

Numerical Simulation of Nutrient Dispersion Hot Water from Thermal Power Plant in Mumbai

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ABSTRACT: Two dimensional, MIKE 21 ECO Lab with insignificant stratification is applied for 2D simulations of Dahanu coastal area, tidal creek located at 110Km away from Mumbai in the Konkan Division. Location of Thermal Power plants near the tidal creek and estuary are mainly due to the feasibility of intake and discharge of hot water, which poses serious environmental effect from heated water discharges. The discharge outlet is to be such that the heated water should not recirculate back to the power plant. Current plays the major role in the dispersion of effluent from power plant which is located on the river bank. Nitrate is the important nutrient of the tidal creek, which ensures the healthy estuarine ecosystem. Numerical results for varying wind speed and flow conditions due to tidal currents are depicted in this research paper. The nutrient dispersion results reveals that the Nitrate levels are within the permissible range and the tidal currents plays the important role the plume dispersion.

KEYWORDS: Numerical Simulation, Tidal Current, Nitrate, Coastal Creek

I. INTRODUCTION

Due to rapid growth of urbanization and industrialization, there persist heavy demand for global energy source. These heavy demands are being fulfilled by fossil fuels and natural resources in the world. Coal provides 29.6% of global energy demands. About 42% of world's electricity generation is fulfilled by coal [4]. Large amount of water is required for cooling purposes in thermal power plants. The wind velocity and water hyacinth induces the dispersion of thermal effluents in the water body [8]. 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 [3]. Thermal plant is located on the bay of Dahanu creek which discharges its effluent/hot water in the creek [5]. Thinakaran and Jothiprakash (2012), [7] developed numerical model for river estuary flow. Thinakaran and Jothiprakash (2013), [6] simulated pollutant transport model using MIKE21 for different discharges of a river estuary. The present study aims at analyzing the effect of high pollution loads in Dahanu Creek in Maharashtra, India, by applying 2D-hydrodynamic and pollutant transport model, MIKE21 : ECOLAB. In this paper numerical simulation of dispersion of Nitrate has been carried out to predict the pollutant transport.

II. METHODOLOGY

MIKE21 hydrodynamic module, uses Alternating Direction Implicit (ADI) technique to integrate the equations for mass and momentum conservation in the space-time domain. The equation matrices that result for each direction and each individual grid line are resolved by a Double Sweep (DS) algorithm. The only assumption in these equations is that the fluid should be Newtonian and this is indeed an excellent approximation for water [1].

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:

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

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

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 2D advection-dispersion module solves the advection dispersion equation for the pollutants in the river estuary. The hydrodynamic module solves on u , v (velocities) and h (water depth) at each time step. The solution of the pollutant transport equations (ECOLAB) is closely linked to the solution of the hydrodynamic conditions (MIKE-HD). This numerical 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). The equation for the advection-dispersion module is shown below

$$\frac{\partial}{\partial t} (hc) + \frac{\partial}{\partial x} (uhc) + \frac{\partial}{\partial y} (vhc) = \frac{\partial}{\partial x} \left(hD_x \frac{\partial c}{\partial x} \right) + \frac{\partial}{\partial y} \left(hD_y \frac{\partial c}{\partial y} \right) - F.h.c + S \quad (4)$$

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

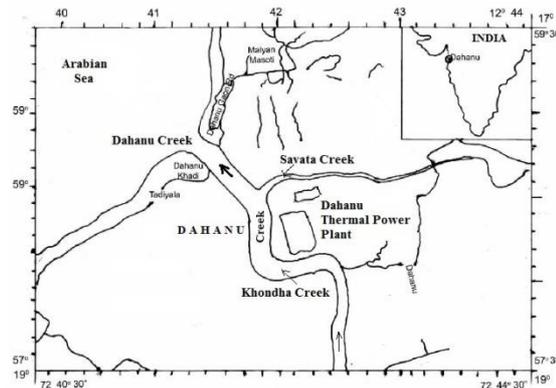


Fig.1: Dahanu Creek – Study Area

Dahanu Creek 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 plant generates about 500MW capacity of the thermal power. 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 [5].

IV. RESULT AND DISCUSSION

Enrichment of nitrate nutrients leads to eutrophication in a water body. Hence, the eutrophication is mainly caused more nitrate levels and the transports of these nutrients are taken into consideration [2]. Extraction points are chosen near the sea entrance in the sea region and at the outfall. Due to the tidal oscillation, the concentration of the nitrate fluctuates in accordance with the time. In the estuary section tides plays an important role in the water flow, the hydrodynamic model has been used for the tidal variation in northern and southern currents. Based on the of the tide calibration, ECO Lab model has been applied to analyze the transport of nutrient, Nitrate 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 for simulation. Total study area covered in this numerical simulation is about 168 sqkm with the prevailing wind speed of 5m/s. Tidal variations around the river estuary has been found to be varying in around 4.47m. The maximum dispersion of the nutrient is observed during the higher tidal level area.

a. NITRATE SIMULATION

One of the main water quality parameter, the nitrate nutrients is simulated using ECO Lab module of MIKE21 model. Particularly, due to the enrichment of nitrates and phosphates, there is an extensive growth of algae, which can deplete oxygen level in the river estuary causing anaerobic bacteria in active state. The presence of nutrients enhances the growth of phytoplankton and benthic algal growth, which deteriorates the quality of water.

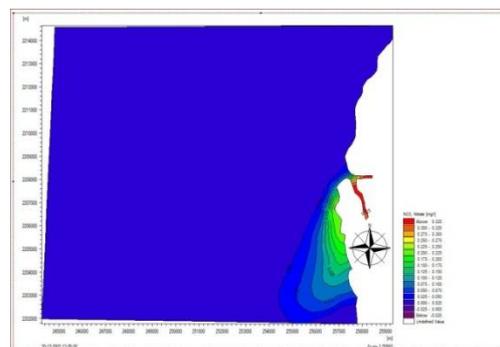


Fig.2 : Nitrate Flow Visualization of Simulated South Current

The dispersion of Nitrate due to south and north currents has been clearly shown in Fig.2 and Fig.3 respectively.

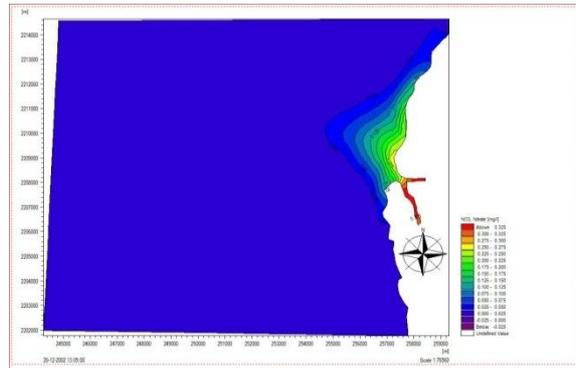


Fig.3 : Nitrate Flow Visualization of Simulated North Current

The results shows that dispersion of Nitrate concentration due to south current in the sea portion varies in the range of 0.325mg/l - 0.025mg/l along the shore length of 6.20km. Due to south current, the dispersion occurs in the south side . The dispersion pattern of north current and south current has been shown in Fig.2 and Fig.3 respectively. The results shows that dispersion of Nitrate concentration due to north current in the sea portion varies in the range of 0.325mg/l - 0.025mg/l along the shore length of 7.40km.

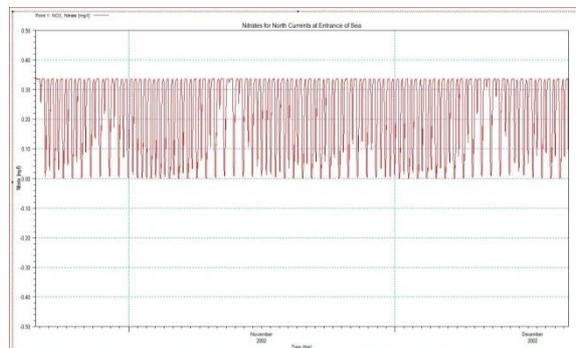


Fig.4 : Nitrate Simulation due to North Current at the Sea Entrance

Two extraction points at the sea entrance and the outfall has been selected to estimate the Nitrate concentration variation at each selected points. For the detailed analysis, the Nitrate variations at the two grid points due to both north and south tidal currents has been considered for simulation. The dispersion of Nitrate due to north current at the sea entrance shown in Fig.4 depicts the Nitrate variation in the range 0-0.34mg/l.

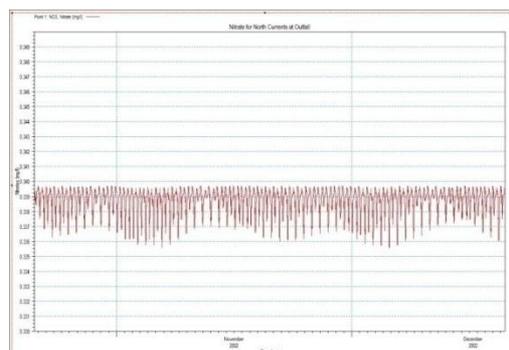


Fig.5 : Nitrate Simulation due to North Current at the Outfall

Due to north current at the outfall, the Nitrate concentration varies between 0.336mg/l to 0.40mg/l (Fig.5). The numerical simulation results shows that the concentration variation of Nitrate at the sea entrance is more than that of concentration variation of Nitrate at the outfall.

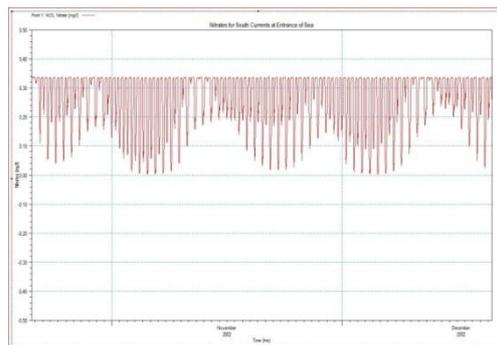


Fig.6 : Nitrate Simulation due to South Current at the Sea Entrance

The concentration range of 0 – 0.34mg/l (Fig.6) has been observed due to south tidal current at the sea entrance. But, the concentration varies between 0.336mg/l to 0.40mg/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 similar impacts on the dispersion of Nitrate simulation.

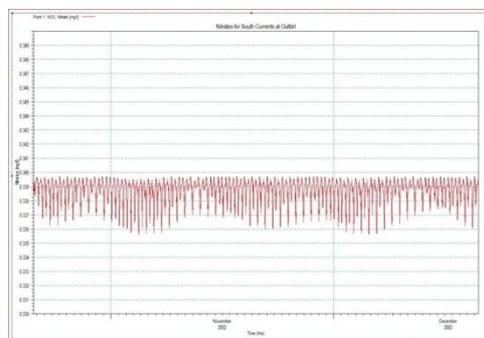


Fig.7 : Nitrate Simulation due to South Current at the Outfall

V. CONCLUSION

Numerical simulations has been carried out at the tidal creek area in Arabian sea to identify the impacts of nutrient load in the power plant effluent discharge. In this research paper, the northern and southern tidal currents are taken into consideration and the dispersion variation of Nitrate has been simulated. The simulations has been carried out with ECOLAB module of MIKE software. Numerical simulation showed that the north and south currents are having identical pollutant dispersion pattern. Also, this Nitrate dispersion are having lesser environmental pollution. This numerical simulation studies of pollutant dispersion are very much useful in fixing the location of outfall.

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