CEE 6314 Project

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Abstract

The members of this group focused on the discharge and leakage of medical wastewater, starting from Shenzhen University General Hospital and ending at the Dasha River estuary, and studied the changes of medical wastewater leaking from Shenzhen University General Hospital with time and distance during the entire flow process. The whole process is divided into 6 sections, and the storage space is considered. The result uses BOD as an indicator to evaluate the impact on the Dasha River fishery after it is discharged into the Dasha River.

1. Introduction

1.1 Environmental Significance

Various facilities in hospitals need to use a large amount of water, and during the use process, corresponding wastewater will be generated according to the services provided by the facilities. Medical wastewater contains a variety of emerging contaminants such as personal care products, endocrine disrupting compounds, and hormones. Once these pollutants enter the natural environment like water and soil, they can threaten human health and aquatic life.[1] Because drugs exist in the environment due to their persistence and stability, they may have toxic effects on human health and organisms in the environment. [2] Researchers indicate that the toxicity of medical wastewater is 5-15 times than that of domestic wastewater.[3] So, it has high risk to water quality, aquatic ecosystems and human health if medical wastewater is discharged into the aquatic environment, especially for those contain endocrine disrupting compounds.[4] Besides, as we know, the microorganisms from the medical wastewater may cause serious diseases. Furthermore, the medical contaminants have the possibility to inhibit the biological activity of water treatment plants as well as concentrating in the food chains.[5]

Therefore, with this in mind, our group assumed that the Shenzhen University General Hospital had a leakage of medical wastewater during the discharge process, which leads the wastewater to flow into the Dasha River. In order to evaluate the concentration and change process of medical drugs in the Dasha River, we construct a close system and assume that the leakage was continuous.

1.2 System Background

Dasha River is the mother river in Nanshan District, Shenzhen, and its water replenishment can play a key role in the degradation and transformation of pollutants in the waters of Nanshan District. During its ecological degradation, people still need to pay attention to the issue of pollutant discharge indicators in the Dasha River waters, so as not to damage its original water environment

The precipitation in Shenzhen is mainly concentrated from April to September. Our team selected the precipitation and flow rate data in July. July is in the flood season, and the river water level rises and falls sharply. Based on this condition, our group constructed a model which is starting from the General Hospital of Shenzhen University and ending at the Dasha River estuary, which is shown in **Figure 1.** The purpose is to study the changes of concentration and concentration profile of pollutants in medical wastewater during this process. We use the long-term monitoring data of the water environment and water ecology of the Dasha River Basin and use MATLAB to model the target area. Then, we analyze the water environment of the Dasha River Basin, and obtain a univariate linear regression model with biochemical oxygen BOD as the evaluation index. Each model can well simulate and calculate the quantitative impact of ecological water replenishment on various water environment and water ecological indicators. Model results show that BOD decreases with increasing flow and velocity, indicating that flowing water can improve the water quality and water ecology of the Dasha River. At the same time, it is also a powerful measure of environmental quality.

Figure 1. General map of target area.

According to the data from the National Basic Meteorological Station in Shenzhen, we get the date of precipitation and temperature in July in Shenzhen. The average temperature is 27 degrees Celsius and the total precipitation is 46.08 mm.[6]

We obtained the hydrological information of the target river by consulting the literature and divided it into six parts, L1, L2, L3, L4, L5 and L6, according to its velocity and width. After dividing, we estimated the length of each segment through Baidu Map. The information of each reach is shown in **Table 1.**

Table 1. The information of each reach.

	Length (km)	Width (m)	Velocity (m/s)	Depth (m)
L1	1.9	8	0.4	0.15
L2	1.2	24	0.03	0.8
L3	1.4	10	0.47	0.15
L4	0.8	12	0.23	0.39
L5	3.2	24	0.32	0.22
L6	2.5	45	0.07	0.64

Noting that there is a storage zone in L3, it is 930-980m away from the starting point of L3. The length of the storage zone is 50m.

2. Model Computation and Analyses

The medical wastewater pollutant parameter index is shown in the following **Table 2.**

Table 2. Major pollutants in water.[7]

COD (mg/L)	200-500
BOD (mg/L)	100-200
Suspended Matter (mg/L)	40-120
Total E. coli count (unit/L)	$1*10^6$-$3*10^8$

The diagram of total BOD concentration changes with x and t is shown in **Figure 2.** We assume the original BOD from the leakage of the hospital is 200 mg/L. We can see the final concentration of BOD at the target destination is 130.135mg/L.

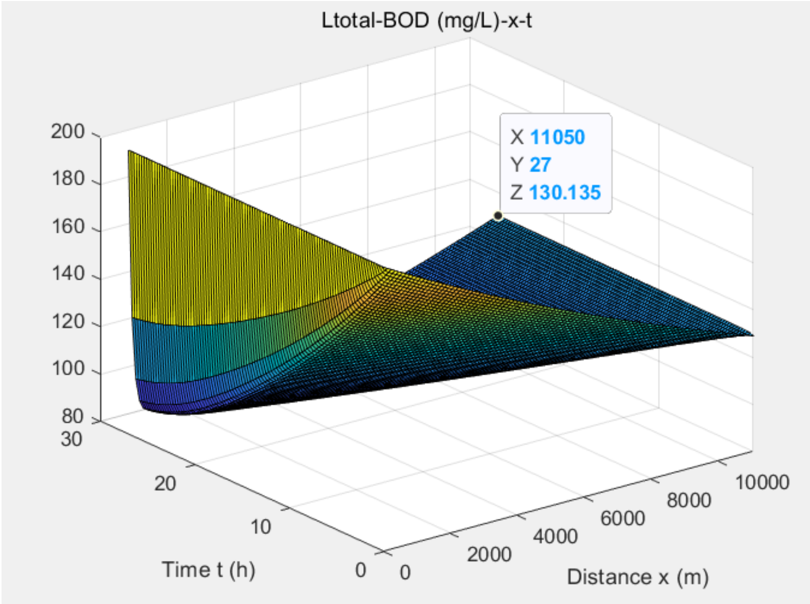

Figure 2. Total BOD (mg/L)-x-t.

2.1 Formula

To calculate BOD, we used the following formula (1) and (2). For the storage space of the third channel, we replaced (K1+K3) by equation (2):

$$A\frac{\partial C}{\partial t} + Q\frac{\partial C}{\partial X} = EA\frac{\partial^2 C}{\partial X^2} + (K1 + K3)AC + AL_a \tag{1}$$

Where X = the horizontal distance along the channel; t= time; A = the cross-sectional area; Q = the flow discharge; v = the mean flow velocity; E is the longitudinal dispersion coefficient, S, accounts for the losses and gains of the system, C is the BOD concentration, L_a = the rate of addition of BOD along the reach.

$$K_{eff} = K\{1 + \left[\frac{\frac{a_s}{K}\left(\frac{A_s}{A}\right)}{\frac{a_s}{K_{sz}} + \left(\frac{A_s}{A}\right)}\right]\} \tag{2}$$

Where As = storage zone cross-sectional area, A = main channel cross-sectional area, Ksz = storage zone first-order decay coefficient (10(K1+K3)), K= instream first-order decay coefficient (K1+K3), a_s=storage zone exchange coefficient.

$$U^* = (gHS)^{0.5} \tag{3}$$

Where U*= shear velocity; S= slope of the river[8]; g= 9.81m/s^2.

$$E\left(\frac{m^2}{s}\right) = 0.011\frac{u^2B^2}{U*H} \tag{4}$$

Where u = velocity; B = width of each reach; H = depth of each reach.

2.2 Calculation of Each Reach

We assume the original BOD concentration is 2mg/L, BOD carbonaceous reaction rate: K1 = 0.1 day-1 = 0.0042 h-1[9], and the rate coefficient for the removal of BOD by sedimentation and adsorption: K3 =0.3 day-1 = 0.0125 h-1[10]

The following **Table 3.** shows the parameter calculation result.

Table 3. Calculation results of parameter

	A (m^2)	**Q(m^3/h)**	**E(m^2/h)**
L1	1.2	1728	40687.7
L2	19.2	2073.6	167.2361
L3	1.5	2538	87772.58
L4	4.68	3875.04	7219.736
L5	5.28	6082.56	131943.6
L6	28.8	7257.6	4473.539

2.2.1 L1

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 3.**

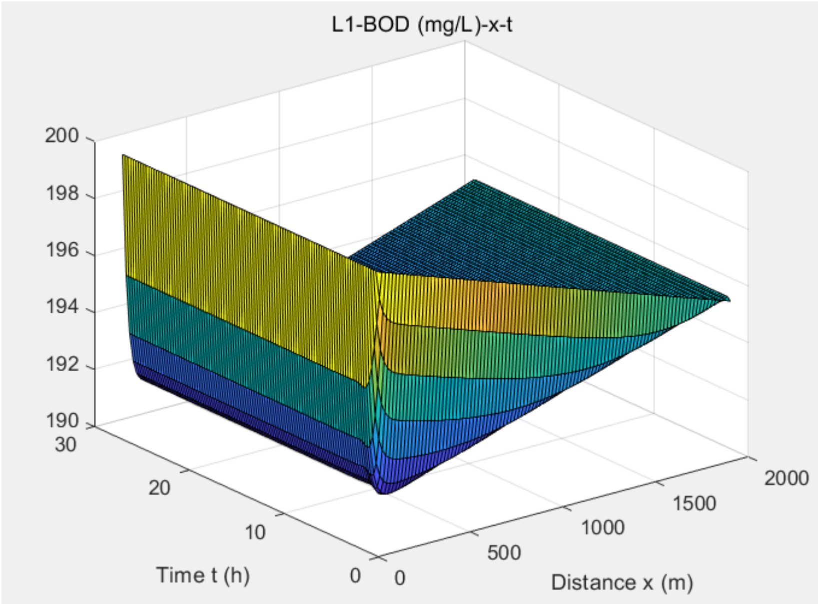

Figure 3. L1-BOD (mg/L)-x-t.

2.2.2 L2

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 4.**

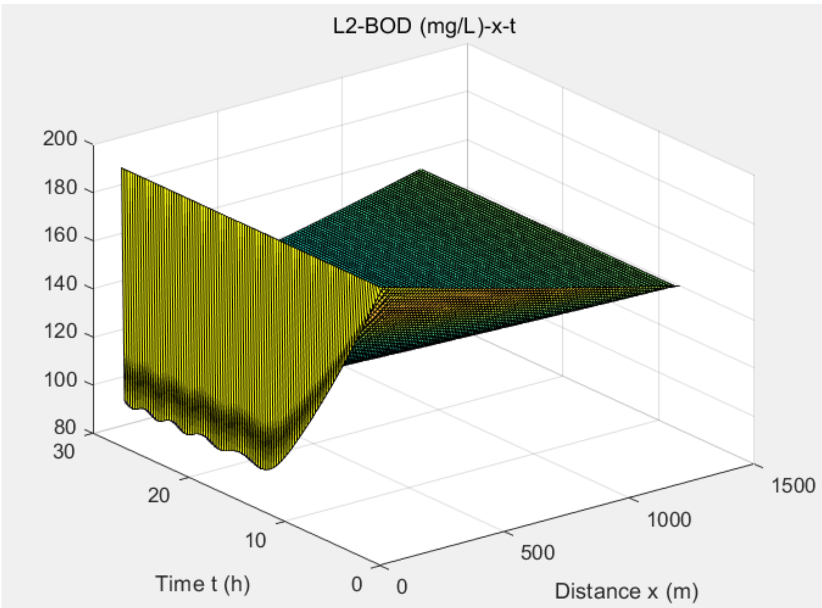

Figure 4. L2-BOD (mg/L)-x-t.

2.2.3 L3

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 5.**

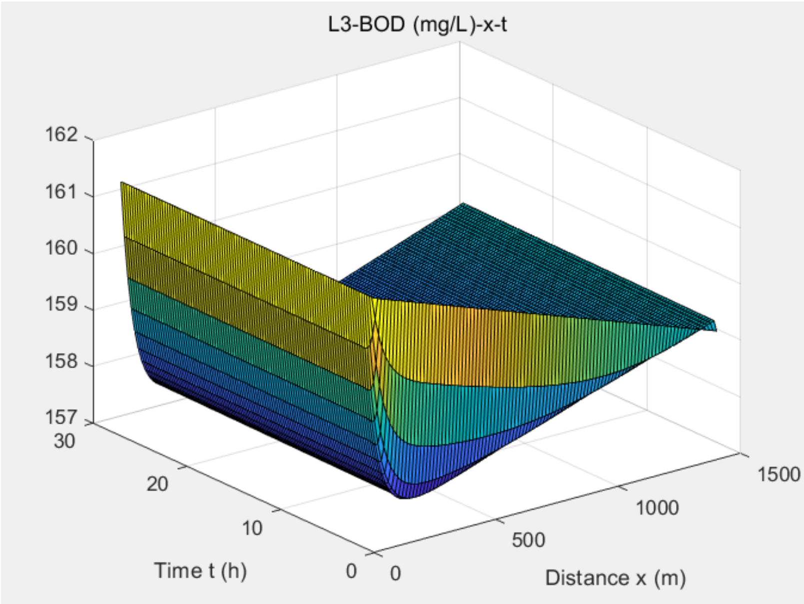

Figure 5. L3-BOD (mg/L)-x-t.

As we mentioned before, there is a storage zone in L3, so we use Keff in equation (2) to get the result. The diagram of BOD concentration changes with time and distance is shown in **Figure 6.**

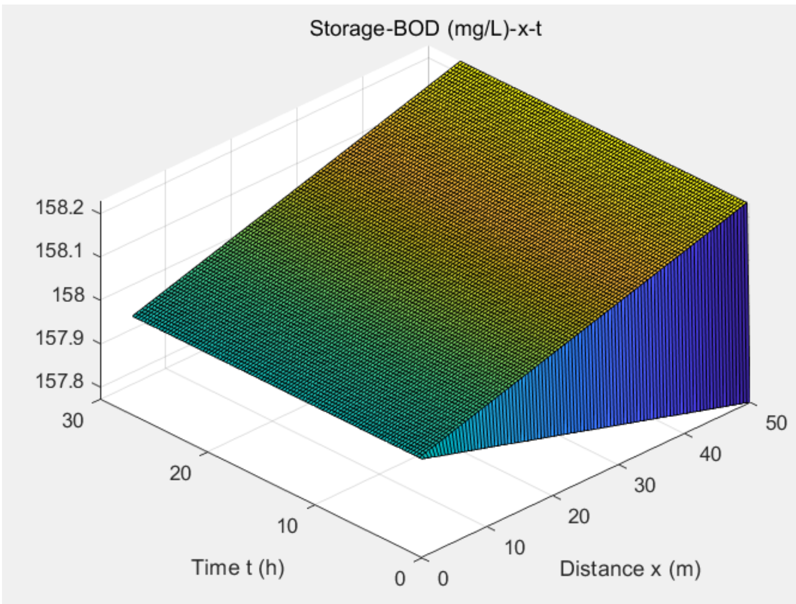

Figure 6. Storage zone-BOD (mg/L)-x-t.

2.2.4 L4

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 7.**

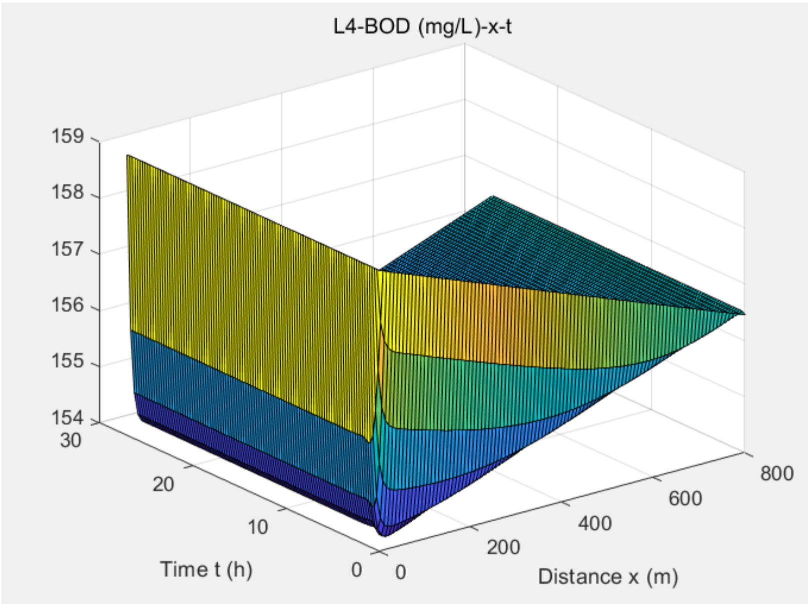

Figure 7. L4-BOD (mg/L)-x-t.

2.2.5 L5

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 8.**

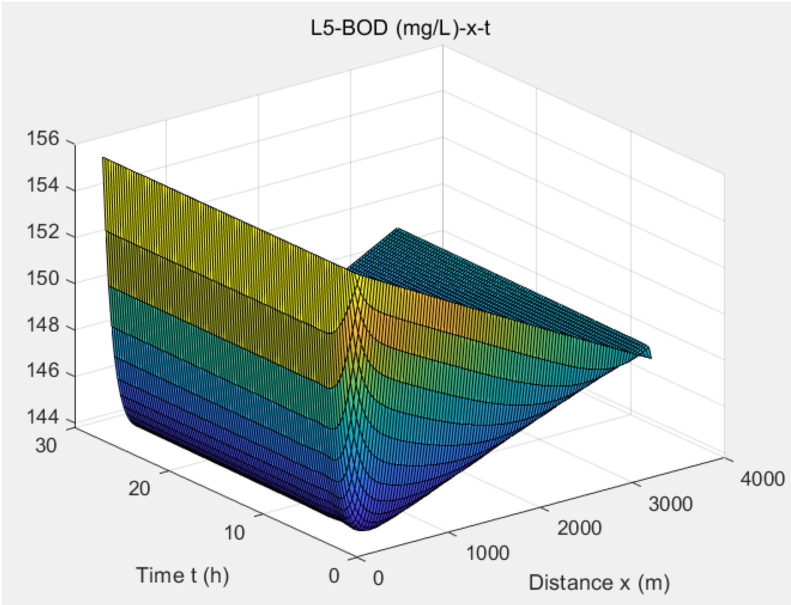

Figure 8. L5-BOD (mg/L)-x-t.

2.2.6 L6

By using the equation (1), (3), and (4), the diagram of total BOD concentration changes with x and t is shown in **Figure 9.**

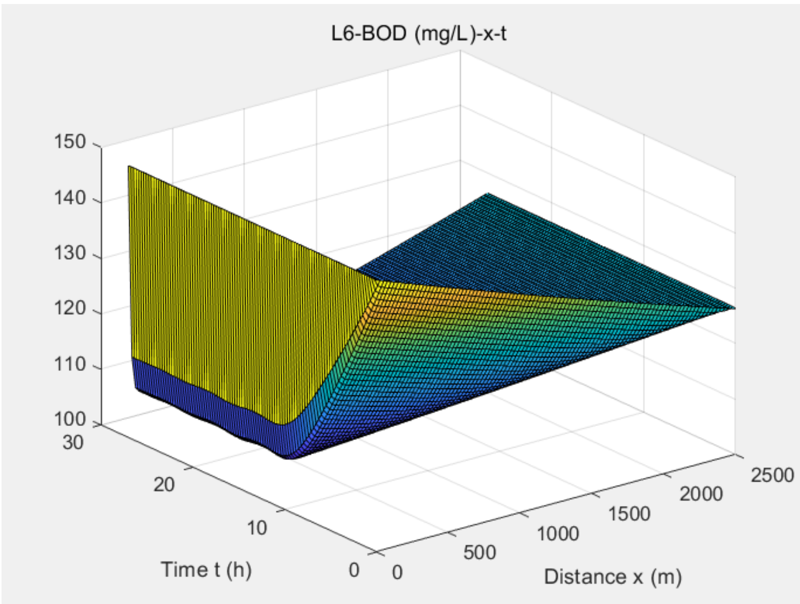

Figure 9. L6-BOD (mg/L)-x-t.

3. Discussion

3.1 Estimation of Transformation Reaction

3.1.1Study on tetracycline (TC)

BOD5 and COD in hospital wastewater are used to represent organic matter in water. Its organic load has been very close to the organic concentration of domestic sewage. This includes pathogens, microorganisms, viruses, residual drugs, and so on. From the perspective of water treatment, the biodegradability of most organic substances is relatively good. It is worth noting the environmental impact of pathogenic microorganisms and some antibiotics that are difficult to degrade.

We team select tetracycline (TC) as a sample contaminant to study and to study its fate and transformation.

3.1.2 Environmental fate of TCs

The environmental fate of TCs contains two parts, abiotic and biotic processes. On one hand abiotic processes mean chemical hydrolysis, photolysis, and oxidation. On the other hand, biodegradation of TCs is an important pathway for their metabolic transformation in the environment. Biotic transformation of TCs is a low-cost and environmentally friendly remediation technique.[11] Therefore, we must concern the environmental fate of the medical organic compound to find proper way to degradate it.

According to measurement, the concentration of TCs in hospital wastewater can reach 100 μg / L. TCs is stable in the environment and difficult to oxidize, but it is unstable at extreme pH, and Henry constant will decrease(reach about 3.45×10^{-24} to 3.91×10^{-26} atm mol). In addition, it may combine with Ca2+ and other ions and get more stable products.

3.1.3 Adsorption

The adsorption process of TCs is mainly related to ion exchange. The mineral and organic components in soil are the main adsorption points of tetracycline. Hydrophobic partition, cation exchange, cation bond bridge, surface coordination chelation and hydrogen bond all play a role in adsorption. Among them, cation exchange is the main influencing factor. Zn2+ and other metal ions have a competitive adsorption relationship with TCs. According to freumdlich equation, increasing humic acid will reduce the adsorption of TCs. When TC is adsorbed to the soil, it will be protected and its half-life will become longer.

3.1.4 Biotic processes

For biotic processes: Due to the formation of inhibitory intermediates and by-products in the degradation process, it is impossible to completely mineralize tetracycline by a single method in today's degradation route. The main factors affecting biodegradation are: initial tetracycline concentration, pH, temperature.

3.1.5 Abiotic processes

Hydrolysis of tetracycline obeys the first-order model and similar rate constant value. When there is calcium ion, the degradation rate becomes slower, which is close to the availability adjusted first order model Hydrolysis in pH neutral solution is much faster. The half-life is

1.2×10^2 days at room temperature .

Under natural conditions, tetracycline will undergo direct photolysis under sunlight. The hardness and pH value of water are the main influencing factors. photolysis was found to be very fast with a degradation rate constant at 3.61 ± 0.06 day^{-1}. The product of the reaction is

no longer antibacterial. Major degradation product is 4a,12a-anhydro-4-oxo-4-dedimethylaminotetracycline.
Oxidation process: Advanced oxidation processes are often used to treat tetracycline in sewage and soil.

3.2 BOD concentration regulated by the country

According to the standard GB7488, the allowable concentration of BOD in water in fishery is 5mg/L .
When the value of this item exceeds the standard, it indicates that the water quality cannot ensure the normal growth and reproduction of fish, shrimp and shellfish, and may cause harm. The specific harm degree should refer to the investigation data of fishery environment and relevant fishery water quality data.

4.Conclusion

In this paper, through geographical data, Dasha River is divided into six sections, and flow analysis and BOD degradation analysis are carried out section by section. In the third river section, considering the existence of water bodies with slow flow velocity, a storage zone is formed. When the water from the upstream is considered according to the composition of the wastewater from the hospital, we get the changes of BOD content with increasing time and transportation distance in each river reach is.
The results of the model simulation are shown in the picture. The overall situation of the whole section of the river is obtained through integration.
According to the calculation results, the river moves 11.05km after 27h to reach the end of Dasha River. The final BOD concentration is 130.135mg/l.
According to the national fishery water quality specification, this concentration is greater than the BOD concentration suitable for fishery activities. Therefore, in this case, the leakage of medical wastewater will have a noticeable impact on the environment.
The possible improvement is that the leakage situation is based on rough assumptions. After considering the upstream water inflow and dilution, the impact may be reduced. [13]

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