Measuring a level of water pollution in sungai pinang using a mathematical model

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Abstract. Mathematical models are now a popular tool in many applications such as physics, economics and engineering; and provide useful information for decision making and planning. Water pollution in Malaysia has reached a level that needs attention and intervention from environmental department and government. In order to make a strong case, this paper has done a study on measuring the pollution level of Sungai Pinang which is located in Penang Island, Malaysia. Advection-Dispersion equation is one of the mathematical models that often use in evaluating the level of water pollution in the river. This paper applies this model and compares the result of this study with the studies done in the previous research worldwide to evaluate the severity of the pollution. The authors hope that this paper will create awareness to relevant department and also to community in general.

Key words: Mathematical Model, Water Pollution.

Introduction

Water pollution is a serious problem in Malaysia and impacts negatively on the sustainability of water resources. It reduces total water availability considerably as the cost of treating polluted waters is too high and in some instances, polluted waters are not treatable for consumption. Water pollution is defined as any direct or indirect changes to the physical properties, thermal, biological, or radioactive which any part of the environment of the release, remove, or put this waste to the detriment of its use and cause a dangerous situation that endangered the health, safety and welfare of the public, or other life such as birds, wildlife, fish and aquatic life and water plants (Environmental Quality Act 1974 Malaysia). Water pollution can occur anywhere as long as there is water especially in the rivers and the oceans. Mathematical models have been developed by many researchers and they effectively describe, understand and evaluate systems. It is widely used in the natural sciences, engineering and social sciences. This paper is focusing on applying a mathematical model in measuring a level of water pollution in a Malaysia's river specifically in Sungai Pinang.

Mathematical Model

We modeled the flow in the river as being one-dimensional, let $x(m)$ be the distance of the river and $t(days)$ be the time variation. By using the Mass Balance Law, we get the equation for one-dimensional advection-dispersion equation expressed as (Saberi 2008, Ataie-Ashtiani 1996)

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x} - \lambda C \qquad (1)$$

where $C(x,t)(kg/m^3)$ is a concentration of a chemical or biological within the river, $D(m^2/day)$ is the dispersion coefficient of concentration in the x direction, $v(m/day)$ is the water velocity in the x direction, and λ (*per day*) is the reaction rate coefficient. Assuming that v has a constant velocity and the average velocity is expressed as $\bar{v} = \frac{V}{\omega}$ (Saberi 2008, Ataie-Ashtiani 1996).

The initial and boundary conditions are:

$$C(x,0) = 0 \text{ for } x \geq 0 \quad (2)$$

$$C(0,t) = C_0 \text{ for } t \geq 0$$

$$C(\infty,t) = 0 \text{ for } t \geq 0 \quad (3)$$

Statictical Data

Sungai Pinang is a meandering river on the southern side of George Town, Penang. The length of the river is 3.2 km and the area of the water river basin is 50.97 kilometer per square (km^2). For many years, Sungai Pinang was regarded as the filthiest river in Malaysia. At one time it held the dubious Class 5 category, which means it is a dead river unable to sustain any life form (DID 2000). Since 2008, state government has started rehabilitant the river in order to improve it from highly polluted to lightly pollute.

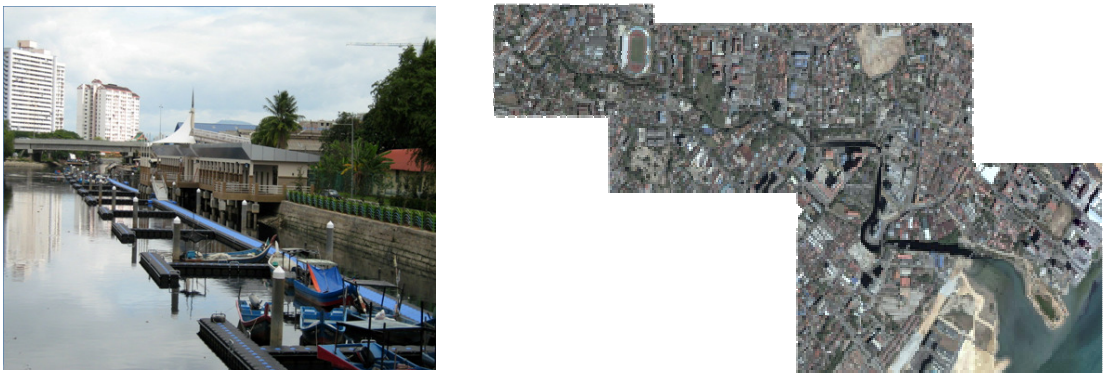

Figure 1. The Picture and The Map of Sungai Pinang (Source from Water Quality Monitoring System)

Table 1. Data Collections from Water Quality Monitoring System

Day / Time	Temperature (Celcius)	pH (Unit)	NH3 (mg/l)	DO (mg/l)	DO (%)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)
1/1/2012 11:30	29.00	6.64	1.59	2.99	37.30	2.79	9.83	17.16
1/1/2012 17:30	29.40	6.65	1.75	3.46	43.20	2.07	9.28	16.41
1/1/2012 23:30	28.80	6.69	1.14	3.57	44.60	2.33	9.54	17.52
2/1/2012 11:30	28.50	6.68	1.65	3.24	40.50	2.97	9.74	16.11
2/1/2012 17:30	28.70	6.67	1.82	3.23	40.30	2.30	11.75	16.26
2/1/2012 23:30	28.70	6.69	1.84	2.92	36.50	3.60	10.51	16.59
3/1/2012 11:30	28.60	6.61	1.38	3.25	40.60	2.46	8.81	15.00
3/1/2012 17:30	29.20	6.66	1.18	3.27	40.80	3.07	8.02	15.12
3/1/2012 23:30	29.20	6.70	1.65	3.24	40.50	3.91	10.51	17.10
4/1/2012 11:30	28.80	6.76	1.21	3.46	43.20	3.40	9.05	18.00
4/1/2012 17:30	28.60	6.67	1.05	3.03	37.80	3.74	10.01	19.77
4/1/2012 23:30	29.30	6.71	1.82	3.39	42.30	2.38	10.90	16.41
5/1/2012 11:30	28.90	6.75	1.29	3.39	42.30	2.81	10.77	19.23
5/1/2012 17:30	29.10	6.67	1.18	3.25	40.60	2.46	8.26	16.32
5/1/2012 23:30	28.90	6.66	1.86	3.46	43.20	3.02	10.64	15.54

NH3 = Ammoniacal Nitrogen
DO = Dissolved Oxygen
BOD = Biochemical Oxygen Demand
COD = Chemical Oxygen Demand
TSS = Total Suspended Solid
***Source** from Water Quality Monitoring System*

Malaysia government has installed Water Quality Monitoring System (WQMS) at Sungai Pinang to monitor the effectiveness of rehabilitant a highly polluted river. The data has been collected based on the main parameters of Water Quality Index.

We used the data from WQMS to measure a level of water pollution using advection-dispersion equation.

Numerical Illustrations

The one-dimensional advection-dispersion equation is solved by using implicit finite-difference equation with initial and boundary conditions as in (2) and (3).

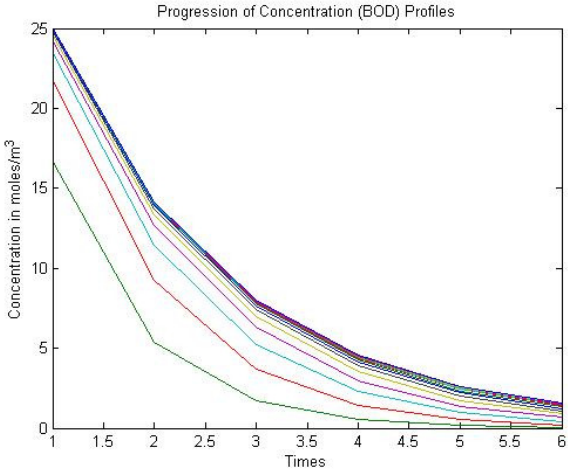

Figure 2. Biochemical Oxygen Demand of Sungai Pinang

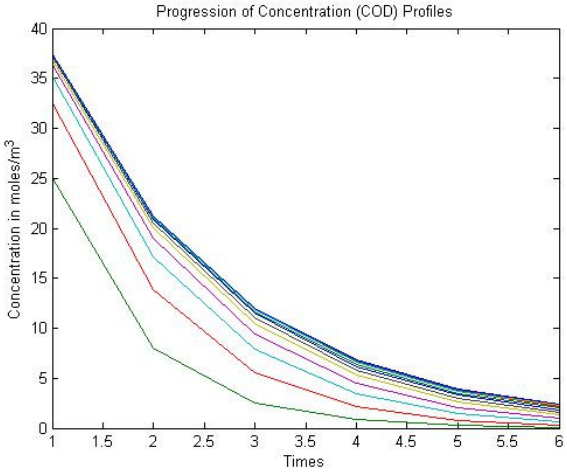

Figure 3. Chemical Oxygen Demand of Sungai Pinang

The BOD test measures the oxygen demand of biodegradable pollutants whereas the COD test measures the oxygen demand of biodegradable pollutants plus the oxygen demand of non-biodegradable oxidisable pollutants (Greenberg 1995). The same model have been applied to Sangam River, India to make a comparison between two rivers from different countries.

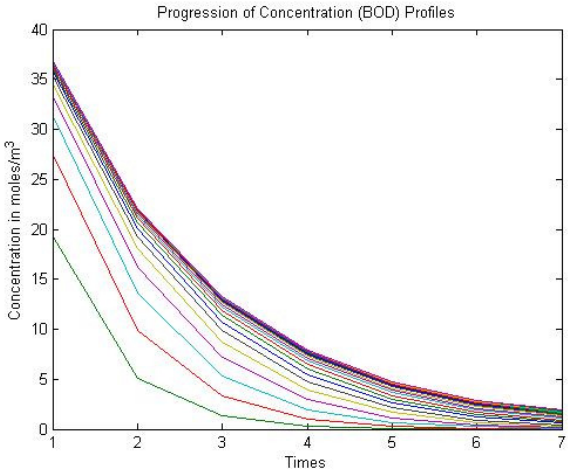

Figure 4. Biochemical Oxygen Demand of Sangam River

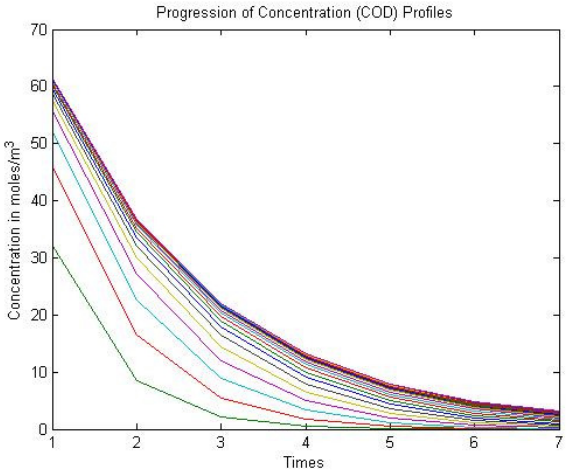

Figure 5. Chemical Oxygen Demand of Sangam River

Based from the figures above, the progression of concentration between Sungai Pinang and Sangam River doesn't have much difference in trend. Sungai Pinang contains less concentration of COD and BOD compare to Sangam River. Since the velocity of river flow is different between Sungai Pinang and Sangam River, the progression of the concentrations is also different since the dispersion coefficient is affected. If the river is polluted, the velocity of river flow will decrease and this will affected the dispersion coefficient. Hence, the longer times it takes for the progression of concentration, the level of water pollution is high. Thus, Sungai Pinang can be regarded as a lightly polluted river since the progression of concentration doesn't take too long or too short time period.

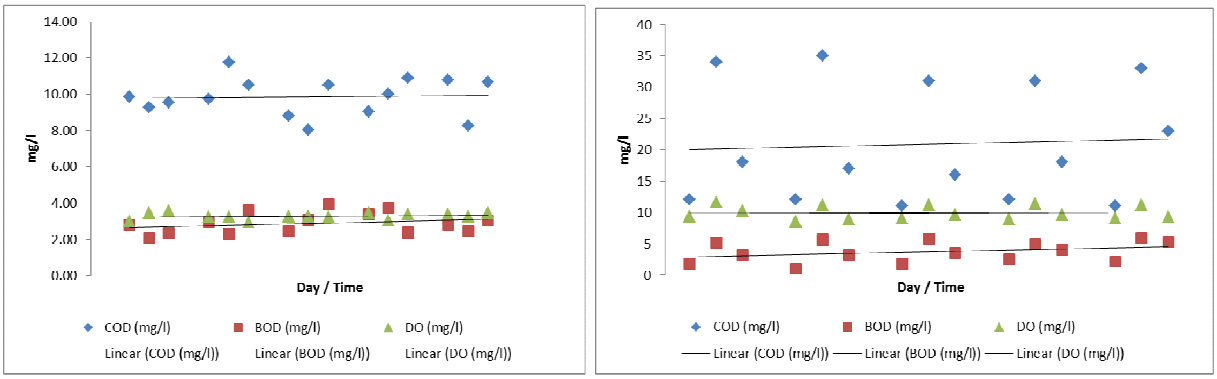

Figure 6. Linear Regression for Sungai Pinang 2012 (left) and Sangam River 2007 (right)

From Figure 6, both of the rivers show a slightly increasing on dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). The level of water pollution will remain the same but it might be increasing if people or society nearby the river didn't stop their activities that can increase the concentration of BOD and COD such as domestic waste and industrial waste.

Conclusions

The study shows that the Advection - Dispersion equation is one of the mathematical models that can be used to measure a level of water pollution in Sungai Pinang. The result show that even though there are many mathematical models that can be used to measure and solve the river pollution, we have to change our attitude by reminding ourselves and the community that preventing is better than cure. No matter how much the government spent to rehabilitant the river, it will be a waste of effort if the attitude of the society is still in third class mentality.

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