The importance of Environmental Conservation
– Lake Biwa's Case –

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ABSTRACT:

The problem of environmental pollution is rampant around the globe with the passage of time. Here, we take up water pollution seen at Lake Biwa located in Shiga Prefecture in Japan. A few decades has passed since the water pollution of the lake became a topic. Many people who live in Kyoto and Osaka areas highly depend on their water in the lake. If we take contaminated water and fish periodically, our heath will be destroyed gradually. The serious problem is that some materials which cause cancer are included. Thus, we must show some prescription to provide for the safe water and maintain the fishing volume in the lake. Basically, this analysis is based on the models of liner first order differential equations made up by the author. At first, we show the mechanism how this kind of pollution occurs. Generally speaking, many causes are considered including contaminated materials discharged by houses and factories, etc. adjacent to the lake. Time series analysis is taken into consideration to indicate the pollution mechanism. Secondly, we show the decline of fishing volume in the lake. Intuitively, we can imagine the negative correlation between water pollution and fishing volume. Namely, if the water pollution be serious, the fishing volume would decline. Furthermore, we refer to the metamorphosis of ecosystem in the lake. Thirdly, we show the status quo of the lake and how administrative sides tackle this problem. Fortunately, the water pollution of the lake is diminishing and fishing volume is increasing due to the efforts of the parties concerned. However, it seems there needs more improvement to reach the satisfactory level. Finally, we show a future perspective to resolve this problem smoothly by indicating the concrete examples.

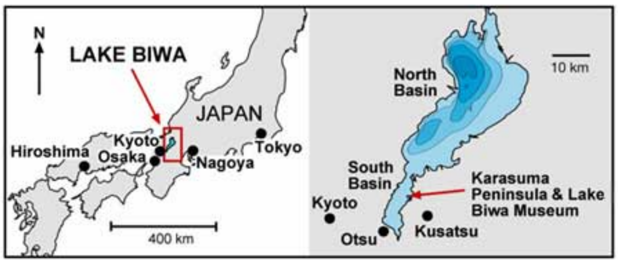
Key Words : Environmental pollution, Environmental Conservation, Differential Equation

1. INTRODUCTION

Industrialized nations are now facing the problems of water pollution.

Once pollution of a river is stooped, it will rapidly clean itself provided the pollution has not caused extreme damage. Lakes are not quite so easy to deal with since a considerable amount of water has to be cleaned. How long will this take? For example, how long would it take to clean up the Lake Biwa? The main cleanup mechanism is the natural process of gradually replacing the water in the lake, provided of course that the pollution has not caused irreversible damage and already perished the lake. Figure 1. shows a map of lake Biwa.

Figure 1.



(Source : © Lake Biwa Museum. ALL RIGHTS RESERVED.)

2. Model

The basic idea behind the model is to regard the flow in the lakes as a perfect mixing problem, ignoring biological action, sedimentation, etc. The following assumptions are made.

1. Rainfall and evaporation balance each other.
2. When water enters the lake, perfect mixing occurs, so that pollutants are uniformly distributed.
3. Pollutants are only removed from the lake by outflow.

By these assumptions, the net change in total pollutants during the time interval

δ_t is $\delta_t(VP_\beta) = (P_\alpha - P_\beta)(r\delta_t)$ ……...…….(1)

where V is the volume of the lake, P_β is the pollution concentration in the lake, P_α is the pollution concentration in the inflow to the lake, r is the rate of flow.

Thus, dividing by δ_t and letting $\delta_t \to 0$, we obtain the differential equation

$$\frac{dP_\beta}{dt} = \frac{(P_\alpha - P_\beta)r}{V} \quad \text{………………………..…… (2)}$$

This is a linear first order differential equation with integrating factor

$e^{\int r/V dt} = e^{rt/V}$; that

is, $\frac{d}{dt}\left(e^{rt/V}P_\beta\right) = e^{rt/V}P_\alpha r/V$ ……...…………. (3)

Integrating both sides and evaluating at $t = 0$ and t gives

$e^{rt/V}P_\beta(t) - P_\beta(0) = \int_0^t \left(e^{rt/V}P_\alpha r/V\right)dt$, i.e.

$$P_\beta(t) = e^{-rt/V}P_\beta(0) + e^{-rt/V}(r/V)\int_0^t e^{rt/V}P_\alpha dt$$

………………………………………..…. (4)

We can determine the effect of various anti-pollution schemes by using (4).

The fastest possible cleanup will occur if all the pollution inflow ceases.

Namely, $P_\alpha = 0$, so that $P_\beta(t) = e^{-rt/V}P_\beta(0)$

giving

$$t = \tau ln\left(\frac{P_\beta(0)}{P_\beta(t)}\right)(\because \tau = V/r) \quad \text{........................(5)}$$

where $\tau = V/r$ is Rainey's value. The model is apparently a very simplified one, but this model can be used to find out how long it would take to reduce pollution to a given percentage of its present level.

While, when we consider the fishing volume of the lake Biwa, we must think about the model of fishing populations. If there is no harvesting, the number in this group would decline due to various other reasons. We will suppose that the total number declines in an exponential manner,

i.e. $n(t) = n_0 e^{-ct - P_\alpha(t)r}$ ………..…………….(6)

where n_0 is a total number of initial group of young fish and c is a constant.

Thus, $n(t)$ is the number of fish which survive to age t years when there is no harvesting. We can surmise that the size of each individual fish increases with the passage of time. And the total weight of the fish population is increasing even though the total number is decreasing. We can also incorporate into the model the effect of fishing. Fish which are too young to be caught can be avoided by using a certain minimum mesh size for the nets. So, we can suppose that fish no younger than m years old are caught. The effect of fishing can be modeled by supposing that the decline rate is increased from $c + P_\alpha r$ to $c + P_\alpha r + f$, where f is some measure of the fishing effort. So,

$$n = n_0 e^{-cm - P_\alpha (m) r} \quad (\because t = m) \text{……………….}(7)$$

and

$$n(t) = n_0 e^{-cm} e^{-(c+f)(t-m) - P_\alpha (t-m) r} \quad (\because t \geq m) \text{……………………………………………………(8)}$$

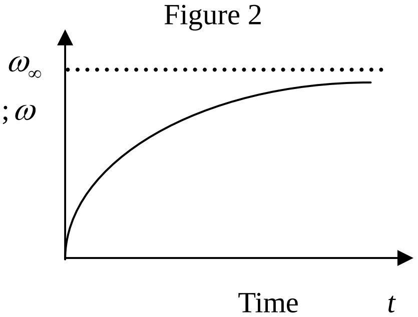
This yield is now given by

$$y = \int_m^\infty \omega(t) f n(t) dt = \int_m^\infty \omega_\infty \left(1 - e^{-\lambda t}\right)^3 f n_0 e^{-cm} e^{-(c+f)(t-m) - P_\alpha (t-m) r} dt \text{…………………………………………………(9)}$$

Where the predicted growth in fish size is given by $\omega = \omega_\infty \left(1 - e^{-\lambda t}\right)^3$ and the factor f represents the proportion of the fish alive at age t which are caught.

The predicted growth in fish size is illustrated in Figure 2.

Figure 2

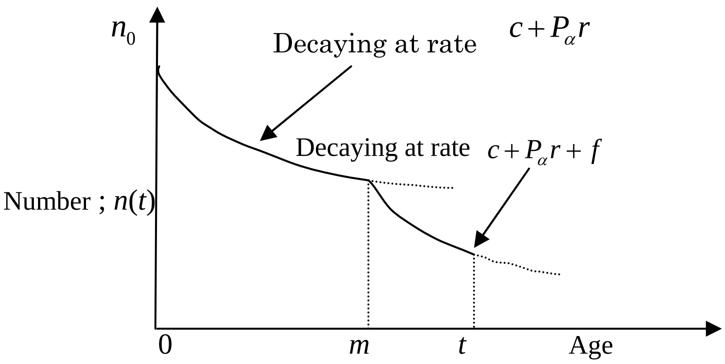


Evaluating this integral gives

$$y = y(f, P_\alpha, m) \text{…………………………………………….(10)}$$

That is, the yield is a function of the controls, f the fishing effort, P_α the pollution concentration in the inflow to the lake and m the minimum size caught. The following Figure 3. shows the number of fish surviving to age t years.

Figure 3.



3. Status quo of the lake Biwa

The lake Biwa is a freshwater lake and the largest lake in Japan. But, the rank is 129th in the world. The area is 670 square kilometer. The circumference is about 235 kilometer. There is a bridge on the narrowest part of the lake. The bridge divides the lake into two parts. That is, the north and south of Lake Biwa. The quality of water in Lake Biwa used to be critical conditions. The south of Lake Biwa occurred plankton frequently as compared with the north of Lake Biwa. Concerning the COD (Chemical Oxygen Demand), the figure of south of Lake Biwa is worse than the north of Lake Biwa. There were three stages in the pollution of Lake Biwa. The bad smell of mold occurred at the first stage in 1969. The red tide of fresh water occurred at the second stage in 1977. The Microcystis aeruginosa occurred massively at the third stage in 1987. There are 460 rivers flowed through Lake Biwa. Household wastewater, factory wastewater, chemical fertilizer of agricultural lands and golf courses, and agrochemicals are flowed in through the water of rivers. It is often said that at least nineteen years is needed to replace all the water in Lake Biwa. If we want to know the time to reduce pollution to a target level, we can measure the time by applying for equation (5).

For example, if we plug into the actual value in equation (5), We can get

$$\therefore t = \tau ln\left(\frac{P_\beta(0)}{P_\beta(t)}\right) = 1.31(year)$$

$$(\because P_\beta(0) = 2.8, P_\beta(t) = 3.0, \tau = 19)$$

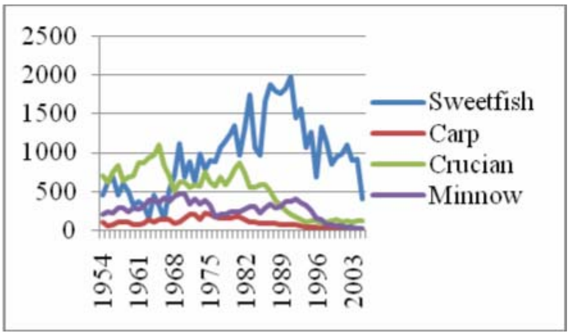
So, the wastewater in Lake Biwa flows in Yodo river at Osaka and this wastewater is used for about 14 million people in Kyoto, Osaka and Kobe area. Thus, a water filtering plant treats drinking water with a large amount of chlorine. However, this water contains high density carcinogen such as trihalomethane. The density of carcinogen in Osaka is much higher than Tokyo and Nagoya areas. Recently, it seems that the water in Osaka is improved thanks to highly sophisticated water filtering plant.

On the other hand, historical fishing volume is exhibited in Figure 4.. We can see that fishing volume is decreasing with the passage of time. Apparently, sweetfish increased around 1990, but declined again after that. And we can also conjecture the reason of declining the fishing volume from Figure 3.. Namely, one of the major factors of declining the fishing volume lies in the pollution of Lake Biwa. We must note that there is a time lag between pollution inflow cease and cleanup of Lake Biwa. Then, even if we stop the pollution inflow to the Lake Biwa, it will take much more time to recover its fishing volume to the original level. Because the cleanup level and fishing volume have a positive correlation from the past examples.

In addition, global warming is now worsening rapidly. This trend spurs the deterioration of cleanup of Lake Biwa. Because the snowfall is useful to accelerate the pace of replacement of the polluted water in the Lake. Recently, the volume of snowfall is decreasing year by year due to the affection of global warming.

Sweetfish Carp Crucian Minnow

Figure 4.



4. Conclusion

We examine the relationship between pollution and fishing volume at Lake Biwa from the perspective of environmental conservation in this paper. And we notice that once the water was polluted, it will take a long time to recover the cleanup water again. Furthermore, if the pollution level becomes lower with efforts, fishing volume would increase gradually with some time lag. We can not see a noteworthy improvement now in Lake Biwa. So, we must utilize the latest technology to clean up the water in Lake Biwa in order to reduce the level of COD. Because if the level of COD will increase year by year, the environments of Lake Biwa will not be suitable for the life of fish, etc. The increase of COD is highly correlated with the chemical materials which are not dissolved in the water. This chemical materials are derived from the artificial materials. As for the lake Biwa, we should oblige each house to install sewerage systems and to use soap instead of synthetic detergent. Concerning the factories and business offices, they are controlled by the Water Pollution Control Law under the surveillance of Shiga prefecture.

Finally, we would highly anticipate and support for the continuous efforts of Shiga prefecture such as environmental education and social awareness to keep the water clean forever.

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