the problem. An overly complex model not only increases computational time and costs but also introduces additional uncertainties if detailed data are not available (Akoteyon et al., 2009).

Conclusions

In this article, we have analysed five water samples of Taladanda canal from different sample points, nearby the Paradip area and nine water samples are collected from Mahanadi River from the different points in the command area of Paradip. From the calculated data WQI is found to be maximum at PPL area (147.08) because it is a major fertilizer plant in Odisha and discharging a huge amount of effluents and solid waste to the Taladanda canal and in Tirtol area WQI is 43.16, which is good in quality because the area is free from industrial belt. In the other areas, i.e., Choumuhani, Atharabanki, Bhutamundai WQI value is above 100 indicating very poor quality of water. In Mahanadi WQI is maximum in the Jambua area which is the industrial belt of Paradip and WQI is 176.13 which indicates very poor quality of water and in other areas i.e. in the area of fishery harbour, Nehru Bungalow, the WQI is combatively more due to extensive fishing, industrial effluent discharge and disposal of food processing waste materials from different fish processing units and fish markets. The modelling figure also indicates the very poor quality of water both in Taladanda and river Mahanadi. Hence it was suggested that before it goes beyond the limiting value it should be properly managed and water should be made suitable for human consumption.

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