NGO’s “come back ayufish” campaign and preservation of drinking water sources in Murasaki River, Kitakyushu city, Japan

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Abstract Good quality raw material gives a good quality product. This is a fundamental rule of production not only for commodities but also for our drinking water. The citizens of Kitakyushu city have been aware of this rule and started the campaign to preserve the drinking water source, and its surrounding natural environment. The catchphrase for the campaign is “Come back Ayufish to the river”. For Japanese people, ayufish is one of the most suitable indicators of clean water or clean river. More than a thousand citizens take part in this campaign every year. A group of environmental chemists have supported this campaign by sharing the long-term monitoring data for 40 years with the NGO and also the relationship between physiological impact of water quality such as BOD and MBAS on the behavior of ayufish to return to the river is discussed.

Keywords Avoidance reaction; ayufish; BOD; drinking water source; MBAS; NGO’s campaign; preservation of natural environment

Introduction
The City of Kitakyushu is one of the industrialized cities in Japan, with a population of one million or a population density of more than 2,000 people/km². Its industrial production output in year 2001 was US$1.7 billion.

Murasaki river runs through a highly populated and industrialized area from south to north, stretching about 20 km in length. The river has two reservoirs: Masubuchi reservoir with an impounding capacity of 13.2 million m³ and Dobaru reservoir with an impounding capacity of 450,000 m³. About 41,000 m³ of raw waters are withdrawn daily from both surface and underground sources at the intake facility located 2 km upstream from the river mouth. Nippon Steel Company also withdraws 50,000 m³/day of industrial water from the river. There are three municipal water purification plants (WPPs) drawing water from the river: Ideura WPP with the maximum treatment capacity of 255,200 m³/day, Dobaru WPP with the maximum treatment capacity of 7,800 m³/day and Kuzumaki WPP with the maximum treatment capacity of 41,000 m³/day. Good quality raw material gives a good quality product. This is the fundamental rule of production not only for commodities but also for our drinking water. The citizens of Kitakyushu city have been aware of this rule; therefore, Murasaki river “Come back Ayufish Project” (M-CAP), an environmental non-governmental organization (NGO) composed of Kitakyushu citizens, was organized in 1993 and undertook its first activity that same year. It was organized to preserve the natural environment and the ecological soundness of Murasaki river as the source of drinking water by recovering ayufish (*Plecoglossus altivelis altivelis*). The activity of M-CAP includes: (1) river clean up including river bed and river bank; (2) release of ayufish and follow-up investigation; and (3) study of the relationship between water quality and recovery of ayufish in order to raise citizens’ environmental awareness.

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Ayufish lives in a clean river less than 3 mg/L of biochemical oxygen demand (BOD) and is a very good indicator of clean water or clean river which is a good source of drinking water. Murasaki river has one of the rarest experiences in the world as it has succeeded in cleaning its waters, getting rid of heavy pollution caused by both domestic and industrial effluents. The presence of ayufish and ice goby indicates ecological soundness of the natural and clean water environment of the Murasaki river. The Kitakyushu citizens, in cooperation with NGO, enterprise and local government, were able to conquer the heaviest water pollution problems after a long and tough struggle. The main purpose of this paper is to discuss the physiological impact of water pollutants including BOD and Methylene Blue Active Substances (MBAS), widely used in synthetic detergents worldwide, on the behavior of ayufish to come up the stream. In addition, I would like to discuss the pollution problems of Murasaki river particularly its history of water pollution, our management efforts and countermeasures against pollution problems. The map of Murasaki river is shown in Figure 1.

Methods

Monitoring data

BOD, MBAS, etc. are analyzed according to Japanese Analytical Methods for Drinking Water (2001), and the database of the monitoring data was obtained from the annual report published by the Water Quality Research Laboratory, Kitakyushu City Water Works (2002). Obtained data were tabulated using MS Excel.

Calculation of the total number of ayufish come-up

Thirty thousand ayufish, marked by cutting off their adipose fin, are released into Murasaki river. One week later ayufish are caught using a throwing net. The number of caught ayufishes without fin \( R \) and the number of caught ayufishes with fin \( N \) are then recorded.

The relation between \( R \), \( N \) and \( X \), \( Y \) follows Equation (1):

\[
\frac{R}{N} = \frac{X}{Y}
\]

where \( Y \) is the total number of natural ayufish (with fin), and \( X \) is the total number of ayufish released (without fin).

Thus it is possible to calculate \( Y \) by using the data of ayufish caught.

Ayufish (Plecoglosus altivelis altivelis TEMMINCK et SCHLEGEL). Ayufish is a small salmon-like anadromous fish of Japan shown in Figure 2. That is highly esteemed as a food fish. It is called also sweetfish. Ayufish lives in the clean rivers of Japan islands.
except for Hokkaido, after coming up to clean rivers every spring from surrounding sea in order to grow up in the upper part of river and spawn in the region of downstream in autumn. After spawning, they end their one-year life span.

*Ice goby (Leucopsarion petersi Hilgedorf).* Ice goby is small fish of 50 mm in length and semitransparent in appearance, and belongs to goby family and usually lives in the adjoining seas of Japan and Korean peninsula. During early spring they return to clean stream in the tidal reaches of the river in order to spawn. After spawning, they end their one-year lifespan.

**Results and discussion**

**History of water pollution of Murasaki river**

In the Murasaki river the farmers in Kokura castle town started fishing for ayufish to be presented to their lord in 1827 (*The Kitakyushu City History Museum, 1997*). In Meiji era (1868–1921), ayufish fishing using cormorants had been conducted. Because of the cleanness of water, easiness of obtaining raw material and convenience of transportation, a paper mill was established in 1892 on the right bank of the river 1 km upstream from its mouth and discharged industrial effluent without treatment.

In 1899, *Mori (1952)*, who was a famous Japanese writer and medical doctor majored in hygienics, recorded in his famous diary that industrial effluent discharged from the paper mill was bad for the pond of fish preserve.

At the river mouth, the production of green laver growing in the tidal reaches of the river ceased due to the water pollution caused by the industrial waste discharged from the paper mill in 1921. Kokura city started a water supply service in 1913. The world famous sanitary ceramics company in 1917 and iron steel company in 1918 were established at the mouth of river and industrial effluent was discharged.

In 1919, the state run Iron Steel Company constructed the barrage for drawing tremendous amount of industrial water of 110,000 m³ per day from the river with an average total flow of 200,000 m³ in those days.

**Variation of BOD at the mouth of Murasaki river**

The tidal reaches of the river extend up to 2 km upstream from its mouth. Yearly average BOD in the tidal reaches is shown in *Figure 3*. The highest value recorded is 32.5 mg/L which was obtained in 1967. This gradually decreased to 5 mg/L in 1972.

However, BOD value increased to 15 mg/L in 1973 and then decreased again to 7 mg/L in 1977. After that, BOD increased to 12 mg/L in 1978, and decreased again to 3.0 mg/L in 1981. In 1983, the value of BOD decreased abruptly to 1.0 mg/L due to the expansion of the sewerage network. Meanwhile, it was observed that green laver was growing again in the tidal reaches of the river.
In 1983 about 5,000 ayufish were released by the Kitakyushu city government and in autumn a spawning fish was caught. It proved that the river recovered from its serious state of pollution.

Impact of BOD and synthetic detergent to ayufish. The physiological impact of water pollutants including BOD and MBAS, synthetic detergent, on the behavior of ayufish is discussed here using the long-term water quality monitoring data for forty years from 1963 to 2003.

The relationship between water quality including BOD and linear alkyl benzene sulfonate (LAS), and behavior of returning of ayufish is discussed. Here, MBAS is used as a surrogate parameter instead of LAS concentration. The variation of water quality at the sampling point of Shinozaki Bridge (the spawning ground of ayufish) is shown in Figures 4 and 5 for MBAS and BOD.

Variation of BOD concentration. According to Environmental Standards for Fisheries (1972), the required BOD concentration for reproduction of ayufish, including spawning and hatching, is 2.0 mg/L and for living is 3.0 mg/L. On the other hand, the level of BOD ranged from 0.5–6.0 mg/L for 11 years from 1963–1971 with a mean value of 3.0 mg/L. Within the 40 year monitoring period, the river was most polluted during 1976 to 1980.
with the highest BOD value of 7.3 mg/L recorded in May 1979. However, BOD value began to decrease from 1983.

BOD value exceeded 3.0 mg/L three times within the period, first in September 1983, then in February 1984 and again in March 1986. Outside these three instances, BOD level has been maintained at less than 3.0 mg/L during the season from April to December causing the ayufish to come up the river and finish spawning. Because natural ayufish were officially confirmed to be coming up the river since 1985, it appears that concentrations described above did not adversely affect the return of ayufish to the river. BOD value has never exceeded 3.0 mg/L, even in the winter season, since 1989 and the numbers of ayufish coming up the river greatly increased to around 300,000 fishes.

**Variation of MBAS concentration.** According to the field study on the avoidance reaction of ayufish to synthetic detergent LAS in Shigenobu river, Ehime prefecture, Japan in 1987, ayufish clearly showed an avoidance reaction or avoided entering the stream at the concentrations of 0.044 mg/L and 0.190 mg/L of LAS (Hidaka, 1987).

Concentration levels of MBAS during the period from 1968 to 1976 ranged from undetected to 0.4 mg/L. Within the 40-year period, it recorded its highest MBAS level in 1977–1980 with the highest value reaching 0.93 mg/L in 1979. Since 1981, the MBAS level began to decrease. Since 1984, the peak value of MBAS was recorded in winter higher level than 0.1 mg/L. During the warm and hot season from May to August, when ayufish grow and spawn in the river, the MBAS level was less than 0.05 mg/L which is a level that appears to have no effect on ayufish. The mean concentration of MBAS from 1989–2003 is 0.028 mg/L, ranging from a value of 0.1 mg/L to undetected ($n = 99$), which is sufficiently below the LAS avoidance level (0.044 mg/L) of ayufish, as reported by Hidaka (1987).

**Return of ice goby.** According to the report (Matsui, 1986), it was confirmed that ice goby did not come up Murasaki river before 1984. However, in 1989 they suddenly began coming up the river and spawn at the spawning ground in the tidal reaches of the river located 1.5 km upstream from the river mouth, with an area of 50 m wide and 500 m long.

Before 1988, MBAS level in winter showed relatively high concentrations as much as 0.4, 0.2 and 0.1 mg/L in 1984, 1985 and 1987, respectively. BOD concentrations were also high at 4.0 mg/L in 1983 and again in 1985.
Ayufish usually return to the river every spring when water temperature rises above 10°C. It is considered that at warm water temperature the microorganism activity in the river is accelerated; thus self-purification of the river is faster at this temperature than at lower temperature during winter. Therefore, during warm season, the BOD and MBAS concentrations are reduced to a level that does not affect the growth and spawning of ayufish. This is the reason why during cold season, the river water quality does not hinder the return of ayufish to the river.

On the other hand, because ice goby usually begin to return to river from late winter to early spring, they are directly affected by the water quality during winter season. Although about one million or more ice gobies returned to Murasaki river since 1989, this happened four years later than with ayufish. The year when ice goby began returning to Murasaki river (1989) coincided with the year when the average water quality of both MBAS and BOD were reduced to 0.05 mg/L ranging from 0.02 mg/L to 0.07 mg/L (n = 5) and 1.98 mg/L ranging from 2.7 mg/L to 1.1 mg/L (n = 5), respectively, as shown in Figure 5. This occurred during the winter season from December to March and early April.

Other water quality parameters showing recovery of river

Variation of ammonium nitrogen. Ammonium nitrogen (NH₃-N) is also a good indicator for water pollution caused by human activity such as discharging domestic waste including human excreta.

Murasaki river began cleaning up since 1983, so the data of NH₃-N concentration before and after 1983 were compared. The average concentration of NH₃-N from March 1963 to March 1983 is 0.13 mg/L and ranged from 0.65 mg/L to undetected (n = 202). The average concentration of NH₃-N from April 1983 to March 2003 is 0.025 mg/L and ranged from 0.23 mg/L to undetected (n = 240). Thus, the average value of NH₃-N decreased from 0.13 mg/L to 0.025 mg/L, from the value before 1983 to the value after 1983, as shown in Figure 6. On the other hand, nitric acid nitrogen (NO₃-N) concentration, the average concentration of NO₃-N from March 1963 to March 1983 is 0.86 mg/L and ranged from 2.5 mg/L to 0.1 mg/L (n = 201), and the average concentration of NO₃-N from April 1983 to March 2003 is 0.98 mg/L and ranged from 2.40 mg/L to 0.1 mg/L (n = 240). Therefore, the average values of NO₃-N slightly increased from 0.86 mg/L to 0.98 mg/L from the value before 1983 to the value after 1983, as shown in Figure 6. These results show that the load of NH₃-N was cut off by the expansion of sewerage network.

![Figure 6 Variation of the concentrations of NH₃-N and NO₃-N in Murasaki river](image-url)
Variation of pH value in Murasaki river. The variation of pH value within the 40 year period, from March 1963 to March 2003, is shown in Figure 7. The average pH value increased from 7.4 in 1963 to 8.4 in 2003 and the variation is simulated by Equation 2 as shown in the figure.

\[
\log Y = \log 7.08 + 0.028 \times \log X
\]  

(2)

where Y is the pH value measured and X is the months from the start of monitoring.

For the F-test, \( f_0 = (n - 1) \times r^2 / (1 - r^2) \) with the degree of freedom \( (1, n - 2) \) is calculated to be 55.7, where \( r = 0.575 \) is the correlation coefficient of Equation 2 and \( n = 456 \). And also \( f_{1454}(0.01) \), obtained from F-distribution table, is 6.7. Thus \( f_0 \) is bigger than \( f_{1454}(0.01) \), therefore Equation 2 is significant at the significance level of 0.01.

This phenomenon shows a high microbial activity involving chlorophyll-containing microorganisms that take up carbon dioxide from the Murasaki river water and generate carbohydrate and oxygen through a process called photosynthesis. Carbonate in the river water is used by chlorophyll with the help of sunlight, and then pH value rises.

This phenomenon also means that enough food is supplied to ayufish in accordance with a high microbial activity, because ayufish grows up by eating such kind of algae as diatoms growing on the stone in the riverbed.

Number of Ayufish returning to the river. The total number of natural ayufish \( (Y) \) returning to the Murasaki river is calculated by using the data of ayufish caught from late April to June (2001) after release as follows: \( N = 15 \), \( R = 22 \), \( X = 30,000 \), so \( Y = 15 \times 30,000 / 22 = 20,454 \), that is, about 20,000 ayufish came up the Murasaki river in the spring of 2001 (Table 1).

Conclusions

There are three major reasons why the water quality of Murasaki river has been so cleaned up. The first reason is the integration of sewerage system. Hiagari sewerage treatment plant started treatment in 1970, and all loads of domestic effluent generated by individual households in the densely populated area of the city were no longer discharged directly into the river.
Murasaki river. The second reason is the enforcement of the Water Pollution Control Law since 1971 which forced a major ceramics company located near the river to establish a closed-loop system in its use of industrial water and required a major iron steel mill located at the mouth of the river to treat its industrial waste discharges. The third reason is the relocation of many squatters, some with pigsties, located along the river banks to new public apartment houses constructed for squatters from 1966 to 1980. Thus, we were able to successfully cut off the entry of major pollutants into Murasaki river. Now the Murasaki river and its surrounding environment are conserved by the environmental NGO composed of Kitakyushu city citizens and supported by a group of environmental chemists in cooperation with enterprise and local government. Now many citizens enjoy river watching and ayu fish watching in Murasaki river.

References