POLLUTANT DISPERSION IN SOME FISHING COAST AREAS OF EAST JAVA INDONESIA

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Abstract: *The existence of pollutant in some coastal areas in Muncar has drawn attention from local government. The indicator of the existence of pollutant was measured as Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), N-ammonia, and Fat and Oils. There are several fishery industries located nearby the coast. Sample were taken from the outlet discharge of several industries in three coastal areas which are located close each other in each cluster. The discharge of waste water from several industries which the samples taken flows to each river in each cluster. This paper reported pollutant dispersion model in three rivers, named Kalimati, Kali Tratas, and Irigasi. Results showed that the rate of dispersion in irigasi river is the fastest compared to two other rivers. It took 2000 seconds for the COD and TSS to disappear at 100 meters length distance, while it took 2000 seconds for N-ammonia and Fat and Oils to disappear at 60 meters length distance from the discharge spot in irigasi river. There is about 24.500 seconds for COD, TSS, N-ammonia and Fat and Oils to disappear at the distance of 200 meters length and 4 meters width from the discharge spot in Kali Tratas. It also took about 24.500 seconds for COD, TSS, N-ammonia and Fat and Oils to disappear at the distance of 200 meters length and 2.4 meters width from the discharge spot in Kalimati.*
Keyword: *pollutant dispersion, muncar, fishery industry, waste water.*

Abstrak: *Keberadaan pantai muncar yang tercemar telah menarik perhatian pemerintah local. Indikator yang dapat menunjukkan adanya pencemaran tersebut ditunjukkan dengan nilai Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), N-ammonia, and Fat and Oils. Ada beberapa industri perikanan yang terletak dekat dengan posisi pantai Muncar, Sampel diambil dari beberapa keluaran pembuangan limbah dari beberapa industri yang letak keluaran pembuangan sangat berdekatan di tiga area pantai . Keluaran limbah dari beberapa industri yang diambil mengalir ke sungai yang ada di masing-masing cluster. Tulisan ini menunjukkan model dispersi polutan di tiga sungai yaitu Kalimati, Kali Tratas dan sungai irigasi. Hasil simulasi menunjukkan laju dispersi di sungai irigasi adalah yang tercepat dibandingkan dengan laju dispersi di dua sungai yang lain. Waktu yang dibutuhkan untuk konsentrasi COD dan TSS mencapai nilai 0 ppm , pada jarak 100 meter ke arah axial dari sumber pembuangan di sungai irigasi adalah 2000 detik. Dibutuhkan waktu yang sama untuk kandungan N-ammonia , minyak dan lemak yang ada di sungai irigasi mencapai nilai 0 ppm,pada jarak 60 meter dari sumber pembuangan di sungai irigasi. Dibutuhkan 24500 detik untuk membuat konsentrasi COD,TSS, N-ammonia, minyak dan lemak mencapai 0 ppm di Kali Tratas pada jarak 200 meter panjang sungai dan 4 meter lebar sungai dari sumber pembuangan. Sedangkan, untuk Kalimati, dibutuhkan waktu 24500 detik untuk konsentrasi COD, TSS, N-ammonia, minyak dan lemak untuk mencapai 0 ppm, pada jarak 200 meter panjang sungai dan 2.4 meter lebar sungai dari sumber pembuangan limbah.*
Kata kunci: *dsipersi polutan, muncar, industri perikanan, air limbah industri.*

INTRODUCTION

There are several coast areas in Banyuwangi that have been identified as famous fishery industries in East Java, Indonesia. There are around 130.000 inhabitants in the area. There are many fish processing industries which were located in several villages along the coast that connected to Bali Strait. The coast area is called Muncar. It was noted that those are around 70 big fishery industries and hundred home fishery industries. The activity of those big industries are fish flour processing, cold storage, fish oil and fish cannery. The small industries produce fish fermented paste and smoke fish. Having said that, fish industries in Muncar were the main contributor for economic growth and the development of the city. It has also identified that some industries produced waste water which are not yet properly treated, hence the pollutant is discharge to the water stream in Muncar coastal areas. There are three coastal areas which were visited to take the sample and data from the coast in the areas. We took sample from discharge spots of several industries in each cluster which is located close each other. The waste water discharged form the big industries is around 15.000 m^3 daily. It hasn't been counted for waste water from home fish industries. The river which was visited are Kalimati, Irigasi, and Kali Tratas. The dimension in width and depth of Kali Tratas, Kalimati, Irigas rivers are 20 m x 1 m; 12 m x 1 m; 1.5 m x 0.8 m consecutively. The samples taken from several industries which are closed to the three rivers. The flow rate of the waste water discharged to the Kalimati river is 5200 m^3/day, to the Tratas river is 500 m^3/day and to the Irigasi river is 3560 m^3/day, there is about 5740 m^3/day of waste water discharged to the sea which was not taken for the observation.

THEORY

The Dispersion Process

The two dimensional model (Figure 1) is used because we need to predict the mixing relatively close to the source which is concentrated at one bank, and to predict the depth-average concentration anywhere in the cross section. The two dimension model, depth-average equation is :

$$h\frac{\partial C}{\partial t} + \frac{\partial}{\partial x}(huC) + \frac{\partial}{\partial y}(h\,w\,C) = \frac{\partial}{\partial x}\left(h\varepsilon_x \frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(h\,\varepsilon_y\,\frac{\partial C}{\partial y}\right) \qquad (1)$$

$\varepsilon y = 0.23\ u * h$;

u= linear (longitudinal) velocity of the river stream (LT^{-1}); h = depth of the river (L); ε= empirical mixing coefficient ($L^2\,T^{-1}$); w = transverse velocity (LT^{-1})

$\varepsilon x = 5.93\ u * h$
$\beta\ = (\varepsilon x.\Delta t)/(\Delta x)^2$ has to be less than 0.5
$\Upsilon = (\varepsilon y.\Delta t)/(\Delta y)^2$, Υ has to be less than 0.5

$\Delta y\ = L/n_y$, L = width of the river
β, Υ = non-uniform velocity distribution coefficient
Δx = distance between two computational points in x-direction
Δy = distance between two computational points in y-direction

The source of the waste water is modeled as a tracer which is injected instantaneously, then the dispersion equation is assumed to be of the form :

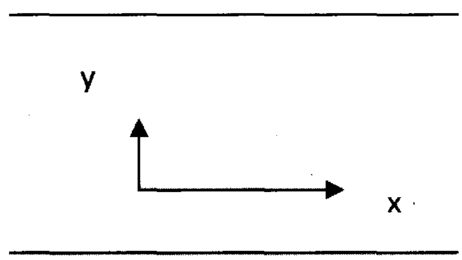

Figure 1. Two dimensional model

$+\Delta t$ = time between two computational intervals
n_y = number of increment in y-direction

$$\frac{\partial}{\partial t}(AC_a) + \frac{\partial}{\partial x}(AUC_a) = \frac{\partial}{\partial x}\left(AK_x\frac{\partial C_a}{\partial x}\right) \qquad (2)$$

K_x= longitudinal mixing coefficient = 12.5 h.u (L^2T^{-1})
C_a = cross sectional average concentration(ML^{-3})
U=cross sectional average velocity (LT^{-1})
A = flow area (L^2)

The Convection Process

The convection which is expressed for the flow area A and for steady flow is

$$\frac{\partial ACa}{\partial t} + \frac{\partial (AUCa)}{\partial x} = 0 \qquad (3)$$

Some finite difference approximations to equation (3) represent a different equation ,

$$\frac{\partial Ca}{\partial t} + U\frac{\partial Ca}{\partial x} = K_n\frac{\partial^2 Ca}{\partial x^2} \qquad (4)$$

$\alpha = 0.25\ \Delta x$
Kn < Kx

$$Kn = \frac{\alpha(\Delta x - \alpha)}{2\Delta t}$$

α = factor if $\Delta x \neq U\,\Delta t$
Kn = artificial diffusion coefficient (L^2T^{-1})
Kx = longitudinal dipersion coefficient (L^2T^{-1})
(M = mass, L= length, T= time)

A two dimensional model based on equation (1) could be developed by writing a finite difference algorithm to solve for convection and diffusionin the longitudinal (x) and transverse diffusion (y direction). By assuming the steady river flow conditions, the transverse velocity w is small compared to the longitudinal velocity u. The river is divided into a series of adjacent stream tubes, in each the discharge is constant, steady river flow condition is used as assumption. An algorithm was developed which stimulates two dimensional mixing as the simultaneous occurrence of three mechanisms, 1) longitudinal convection in each stream tube, 2) longitudinal diffusion in each stream tube, 3) transverse diffusion between adjacent stream tubes (2), since the quasi-two-dimensional model recognizes only an average concentration in each stream tube. The resulting expression is :

$$A\frac{\partial C}{\partial t}+\frac{\partial}{\partial x}(AuC)=\frac{\partial}{\partial x}\left(A\varepsilon_x\frac{\partial C}{\partial x}\right)-(h\varepsilon_y\frac{\partial C}{\partial y})_l+(h\varepsilon_y\frac{\partial C}{\partial y})_r \quad (5)$$

the finite difference solution in equation (5) is done by dividing the river into a series of computational reaches separated by computational points.

Longitudinal Convection

It is calculated in each stream tube from its upstream limit to its downstream limit. For pure convection, the equation is written :

$$A\frac{\partial C}{\partial t}+\frac{\partial (AuC)}{\partial x}=0 \quad (6)$$

The velocity in each one is different, Δt and Δx will be the same for all tubes

Longitudinal Diffusion

This diffusion proceeds in each stream tube from upstream to downstream boundary. The equation is :

$$A\frac{\partial C}{\partial t}=\frac{\partial}{\partial x}(A\,\mathcal{E}_x\frac{\partial C}{\partial x}) \quad (7)$$

Transverse Diffusion

This diffusion occurred between stream tubes and along their entire length is calculated using :

$$A\frac{\partial C}{\partial t}=-(h\varepsilon_y\frac{\partial C}{\partial y})_l+(h\,\varepsilon_y\frac{\partial C}{\partial y})_r \quad (8)$$

Based on equation (1), which describes tracer mass conservation at a point, must be integrated over the width of a stream tube, since the quasi two dimensional model which is proposed recognizes only an average concentration in each stream tube.

The resulting expression is the following :

$$A\frac{\partial C}{\partial t}+\frac{\partial}{\partial x}(AuC)=\frac{\partial}{\partial x}\left(A\varepsilon_x\frac{\partial C}{\partial x}\right)-(h\varepsilon_y\frac{\partial C}{\partial y})_l+(h\,\varepsilon_y\frac{\partial C}{\partial y})_r \quad (9)$$

MATERIALS AND METHODS

Samples were taken from the sampling points at the end of pipeline for waste water effluent discharged from several industries which flow to Kalimati, Tratas and Irrigasi rivers. The samples were mixed for each river and analysed for Chemical Oxygen Demand (COD) , TSS (Total Suspended Solid), N-ammonia, Fat and Grease. All samples were preserved prior laboratory analysis. COD was measured using closed reflux, colorimetric method, TSS was measured by dry weight method. N-ammonia was measured by titrimetric method (1), whereas Fat and Grease was measured using soxhlet extraction method (1). The dispersion of pollutant is simulated using two-dimensional dispersion modeling using MATLAB. The two dimensional dispersion consider three mechanisms : 1) longitudinal convection; 2) longitudinal diffusion; 3) transverse diffusion. We used three mechanisms for pollutant dispersion in Kalimati and Kali Tratas, whereas we used two mechanisms (longitudinal convection and longitudinal diffusion) for irigasi river.

RESULTS AND DISCUSSION

The characteristics and flow rate of waste water to each river is shown in Table 1.

There was a two dimensional model used to solve a problem of natural mixing in rivers by Czernuszenko (3) without using real pollutant data from the field. Recently, an ecological models were also developed to solve the complexity of the real ecosystem using three-dimesional model since several of the biological models have now been linked to three-dimensional hydrodynamic models (4). Our two-dimensional model was used to get the profile of each pollutant which we consider as major contributor of river pollution on site. Some data taken from samples laboratory analysis were used to make a dispersion pollutants model in each river.

Table 1. Characteristics of waste water discharged

	Kali Tratas	Kalimati	Irigasi
Initial COD,ppm	4320	8420	1200
Initial TSS,ppm	620	12430	595
Initial N-ammonia,ppm	60	3564	67
Initial Fat and Grease,ppm	952	41094	225
Flowrate of river, m^3/second	0.398	0.11	0.1

If we look at the Figure 2, the dispersion rate of COD in Kalimati (at the position of 4.8 m width) is slower compared to the distribution rate of COD in Kali Tratas (at the position of 4 m) for 34.500 seconds. It is due to the linear velocity in Kali Tratas is higher than that in Kalimati rivers. Figure 3 and Figure 4 showed the dispersion rate of COD, at different period were same both in Kalimati and Kali Tratas, which can be seen from the overlapping curve for concentration vs time profile. The same profiles occurred for TSS, N-ammonia, Fat and Oils both in Kalimati and Kali Tratas. Hence, the diffusivity for COD, TSS, N-ammonia Fat and oils in Kali Tratas were same, as well as that for Kalimati. Since the width of the irigasi river is not as wide kalimati and kali Tratas, the dipersion rate was simulated as a function of time and length of the river. At 2000 seconds, dispersion rate of COD, N-ammonia, TSS, Fat and Oils in Irigasi river were different for each pollutant with the highest dispersion rate was the COD dispersion rate and the lowest was Fat and Oils dispersion rate which can be seen in Figure 5.

At 2000 seconds and 80 meters from the outlet discharge in Irigasi river, the COD concentration has been reduced 94 %, which was from 334 ppm to 19.94 ppm. The TSS concentration has been reduced 94 % from 166 ppm to 9.89 ppm. The N-ammonia concentration has been reduced 94 % from 19 ppm to 1.11 ppm, whereas the concentration of Fat and Oils has been reduced 94 % from 63 ppm to 3.74 ppm

There is about 24.500 seconds for N-ammonia to disappear at the distance of 200 meters length and various position width from the discharge spot in Kali Tratas. It also took about 24.500 seconds N-ammonia to disappear at the distance of 200 meters length and various position width from the discharge spot in Kalimati,

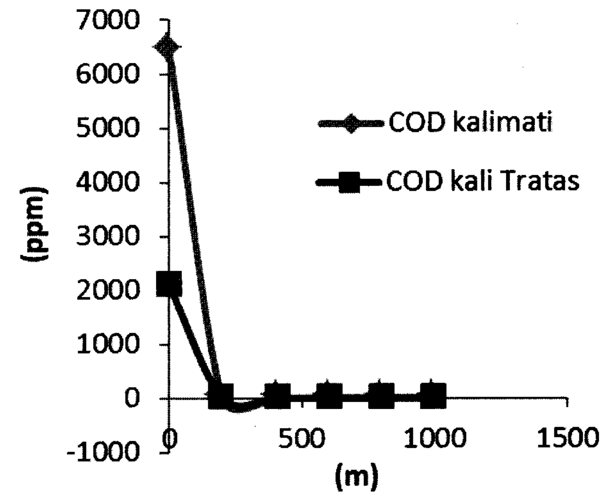

Figure 2. Concentration of COD (ppm) at 4.8 m width of Kalimati and 4 m width ofkali Tratas vs length of river (m) at 34.500 seconds

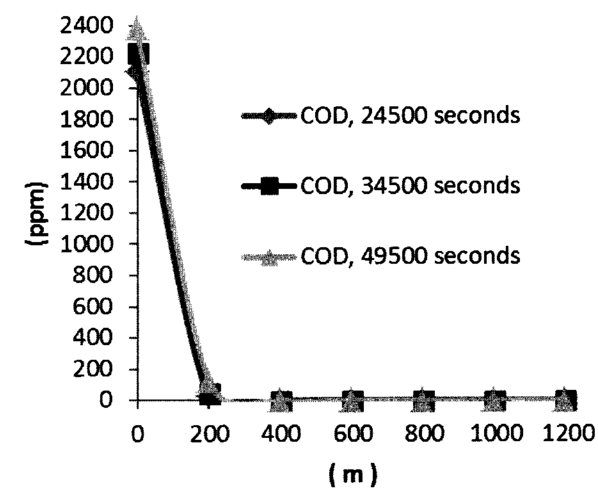

Figure 3. The COD concentration profiles vs length of river (m) in Kali Tratas

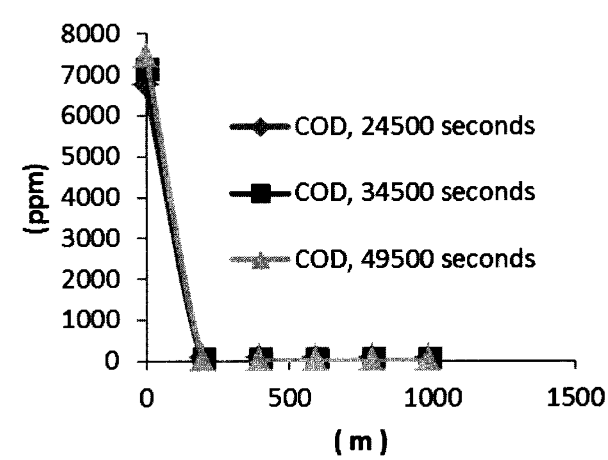

Figure 4. The COD concentration profiles vs length of river (m) in Kalimati

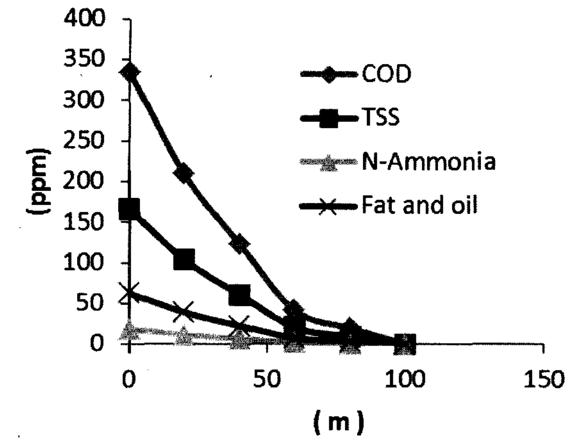

Figure 5. Concentration of pollutants vs length of river (m) at 2000 seconds in Irigasi river

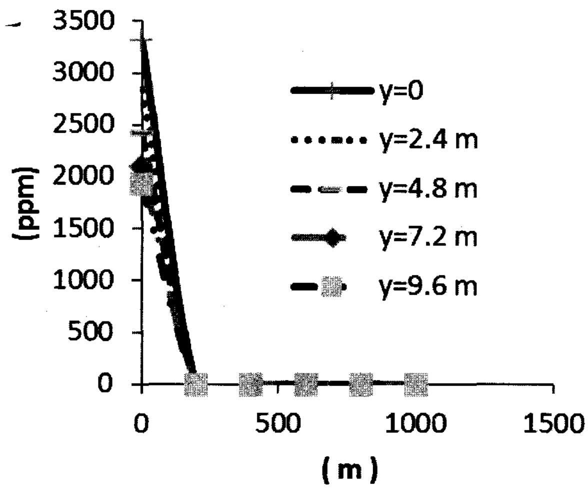

Figure 6. Concentration of N-ammonia profile vs length of river at various width of Kali Tratas river (y)

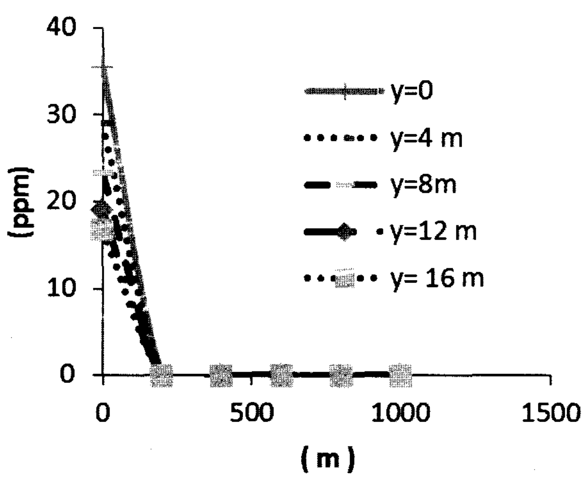

Figure 7. Concentration of N-ammonia profile vs length of river at various width of Kalimati river (y)

CONCLUSIONS

The pollutant dispersion model showed that the high concentration of COD, TSS, N-ammonia, Fat and Oils will be reduced to lower concentration due to the dilution of river water which has a certain linear velocity. The dispersion model has been simulated using transverse diffusion and longitudinal convection and longitudinal diffusion model for both Kalimati and Kali Tratas . The dispersion model has been simulated using longitudinal convection and longitudinal diffusion model for irigasi river. The dispersion rate of COD, TSS, N-ammonia, Fat and Oils at different period time were same both in Kalimati and Kali Tratas. The dispersion rate of COD, N-ammonia, TSS, Fat and Oils in I rigasi river were different for each pollutant with the highest dispersion rate was the COD dispersion rate and the lowest was the dispersion rate of Fat and Oils.

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