HOW MUCH DOES DIFFUSE POLLUTION AFFECT AN AQUATIC ECOSYSTEM

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ABSTRACT

Japanese people like green tea very much, as well as its vivid green color and sweet taste. In order to produce such kind of tea, farmers apply a great amount of nitrogen fertilizer. The amount of fertilizer has reached to 1,000 kg/ha to our understanding heard from several farmers. Tea plants uptake about 300 kg/ha, hence, the residues become diffused pollution. Since the soil condition of tea fields is aerobic, ordinary nitrogen fertilizer oxidizes to nitrate quickly and diffuses into soils. Usually the cation exchange capacity (CEC) of soil is great, however, if a great amount of nitrate acid soil loses its CEC, then the H+ ions runoff. We observed that the pH is 4.3 in small river water, and further when there was heavy rain, the river water became below a pH of 3.5 at times. As a result, the small irrigation reservoir receives this water below pH 5.0, and thus fauna cannot live there. Hence, we observed the water quality of the river and reservoir, and then we discussed the impact it had on the aquatic ecosystem and pH simulation of the reservoir.

Keywords : nitrate pollution; irrigation reservoir; aquatic ecosystem; acidification of lake; low pH

INTRODUCTION

It is well known that acidic lakes are derived from acidification of rain in northern Europe. As a result, the ecosystem of lakes were infected and deteriorated. The color of the lake is light blue, which people feel is very beautiful scenery. However, the aquatic ecosystems suffer seriously and the fish population decreases rapidly. Sometimes it is difficult to find any fish in the lakes. As mentioned previously, these acidic lakes come from acidic rain in northern Europe, however, the same problems are starting to be found in small irrigation reservoirs in Japan. The reason of acidification of lakes, however, is slightly different in the case of Europe. Japanese cases are derived from diffused pollution from farmlands (Tanaka T. *et al*, 2002; Ii *et al*, 1997). The origins of this pollution come from over use of fertilizer. It is well known that ammonium sulfate has been applied widely as the nitrogen fertilizer in the world because it is cheep, and Japan is no exception. As mentioned in the abstract, a great amount of ammonium sulfate was applied especially into tea fields in Japan. The annual application amount of nitrogen fertilizer for tea fields was 628 kg/ha (Nishio, 2001) on average in Japan in 1989. The amount of application is gradually decreasing today in Japan. However, accumulation of the nitrogen soil layer is even greater today. Therefore, we observe a high nitrate nitrogen concentration in the ground water, river water and reservoirs. The concentration level often reaches to 50 mg/L for nitrate nitrogen (NO_3-N). This is a great problem not only for aquatic ecosystems but also for water resources. Hence, we tried to simulate the pH and NO_3-N fluctuations in the reservoir. Though we could not reproduce a big decrease of pH value just after a heavy rainfall, we could simulate other fluctuations of the pH values and NO_3-N concentrations fairly well.

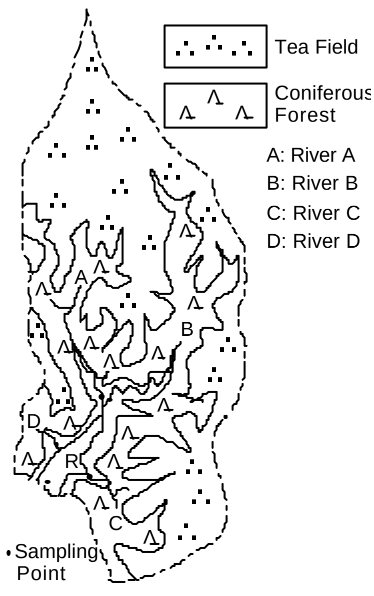

Fig. 1 *Outline of the watershed*

OBSERVATION SITE AND OBSERVATION

The observation site of this research is performed at Shizuoka Prefecture. Its location is 150 km WWS from Tokyo. This area is famous for a tea produc -tion area called Makinohara. Also, many irrigation reservoirs were constructed for paddy irrigation from ancient times. Some of these irrigation reservoirs have high nitrate concentrations from 10 mg/L to 40mg/L for nitrate nitrogen (not nitrate ion). We did, however, find a reservoir called Tanno having a low pH. The outline of the Tanno reservoir and its watershed are shown in Fig. 1. The forest on the fill of the watershed were developed on tea fields from one hundred years ago and there are four small inflow rivers there. The topsoil of the tea fields is loam, while under the topsoil, there is a thick gravel layer. At some part under the gravel layer of the watershed, there is sea layer. Moreover, we observed a shell fossils on the A-river bed, which affect the pH of the inflow river water. Rainfall data was collected from a rain gauge near the bank of the Tanno reservoir. We set an automatic water sampler and automatic water level meter at river-A and collected the data every day. The other three river waters and the reservoir water itself are collected every week. The analyzed water quality consisted of water temperature, pH, COD_{Mn}, EC, T-N, NH_4-N, NO_2-N, NO_3-N, SO_4^{2-}, T-P, Na^+, K^+, Ca^{2+}, Mg^{2+} and Al^{3+}. Among these water qualities, we will discuss pH and NO_3-N next.

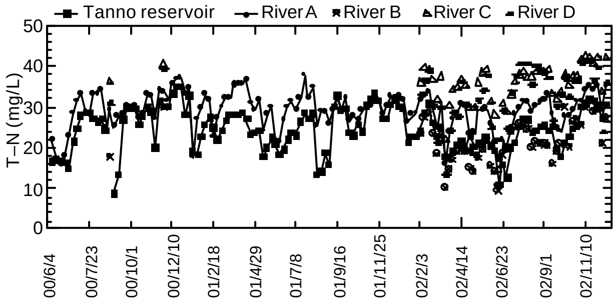

Fig. 2 *Observed T-N concentrations*

OBSERVED RESULTS AND DISSCUSSION

T-N Concentration and NO_3 -N Simulation

After World War , farmers used to apply cheap ammonium nitrate as nitrogen fertilizer for forty years. We conducted research and asked six farmers their annual ammonium application amount. As a result, the average weight was 1,280 kg/ha for the six farmers. Nishino (2001) reported that the annual average N-application of Japan was 628 kg/ha for tea fields as mentioned in the abstract. Com -pared to this amount, the annual application amount of the Makinohara region is great. Nowadays, this application amount is gradually decreasing by means of control by the local government. However, our survey of another region showed that great accumulation was found where there were wastes from cattle industries. This shows that nitrogen loads did not decrease in the last twenty years if a farmer stops the application of nitrogen fertilizer completely. It is a difficult situation for a farmer stop the application of N fertilizer completely. Therefore, the contamination of nitrate in the ground water will continue for a while. Here, we show the observed result of T-N concentration in Fig. 2. T-N concentration changes between 10 mg/L and 40 mg/L and it decreases very sharply when there is heavy rain. After the rain, however, it recovers gradually. From 93% to 98% of T-N is nitrate. The maximum nitrite concentration was 0.77 mg/L and ammonium one was 1.97 mg/L. Next, we show the simulation result for nitrate concentration in the Tanno reservoir. The discharge of each of the rivers, calculated results done by a series tank model that was developed by Sugawara (1972). The nitrate concentration of each river as calculated from the L-Q equation as shown Eq. 1 and 2.

$$L = aQ^n \tag{1}$$

$$C = L/Q \tag{2}$$

Here, L is a pollutant load; Q is the discharge; and a and n are the constants. C is the concentration of water quality; nitrate. The constants a and n are determined from the observed data of discharge and nitrate concentration of each river. The nitrate concentration is calculated from the balance of the inflow load and outflow load of the Tanno reservoir like Eq. 3 and 4.

$$C_T = (L_A + L_B + L_C + L_D + L_T - L_T \quad Q_O) / V \tag{3}$$

$$V = (Q_A + Q_B + Q_C + Q_D - Q_O) \tag{4}$$

Here, C_T is the nitrate concentration of the Tanno reservoir, L_A, L_B, L_C, L_D are the runoff load of each inflow river; L_T is the materials of the Tanno reservoir; Q_O is the outflow from the Tanno reservoir which is calculated from the observed water levels of the reservoir; V is the water volume of the Tanno reservoir which was calculated from the observed water levels. There is a potential of denitrification in the detritus of the reservoir in general. We performed

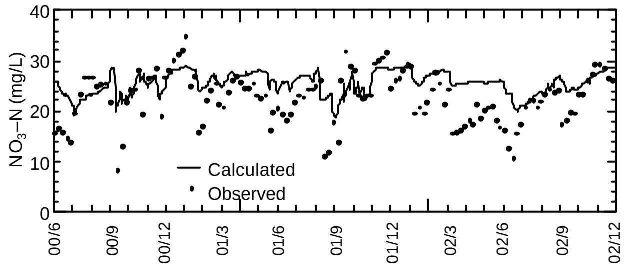

Fig. 3 *Comparison simulated results with observed*

a denitrification test using detritus and water of the Tanno reservoir. As a result, we can admit the denitrification ability of detritus. However, there is a lack of organic matter as for hydrogen donation since the productivity of phyto- plankton is low. It is difficult to say that there is good agreement between the calculated and observed values. However, in order to grasp the fluctuation tendency could be elucidated well. Neverthless, nitrate concentration is higher than the standard of Japanese drinking water; nitrate nitrogen 10 mg/L (NO_3-N). The standard WHO is 50 mg/L for the nitrate ion (NO_3^-), which is approximately the same value for nitrogen. Around the same concentrations of nitrate in ground water can be observed in many areas of the upland fields in Japan. This is a serious problem for water resources.

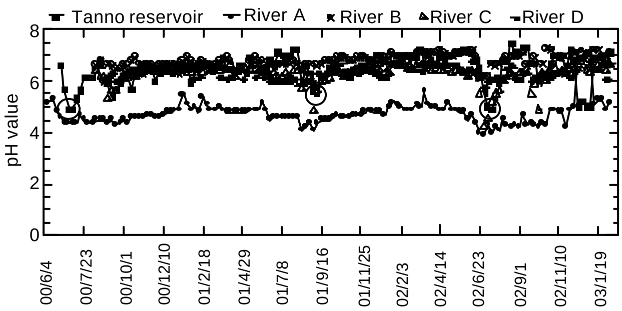

Fig. 4 *Observed pH values*

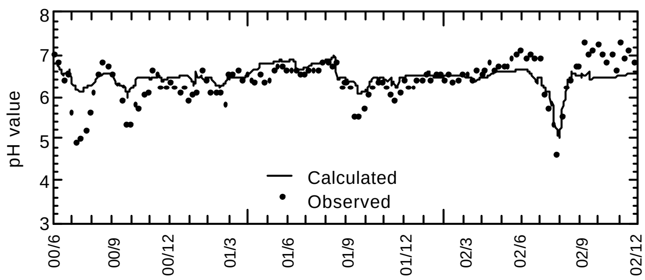

Fig. 5 *Simulation for pH values in the Tanno reservoir*

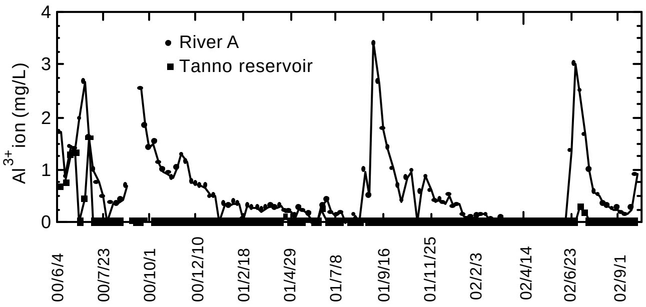

Fig. 6 *Observed aluminum concentration*

pH Values and Its Simulation Result

There were only a few phenomena pertaining to the pH value of river water until recently, although there are special cases such as volcano and hot springs in Japan in the east. However, nowadays acidification can be observed in a reservoir derived from diffused pollution. As mentioned in the abstract, farmers applied ammonium sulfate in the past. Today, popular nitrogen fertilizers are urea and compost of cattle wastes. Furthermore, ammonium sulfate oxidized quickly into sulfuric acid and nitric acid under the aerobic condition of soils. Usually, soils in Japan have anion of the soil surface. Hence, cations such as Na^+, K^+, Ca^{++}, Mg^{++}, and so on are adsorbed with the soils. Therefore, hydrogen ions are replaced by such cations, and thus pH value does not decrease in general. However, when soils gradually lose a CEC (Cation Exchange Capacity), hydrogen ions start to percolate downward and flow into the river. If this phenomenon starts, acidification of water will occur. There is a thick gravel layer under the topsoil in the Tanno reservoir watershed. The well known gravel has good permeability and less CEC and this soil layer condition derives from the acidification of river water. Therefore, reservoirs that receive this river water become an acidic lake. As seen in Fig. 1, there are four small inflow rivers in the Tanno waters hed. We show the observed results of the pH values in Fig. 4. As seen in Fig. 4, river A always has low pH values. The pH of the Tanno reservoir is around 6.8. However, once a year we can see a low pH as is shown by the mark of in Fig. 4. The reason of this phenomenon is that when heavy rainfall occurs, a low pH water runsoff. It was reported that the pH value at that time went down to 3.5. The pH values are not very low except in river A. The phenomenon behind this reason is that we can see shell fossils in the riverbeds of river B and C. A release of the calcium ion from the shell fossil would neutralize the low pH.

We tried this pH simulation and it is shown in Fig. 5. We see that the soil texture of a wide area is not homogeneous. Also, the chemical reactions between soils and liquids in the soil are very complex. It is difficult to take all phenomena occuring in the soils into consideration, therefore, we think of the pH like the case of nitrate simulation. We also assumed that the pH values are calculated from the same equations (1)-(4). Furthermore, the pH in river A is neutralized with anion and organic compounds in other rovers and reservoirs. From this low pH of the river, aluminum ions are dissolved. We show this phenomenon in Fig. 6. As seen in Fig. 6, high concentrations of the aluminum ion clearly coincide with the times when pH of the reservoir was low as seen Fig. 4.

Affect on the Ecosystem from Diffused Pollution

A diffused pollution that will affect an aquatic ecosystem will contain a pH value. Perhaps, other water quality parameter such as aluminum seems to affect the ecosystem as well. It is widely known that aluminum has an affect on plant roots. It has been pointed out that aluminum has an affect on the gills of a fish. However, we believe that the most likely scenario comes from acidification. The acidification in northern Europe derived from acid rain. The main material of the cause of acidification is sulfuric acid derived from combustion of heavy oil at an electric power station. The carbon dioxide in the atmosphere dissolved in the water much the same as the pressure in the atmosphere. The carbon dioxide creates carbonic acid in the water. If a strong acid such as sulfuric acid and nitric acid entered into water, the carbon dioxide is released from the water. This reaction is as follow.

$$H^{+} + HCO_3^{-} + H_2SO_4 \quad 2H^{+} + SO_4^{2-} + CO_2 + H_2O \tag{5}$$

Hence, photosynthesis could not be carried out in the water even though there are rich eutrophic salts such as potassium nitrate and potassium sulfate in the reservoir. As a result, phytoplankton cannot be produced in the reservoir. Hence, zooplankton also cannot be produced. Therefore, fauna cannot alive since there is not foods supply. We also observed COD_{Mn} in the reservoir and rivers and it is shown in Fig. 7. As seen in Fig. 7, COD_{Mn} of the river and reservoir are slightly the same. Concentrations of COD_{Mn} are not so big, which shows that the production of phytoplankton is regulated. The pH values in the Tanno reservoir are not always low. However, as mentioned in the previous chapter, when heavy rainfall occurred once or twice a year the pH values decrease to around 5.0 since the pH values of river A went down to 3.5. Even though fauna start to live, they will die quickly because of this low pH. When we had surveyed this reservoir plants that are growing offshore were withered. We estimated that the phenomenon came from low pH in the reservoir. A major concern is that we are afra id that this kind of phenomena will happen all over the world.

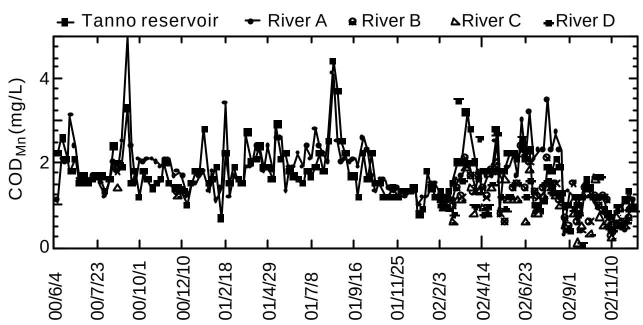

Fig. 7 Obbserved concentration of COD_{Mn}

CONCLUSION

We observed the water quality in the area where the land use of the watershed collecting water is tea fields. The nitrogen fertilizer that is applied to tea fields is great, which oxidized into nitrate quickly and diffused into the ground water and watershed. The application amount in tea fields is so big that it is causing acidification of rivers and reservoirs at certain areas of Japan. It is also causing a melt-out of aluminum at the same time. Although this aluminum causes damage for plant roots, we estimated that a low pH due to nitric acid derived from nitrogen fertilizer would mainly be the cause of non-fauna in the Tanno reservoir. Therefore, the diffused pollution derived from agriculture would have a great affect on the aquatic ecosystem. We would like to point out that this kind of problem occurs all over the world.

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