

Numerical Simulation of BOD-DO Dispersion of Thermal Power Plant Effluent in Arabian Sea, Mumbai

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ABSTRACT: Numerical simulation analysis of flow and BOD-DO dispersion is carried out using an ecological, process oriented model using MIKE 21 ECO Lab model. Two dimensional, MIKE 21 ECO Lab is applied for tidal creek in Dahanu, a coastal town in the Palghar district, Maharashtra, India. Currents in the coastal creek are primarily generated by the coastal winds of various speeds and directions, which are highly variable in time, by tides. Thermal power plants requires huge amount of water for cooling purposes and in-turn it emits large quantity of heated water. To fulfil its needs, mostly Thermal power plants are located near the large water bodies. Dahanu creek: Thermal power plant also discharges hot water into Arabian sea through tidal creek. This emission of power plant hot water may possibly effect the food chain and food web of the aquatic ecosystem. So, in this research paper the most important physico-chemical characteristics such as Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO) flow and dispersion has been studied. Tidal currents plays a vital role in the dispersion of plume from the power plant. Numerical simulation showed that the southern tidal currents are suitable for pollutant dispersion, due to more availability of dissolved oxygen. The study reveals that there is minimal environmental effect with respective to BOD-DO model simulation.

KEYWORDS: Numerical Simulation, Tidal Current, BOD, DO, Coastal Creek

I. INTRODUCTION

Nowadays the global energy demands has been increasend with the advancement in industrialization. These demands has been fulfilled by fossil fuels and natural resources. About 29.6% of global primary energy needs has been fulfilled by coal and its part in the world's electricity generation is around 42% [5]. The purpose of this paper is to identify the dispersion pattern of BOD-DO, due to the effluent emission of Thermal Power Plant in Dahanu, Maharashtra, India. Generally, thermal power plants require large amount of water for cooling purposes. The water withdrawn from the huge water body such as estuaries, bays and rivers circulates throughout the power plant process and returns to the source through outfall with high temperature. For the optimum performance of the plant, the intake and outfall should be assiduously placed, such that the hot water will not recirculate back into the plant [4]. Thermal plant is located on the bay of Dahanu creek which discharges its effluent/hot water in the creek [8], BOD is the important water quality parameter in the water pollution perspective [2]. Roman et al (2010), [6] developed an ad-hoc three dimensional LES model suited for coastal applications, thus able to take into account the physics and geometric complexities usually encountered in real-case applications. Sandy et al (2009), [7] integrated a geographic information system (GIS) and a complex three-dimensional hydrodynamic sediment and heavy metal transport numerical model. Thinakaran and Jothiprakash (2012), [10] developed numerical model for river estuary flow. Thinakaran and Jothiprakash (2013), [9] simulated pollutant transport model using MIKE21 for different discharges of a river estuary. In this paper the BOD-DO dispersion of numerical simulation for Dahanu Creek in Maharashtra, India, has been carried out to predict the pollutant transport.

II. METHODOLOGY

MIKE21 is a two dimensional, finite difference hydrodynamic flow model available from the DHI Water & Environment DHI, 2001b [1]. MIKE21 solves the vertically integrated equations of continuity and conservation of momentum in two horizontal dimensions. In addition, MIKE21 has a modular structure where water quality modules and sediment transport modules are available as add-on modules to the MIKE21 hydrodynamic module. The continuity equation representing the conservation of mass is given as:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0 \quad (1)$$

where: ζ is the water level (m); p and q are flux densities (discharge/m) in x and y directions ($m^3 s^{-1} m^{-1}$); t is time (s); x and y are space coordinates (m). The momentum equations in two dimensional model (x and y directions) are given by equation (2) and equation (3), respectively:

$$\begin{aligned} \frac{\partial p}{\partial t} + \frac{\partial}{\partial x} \left(\frac{p^2}{h} \right) + \frac{\partial}{\partial y} \left(\frac{pq}{h} \right) + gh \frac{\partial \zeta}{\partial x} + \frac{gp \sqrt{p^2 + q^2}}{C^2 h^2} \\ - \frac{1}{\rho_w} \left[\frac{\partial}{\partial x} (h \tau_{xx}) + \frac{\partial}{\partial y} (h \tau_{xy}) \right] - \Omega q - f V_x \frac{h}{\rho_w} \frac{\partial}{\partial x} (p_a) = 0 \end{aligned} \quad (2)$$

$$\begin{aligned} \frac{\partial q}{\partial t} + \frac{\partial}{\partial y} \left(\frac{q^2}{h} \right) + \frac{\partial}{\partial x} \left(\frac{pq}{h} \right) + gh \frac{\partial \zeta}{\partial y} + \frac{gq \sqrt{p^2 + q^2}}{C^2 h^2} \\ - \frac{1}{\rho_w} \left[\frac{\partial}{\partial y} (h \tau_{yy}) + \frac{\partial}{\partial x} (h \tau_{xy}) \right] - \Omega p - f V_y \frac{h}{\rho_w} \frac{\partial}{\partial y} (p_a) = 0 \end{aligned} \quad (3)$$

where: h is water depth (m); C is Chezy resistance ($m^{0.5} s^{-1}$); f is the wind friction factor (dimension-less), V_x and V_y are wind speed and components in x and y directions (ms^{-1}), respectively; Ω is Coriolis parameter (s^{-1}); P_a is the atmospheric pressure ($Kg.m^{-1} s^{-2}$); ρ_w is the density of water ($Kg.m^{-3}$); and τ_{xx} , τ_{xy} and τ_{yy} are components of effective shear stress (Nm^{-2}) in x and y direction.

a. Pollutant Transport Model

The advection-dispersion module solves the advection dispersion equation for the pollutants in two dimensions. Information on u , v (velocities) and h (water depth) at each time step is provided by the hydrodynamic module. The solution of the transport equations is closely linked to the solution of the hydrodynamic conditions. This equation is numerically solved by an explicit finite difference scheme [1]. The pollutant can be modeled with a first order decay for water quality (DO, BOD and nutrients) [3]. The equation for the advection-dispersion module is shown below

$$\begin{aligned} \frac{\partial}{\partial t} (hc) + \frac{\partial}{\partial x} (u hc) + \frac{\partial}{\partial y} (v hc) \\ = \frac{\partial}{\partial x} \left(h D_x \frac{\partial c}{\partial x} \right) + \frac{\partial}{\partial y} \left(h D_y \frac{\partial c}{\partial y} \right) - F \cdot h \cdot c + S \end{aligned} \quad (4)$$

where, c = compound concentration (arbitrary units); u , v = horizontal velocity components in x , y directions (m/sec); h = water depth (m); D_x , D_y = dispersion coefficients in x , y directions (m^2/sec); F = linear decay coefficients (sec^{-1}); $S = Q_s$, ($C_s - c$); Q_s = source/sink discharge ($m^3/sec/m^2$); C_s = concentration of compound in source/sink discharge

III. STUDY AREA

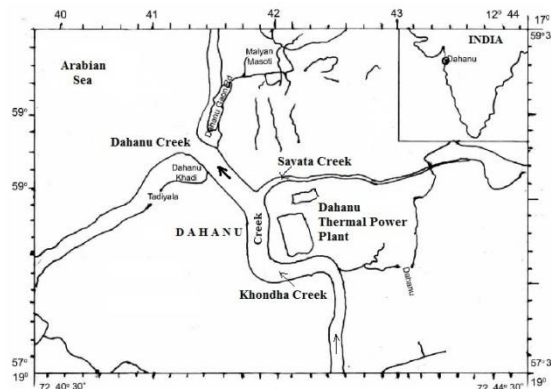


Fig.1: Dahanu Creek – Study Area

Study area is located about 110 km North of Mumbai at Latitude: 19° 59' 26.7036" N and Longitude: 72° 44' 37.2300" E (Fig.1). The power generation capacity of the thermal power plant is 500MW. The intake point of power station is at Savata creek on the North and the outfall at Khondha creek on the south. Both branches of the Dahanu creek converges into the Arabian sea [8].

IV. RESULT AND DISCUSSION

The river estuary flow predictions for DO and BOD are carried out for the Dahanu Creek in Maharashtra, India. Since, in the creek section tides plays an important role in the water flow, the hydrodynamic model has been used for the tidal current variation in northern and southern directions. Based on the calibration of the tides, ECO Lab model has been applied to analyze the transport of water quality parameters such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD) covering the period from 06/11/2002 to 03/01/2003, with total time steps of 518400 in 10 seconds interval. A triangular mesh grid size of 50m - 1417m has been considered. Total study area covered in this numerical simulation is about 168 sqkm with the prevailing wind speed of 5m/s. Tidal variations around the creek area has been found to be varying in around 4.47m. Overall, the maximum dilution of the ecological parameters is seen during the higher tidal level area.

a. BOD SIMULATION

As, BOD is the measure of DO consumed by the microorganisms for the oxidation of organic matter, it is considered in the pollutant transport model. The dispersion factor of 0.1 is given as proportional to the eddy viscosity during simulation and the other factors which influencing the BOD is given as per the considered site condition of the model.

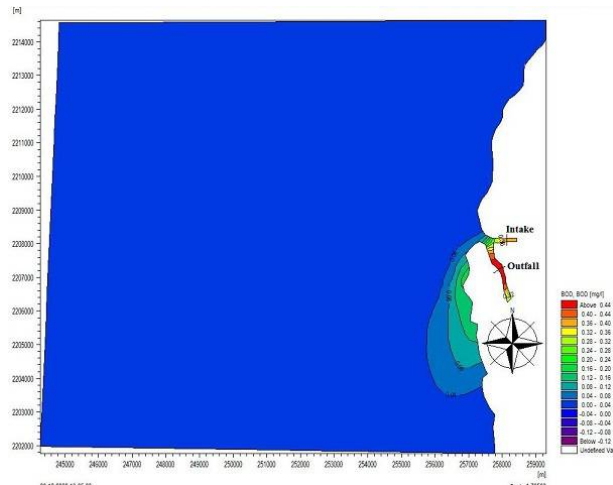


Fig.2 : Flow Visualization of Simulated South Current

The dispersion flow visualization of the dispersion of BOD due to south and north currents has been clearly depicted in Fig.2 and Fig.3 respectively.

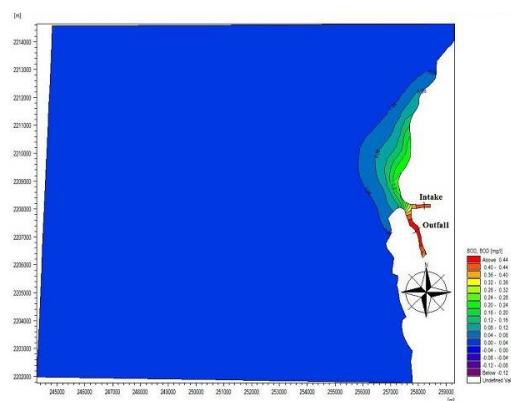


Fig.3 : Flow Visualization of Simulated North Current

The results shows that dispersion of BOD concentration due to north current in the sea portion varies in the range of 0.28mg/l - 0.04mg/l along the shore length of 6km. Due to south current, the dispersion occurs in the south side . The dispersion pattern has been shown in Fig.2 and Fig.3. The results shows that dispersion of BOD concentration due to south current in the sea portion varies in the range of 0.24mg/l - 0.04mg/l along the shore length of 5km.

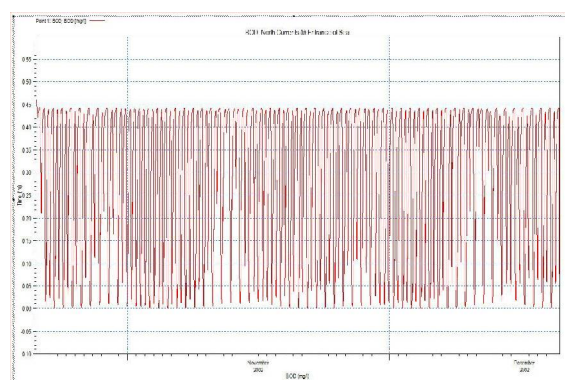


Fig.4 : BOD Simulation due to North Current at the Sea Entrance

Two extraction points at the sea entrance and the outfall has been selected to estimate the BOD concentration variation at each selected points. For the detailed analysis, the concentration variations at the two points due to both north and south tidal currents has been considered. The dispersion of BOD due to north current at the sea entrance shown in Fig.4 depicts the BOD variation in the range 0-0.48mg/l.

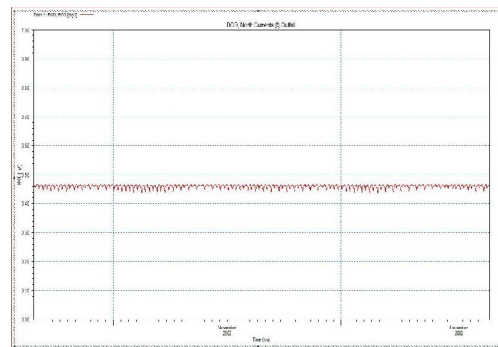


Fig.5 : BOD Simulation due to North Current at the Outfall

Due to north current at the outfall, the BOD concentration varies between 0.44mg/l to 0.465mg/l (Fig.5). The simulation results shows that the concentration of BOD at the outfall is more than that of concentration of BOD at the sea entrance.

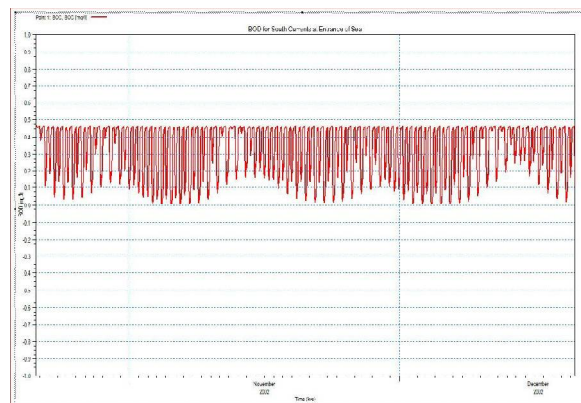


Fig.6 : BOD Simulation due to South Current at the Sea Entrance

The simulation of south current shows the different pattern of BOD dispersion than that of north current. The concentration range of 0 – 0.475mg/l (Fig.6) has been observed due to south tidal current at the sea entrance. But, the concentration has been constant of 0.465mg/l (Fig.7), due to south current at the outfall during two months period of simulation. Comparing the simulations of north and south tidal currents, north currents are having greater impacts on the dispersion perspective of BOD simulation.

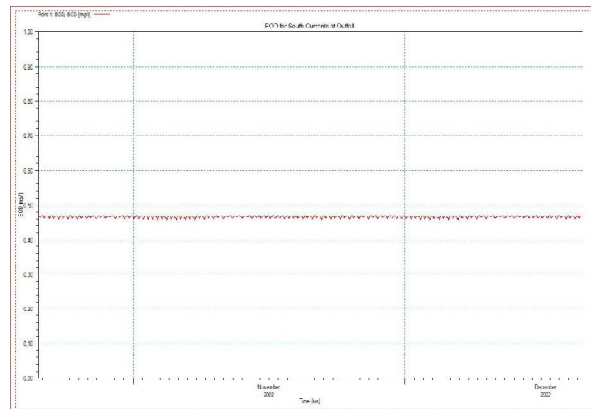


Fig.7 : BOD Simulation due to South Current at the Outfall

a. DO SIMULATION

As indicated earlier, the study area of 168 sqkm is considered for the DO simulation. Due to the natural purification, photosynthesis and other physical factors, the variations of concentration occurs over a period of time. The extraction of dissolved oxygen concentration with time is carried out in the model domain. From the numerical simulation results, it can be noted that there is a significant difference in the DO concentration between north current and south current.

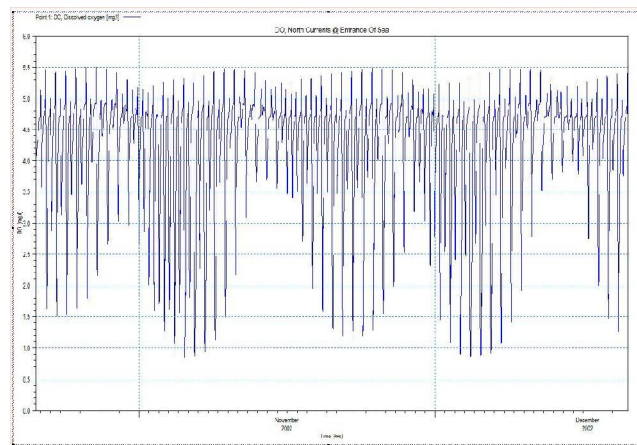


Fig.8 : DO Simulation due to North Current at the Sea Entrance

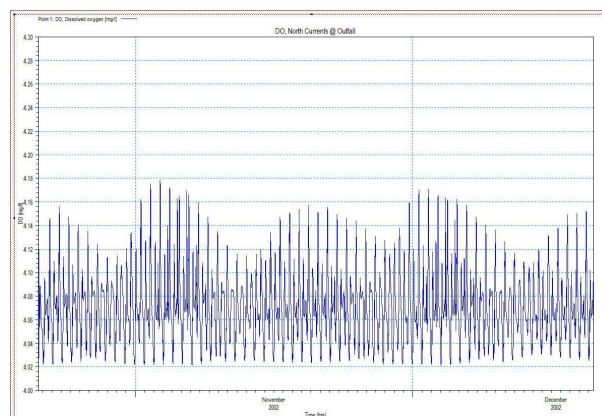


Fig.9 : DO Simulation due to North Current at the Outfall

DO simulation due to north tidal current at the sea entrance are in the range 0.7 – 5.5mg/l (Fig.8) and at the outfall, DO level ranges between 4.02 – 4.18mg/l (Fig.9). The DO concentration variations in north current are very minimum, where as the concentration variation in DO in south current at the sea entrance is varying from 6 mg/l to 16 mg/l (Fig.10). This large DO variation in the south current may be due to thorough mixing by the tidal current. DO level at the outfall varies in the range of 17.5 - 18mg/l (Fig.11).

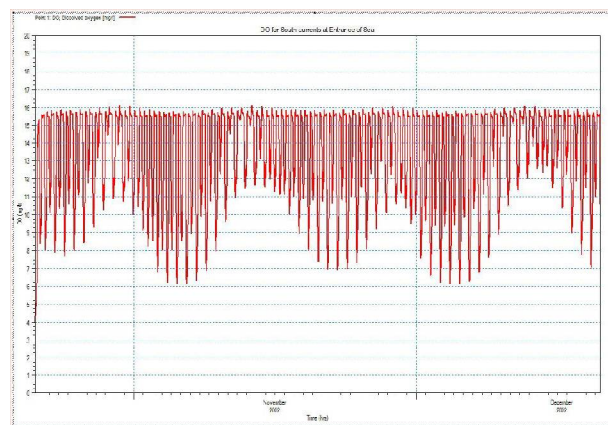


Fig.10 : DO Simulation due to South Current at the Sea Entrance

The simulation results shows that the availability of more DO during south currents and the emission of effluents can be planned during this period, for the sustainable environmental condition.

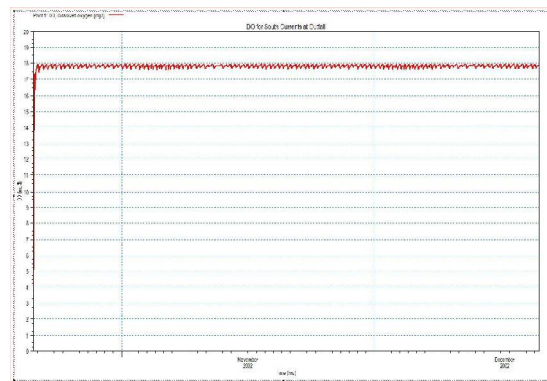


Fig.11 : DO Simulation due to South Current at the Outfall

V. CONCLUSION

Numerical simulations has been carried out at the tidal creek area in Arabian sea to identify the duration of the power plant effluent discharge. Western coastal region in Maharashtra, India is subjected to tidal current variation. In this research paper, the northern and southern tidal currents are taken into consideration and the dispersion variation of the water quality parameters such as BOD and DO has been simulated. The simulations has been carried out with ECOLAB module of MIKE software. Numerical simulation showed that the south currents are suitable for pollutant dispersion, due to more availability of dissolved oxygen. For the sustainable development of the country, this numerical dispersion studies are very important in the decision making process.

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REFERENCES

- [1] Danish Hydraulic Institute (2007), MIKE, "Environmental Hydraulics", User's guide and reference manual.
- [2] Kwak J, Khang B, Kim E, and Kim H, "Estimation of Biochemical Oxygen Demand Based on Dissolved Organic Carbon, UV Absorption, and Fluorescence Measurements", Journal of Chemistry, Vol. 2013, Pg. 1-9.
- [3] Manivanan.R (2008), "Water quality modeling rivers, streams and estuaries", New India publishing agency, New Delhi.
- [4] Mehrdad S, "Thermal Recirculation Modeling for Power Plants in an Estuarine Environment", Journal of Marine Science and Engineering, Vol. 5, Issue 5, 2017.
- [5] Ramachandra T V, Sudarshan P, Bhat, Durga M M and Gautham K, "Impact of Indiscriminate Disposal of Untreated Effluents from Thermal Power Plant on Water Resources", Indian Journal of Environmental Protection, Vol.32, Issue 9, 2012.
- [6] Roman F, Stipcich G, Armenio V, Inghilesi R and Corsini S (2010), "Large eddy simulation of mixing in coastal areas", International Journal of Heat and Fluid Flow, Vol. 31, pp 327-341.
- [7] Sandy M.Y, Wai W H, Li Y S, Li Z L and Jiang Y (2009), "Integration of a GIS and a complex three-dimensional hydrodynamic, sediment and heavy metal transport numerical model", Advances in Engineering Software, 40, pp 391-401.
- [8] Tejashree K S, Utkarsha V K, Manivanan R (2017), "Numerical Model Study of Dispersion of Hot water from Dahanu Thermal Power Station", International Journal of Scientific & Engineering Research, Vol. 8, Issue 3, 2017
- [9] Thinakaran E and V Jothiprakash, "2D Pollutant Transport Analysis of Different Discharges of a River Estuary", Journal of Environmental Research and Development, 7(3), 1237-1245, 2013.
- [10] Thinakaran E and V Jothiprakash, "River Flow Model using Link Node Scheme", Journal of Environmental Research and Development, 7(1), 139-145, 2012.