Some Primary Characeristics of Water Quality in the Tatara River

Lap, Bui Quoc
Laboratory of Bioproduction and Environment Information Sciences,Division of Bioproduction and Environment Information Sciences,Department of Bioproduction and Environmental Science, Graduate School of Bioresource and Bioenvironmental Sciences,Kyushu Unviersity

Mori, Ken
Laboratory of Bioproduction and Environment Information Sciences,Division of Bioproduction and Environment Information Sciences,Department of Bioproduction and Environmental Science,Factory of Agriculture,Kyushu Unviersity

Inoue, Eiji

https://doi.org/10.5109/4645

出版情報：九州大学大学院農学研究院紀要. 50 (2), pp.313-326, 2005-10-01. Faculty of Agriculture, Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **50** (2), 313–326 (2005)

Some Primary Characteristics of Water Quality in the Tatara River

Bui Quoc LAP[1], Ken MORI* and Eiji INOUE

Laboratory of Bioproduction and Environment Information Sciences, Division of Bioproduction and Environment Information Sciences, Department of Bioproduction and Environment Science, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan
(Received June 10, 2005 and accepted July 26, 2005)

On the basis of measuring directly water quality parameters at field in the Tatara river in Fukuoka city, Japan as well as water samples have been taken to laboratory for testing, main water quality parameters of the Tatara river have been collected. Field observations and sample collection have been made at one–hour intervals during a 24–hour day in different seasons within a year, and taken place in different sections along the river body. The measurement in site was performed by using the multi–probe (W–23XD series, Horiba, Ltd., Kyoto–Japan). Collected samples have been analyzed in laboratory for total nitrogen (*T–N*) and total phosphorus (*T–P*) by using absorptiometry method. As a result of the research, new important information on water quality of the Tatara river were obtained and analyzed below. Besides, the result of this research would play an important part as inputs for modeling water quality of the Tatara river which would be studied in further researches.

INTRODUCTION

Rivers and streams are the major sources of water for life. Besides providing water for economic development, human consumption, recreational facilities–fishing, boating etc.; they support a large variety of wildlife and they are part of our natural scenic heritage. Due to industrial development, improvements in living standards and changes in agricultural practices, the demand for good quality water is more and more increasing. However, such developments have produced increased amounts of sewage, industrial wastewater, agricultural discharges and agricultural run–off which may cause their water quality to become more and more degraded. In turn, the deterioration in water quality of rivers can directly and indirectly damage human health and economic activities, as well as aquatic plant and animal communities. The health impact is particularly severe in developing countries, where waterborne infectious diseases affect more people than any other health problem (WRI, 1992). Consequently, rivers and streams are still the subject of great environmental concern, and a river water quality monitoring is necessary to gain insight into characteristics of rivers and streams' water quality as well as the fate of constituents in the water bodies. From that perspective, the Tatara river which flows through Fukuoka city and some different areas in Fukuoka Prefecture–Japan, has been

[1] Laboratory of Bioproduction and Environment Information Sciences, Division of Bioproduction and Environment Information Sciences, Department of Bioproduction and Bioenvironment Sciences, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University

* Corresponding author (Email: moriken@bpes.kyushu–u.ac.jp)

chosen to study in an effort to find the primary characteristics of its water quality. Through this research, new valuable information on water quality of the Tatara river has been obtained and presented as below.

MATERIALS AND METHODS

Study area

The Tatara river basin is located in Fukuoka prefecture in the northwestern part of Kyushu Island. The main flow of the Tatara river is added water from two main distributaries: the Umi distributary which joins the Tatara river at the distance of 1.5 km from the river mouth, the Kubara distributary and the Ino distributary with the confluence at 5.2 km from the river mouth. The Tatara river is roughly 21.5 km in length and flows generally from east to west, starting in the mountainous area of Sasaguri town and Hisayama town, and finally discharging into the Hakata Bay–Japan Sea in Fukuoka city. The river has an average width of about 3 m at the head reach and about 30 m at downstream. Along the Tatara river, there are many weirs constructed across the river.

In this research, a segment of the river is selected from a big weir at Tanotsu, which is about 3.2 km from the river's mouth, to upstream of the Tatara river. This segment has a total length of about 18.3 km, and flows through Sasaguri town, Hisayama town and Kasuya town in Fukuoka City.

The total catchment's area is 101.98 km^2, in which 73.23 km^2 is mountainous and forestal area, 15.93 km^2 is residential area, and 9.96 km^2 is paddy fields and agricultural area. There are total 16 weirs across the river, 27 outtake points and 19 intake points along this segment of the river. Almost intakes are used for the purpose of irrigation, some of them supply water for domestic uses through treatment stations. The sources of receiving water are different, including waste water from residential area, agricultural area, drainage of rain water, etc.

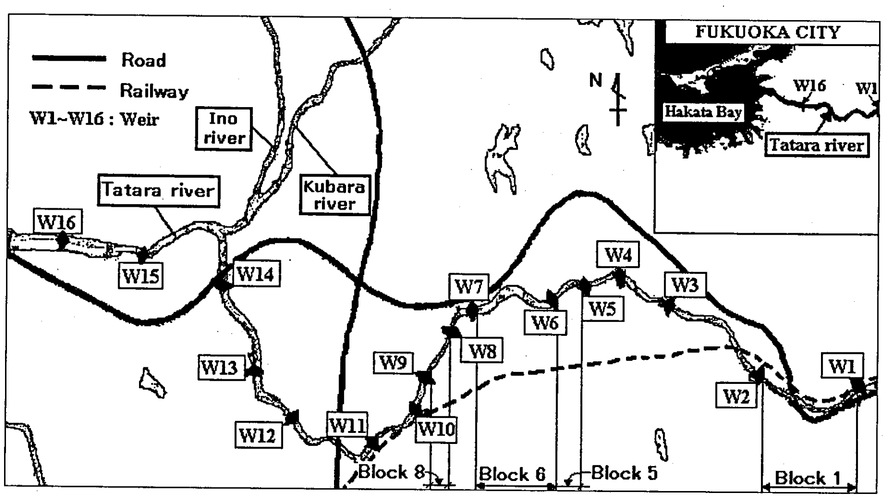

Fig. 1. Location of the studied blocks in Tarara river–Fukuoka, Japan.

For the purpose of the study, this segment of the river is divided into 16 blocks intercepted by weirs at two ends of each block as can be seen in Fig. 1.

Meteorological measurements

Meteorological data that were measured directly in site include solar radiation, air temperature, relative humidity, wind speed and wind–direction. These data were automatically recorded by meteorological sensors at every two minutes during a 24–hour day. They are used as one of the bases accounting for the variation of water quality parameters under the change of meteorological conditions.

Measurement of water quality parameters

The water quality parameters directly measured in site were water temperature (°C), hydrogen ion concentration (*pH*), electric conductivity (mS/m), turbidity (mg/ ℓ), dissolved oxygen (*DO*) (mg/ ℓ), chloride ion (Cl^-) (mg/ ℓ), nitrate ion (NO_3) (mg/ ℓ). These data were measured by using the multi–probe (W–23XD series, Horiba, Ltd., Kyoto–Japan). Total nitrogen (*T–N*) and total phosphorus (*T–P*) were measured by collecting water samples to laboratory for analysis. The analysis of total nitrogen (*T–N*) and total phosphorus (*T–P*) in laboratory were taken by absorptiometry method.

RESULTS AND DISCUSSION

Characteristics of water quality along the whole segment of the river

Along this segment, there are 16 weirs constructed across the river. They are numbered from W1 to W16 as expressed along horizontal axis in Fig. 2 below.

pH change

pH, or the "potential of hydrogen", is a measure of the concentration of hydrogen ions in the water. This measurement indicates the acidity or alkalinity of the water. It is an

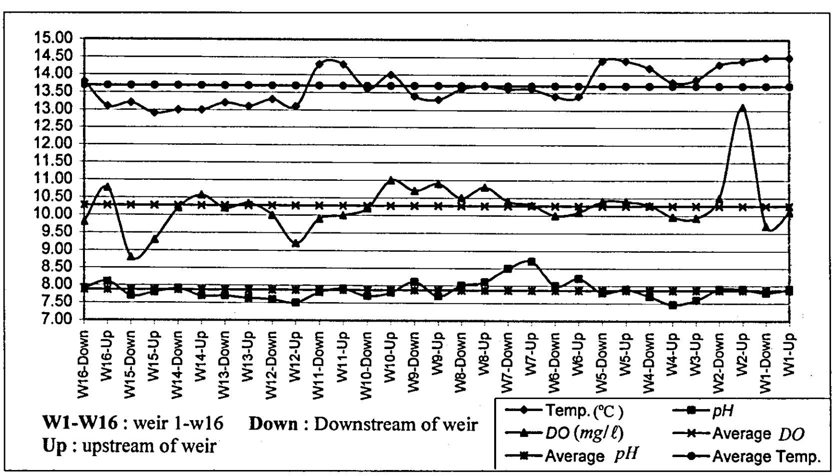

Fig. 2. The variation of water temperature, *pH* and *DO* along the river (Nov. 27, 2003).

important variable in water quality assessment as it influences many biological and chemical processes within a water body and all processes associated with water supply and treatment (UNESCO/WHO/UNEP, 1992). Water with *pH* less than 5 or greater than 9 will support little aquatic life.

The observation results of *pH* are shown in Fig. 2. Along this segment, *pH* fluctuates from the minimum value of 7.47 (at the upstream of weir 4) to the maximum value of 8.7 (at the upstream of weir 7). The average value of *pH* for the whole segment is 7.87. As shown in Fig. 2, all of the values (except for only one value of 7.47 at weir 4) are above 7.5. Generally, the blocks between weir 5 and weir 8 have the high values of *pH* (maximum value is 8.7). This problem will be considered in more detail within each specific block below.

DO change

DO is short for dissolved oxygen. It expresses the amount of oxygen dissolved in water, normally measured in milligrams per liter (mg/ ℓ). The oxygen content of natural waters varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants, and atmospheric pressure (UNESCO/WHO/UNEP, 1992). This component in water is critical to the survival of various aquatic life such as fish. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis.

In general, the value of *DO* below 5 mg/ ℓ is considered unacceptable for most aquatic organisms. As shown in Fig. 2, along the river, the values of *DO* are around 8.8–13.10 mg/ ℓ. The average value for the whole segment is 10.27 mg/ ℓ. These values of *DO* are relatively high.

The fluctuation of *DO* can be caused by various reasons. One of the reasons may be the difference in density of aquatic plants along the river. It leads to contribute the different amounts of *DO* to water when the photosynthesis process takes place. It is also because along the river, there are many sewers discharging different amounts of waste–water with different concentrations of organic matters. As a result, the amounts of *DO* demanded to decompose these organic matters are also different along the river. This also contributes to the fluctuation of *DO* along the river. Besides, physical characteristics of the river also cause the difference in *DO* along the river. For this river, as described above, many weirs were constructed across the river. The presence of these weirs can causes the deficit of *DO* above and below the weirs. This deficit also contribute to the fluctuation of *DO*.

Temperature change

Temperature is a measure of how cool or how warm the water is, normally expressed in degrees celsius (°*C*). Temperature is a critical water quality parameter, since it directly influences the amount of dissolved oxygen that is available to aquatic organisms.

As shown in Fig. 2, water temperature also fluctuates along the river. The maximum water temperature is 14.5 °C while the minimum temperature is 12.9 °C. The average temperature for the whole segment is 13.69 °C.

The fluctuation of water temperature can be explained by some reasons. As we know that water temperature in streams depends on physical characteristics of streams, solar radiation, air temperature as well as regional conditions the streams flow through (for example, shades along the streams). Furthermore, the streams' ratio of width to depth also influences on water temperature. The higher this ratio is, the more sunlight the stream gets. Therefore, water temperature becomes warmer in cross–sections with high width to depth ratio than the cross–sections with low width to depth ratio. For this segment of the river, due to the presence of weirs across the river, the width to depth ratio varies cross–section to cross–section. This leads to difference in water temperature along the river. In addition to the increasing amount of solar radiation reaching the water's surface, the increase of sediments in water also affects water temperature. That is because sediments absorb heat from sunlight rather than reflect it. This heats the water further.

Conductivity change

Conductivity is the ability of the water to conduct an electrical current, normally expressed in microsiemens per centimeter (μS/cm) or milisiemens per meter (mS/m). It is an indirect measure of the ion concentration. The more ions present, the more electricity can be conducted by the water.

Conductivity in water is influenced by the conductivity of rainwater, by road salt application, fertilizer application, and evaporation. Rainwater has variable conductivity depending on whether the rain clouds formed over the ocean (which tends to have higher conductivity due to ocean salts) or land. Besides, land–disturbing activities also tend to elevate conductivity readings, that's why conductivity is usually lowest in stream headwaters. Conductivity can be used as an indicator of human activity.

As shown in Fig. 3, conductivity tends to increase from upstream (at minimum value of 15.6 mS/m) to downstream (at maximum value of 32.40 mS/m). This means that there are more ions present downstream than those upstream. It can be explained that along the river, there are many sewers discharging waste–water that maybe contains various ions. Besides, the river flows through paddy–fields that may contribute ions to the river due to fertilizer application. Therefore, the longer it is from upstream, the more ions are accumulated. This leads to the higher conductivity downstream than that upstream.

In general, there is no single water quality standard determined for conductivity. However, a higher conductivity indicates that more material is dissolved material, which may contain more contaminants.

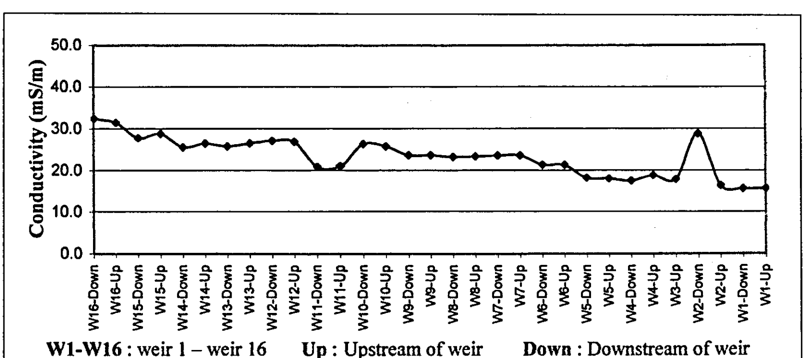

Fig. 3. The variation of conductivity along the river (Nov. 27, 2003).

NO_3^- change

Nitrate (NO_3^-) is one of primary nitrogen-containing compounds. In general, about 90% of the nitrogen in underground water and in river water is in the form of nitrate nitrogen (Nakasone, 2003). Nitrate is the ultimate result of the nitrification process as shown in Fig. 4 below (Chapra, 1997).

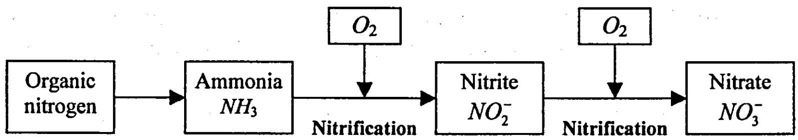

Fig. 4. The process of forming ion NO_3^- in natural water.

Because NO_3^- is the primary source of nitrogen for plants and serves as an algal nutrient contributing to excessive stream and reservoir algal growth. Besides, it can be converted to a very toxic substance (NO_2^-) in the digestive systems of human infants and some livestock. Therefore, nitrate-contanminated water is a serious problem. For those reasons, nitrate is a good indicator for assessing water quality.

It can be seen in Fig. 5, like conductivity, NO_3^- also tends to increase from upstream to downstream. It has the minimum value of 6.6 mg/ℓ at the upstream of the weir 2 and has the maximum value of 34.67 mg/ℓ at the upstream of the weir 16. The average value for the whole segment is 15.05 mg/ℓ.

The reason for the increasing tendancy of nitrate from upstream to downstream can be that along the river, there are many inflows discharging into the river. Each inflow contains an mount of NO_3^- distributing to the river as a point-source pollution. Besides,

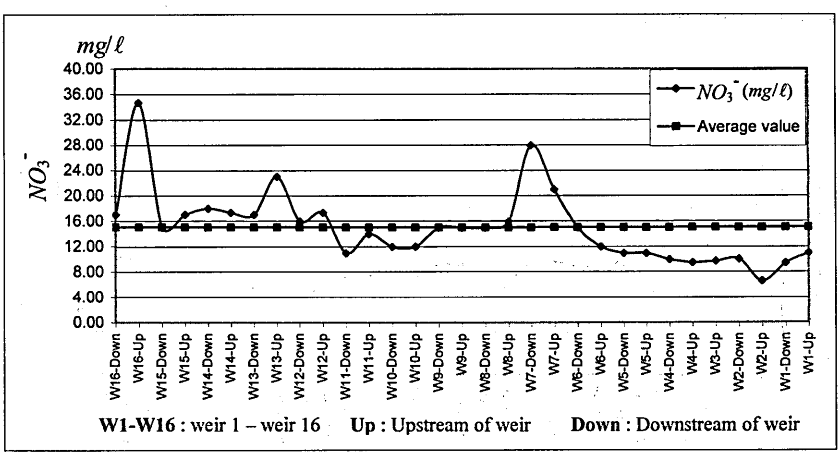

Fig. 5. The variation of ion NO_3^- along the river (Nov. 27, 2003).

due to flowing through paddy–fields, these paddy–fields may contribute NO_3^- to the river as the non–point source pollution through fertilizer application. NO_3^- from those sources flows downstream, it leads to that more and more NO_3^- would be accumulated downward stream.

T–N change

Total nitrogen (*T–N*) is a measure of all the various forms of nitrogen including inorganic and organic forms that are found in a water sample.

Nitrogen is an essential nutrient for all plants, including aquatic plants and algae. Thus it acts as a fertilizer that can overstimulate plant growth in the process called eutrophication. This excess growth can impact water quality directly. That's why it is a good indicator for assessing water quality.

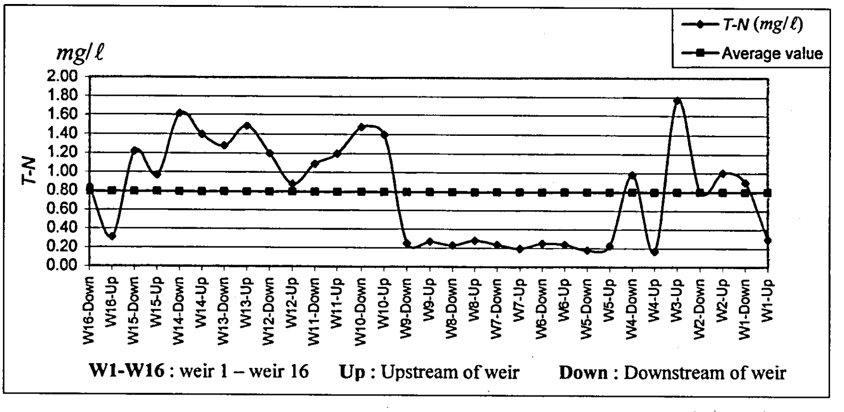

Fig. 6. The variation of *T–N* along the river (Nov. 27, 2003).

As shown in Fig. 6, along the river, *T–N* fluctuates with a relatively high amplitude from the maximum value of 1.77 mg/ ℓ at the upstream of weir 3 to the minimum value of 0.17 mg/ ℓ at the upstream of weir 4. It can be seen that from the downstream of weir 1 to the upstream of weir 3 and from the upstream of weir 10 to the downstream of weir 15, the values of *T–N* are relatively high while from the upstream of weir 5 to the downstream of weir 9, *T–N* remains relatively stable at the value of about above 0.2 mg/ ℓ. The reason for this is that along the river from weir 1 to weir 3 and from weir 9 to weir 15, there are some big inflows that maybe contribute a significant amount of *T–N* to the river.

Daily cyclic characteristics of water quality in the Tatara river

To understand daily cyclic characteristics of water quality in the Tatara river, four specific blocks of the river with the different physical characteristics described in Table 1 below.

The daily cyclic variation of water temperature

It can be seen from the Fig. 7 that the daily alteration of water temperature is directly proportional to that of air temperature and solar radiation. During a daylight, due to the increase of air temperature and solar radiation, water temperature also increases.

Table 1. Some primary characteristics of the studied blocks.

Characteristics of the block	Block			
	Block 1	Block 5	Block 6	Block 8
Mean discharge Q_{mean} (m^3/s)	0.47	0.28	1.03	1.24
Mean velocity V_{mean} (m/s)	0.58	0.28	0.50	0.08
Mean depth h (m)	0.38	0.24	0.28	0.88
Mean width b (m)	2.13	4.17	7.38	17.61
Total length L (m)	1,100	425	450	450
Regional characteristic	forestal and mountainnous area	residential area	fields and paddy fields area	mixed area.
Note	Measured on Feb. 2 & 3, 2004	Measured on Apr. 20 & 21, 2004	Measured on June 7 & 8, 2004	Measured on Feb. 11 & 12, 2004

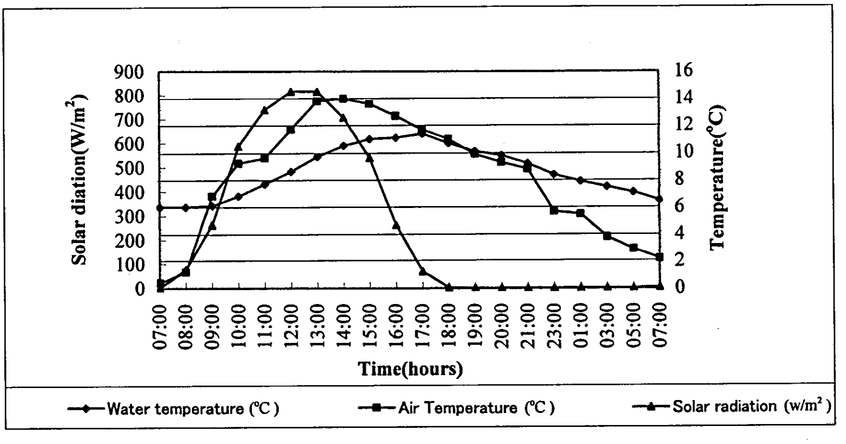

Fig. 7. The daily cyclic variation of water temperature in relationship to air temperature and solar radiation at the downstream of weir 8 (block 8) (Feb. 11 & 12, 2004).

In contrary, at night when air temperature decreases, and solar radiation is extinct, as a result, water temperature also decreases.

It also can be seen that solar radiation reaches at peak some hours earlier than the peak water temperature occurs. Solar radiation reaches at peak at about 12pm o'clock while the peak water temperature occurs at about 17pm o'clock (at the downstream of weir 8–Fig. 7) and at 15pm o'clock (at the downstream of weir 5–Fig. 8). It accounts for

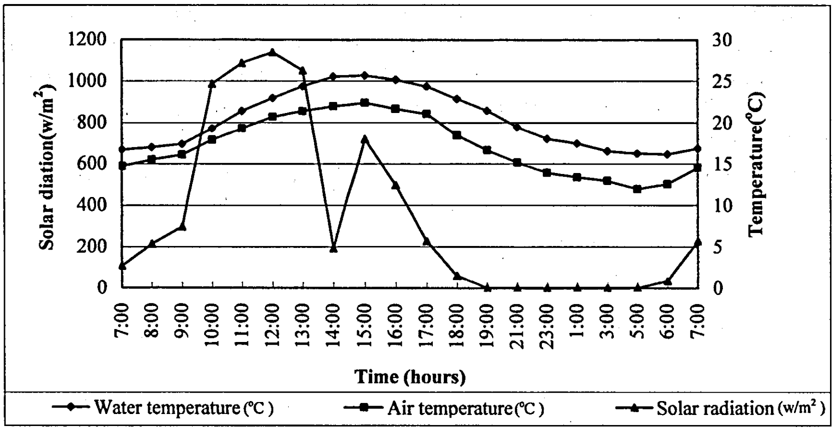

Fig. 8. The daily cyclic variation of water temperature in relationship to air temperature and solar radiation at the downstream of weir 5 (block 5) (Apr. 20 & 21, 2004).

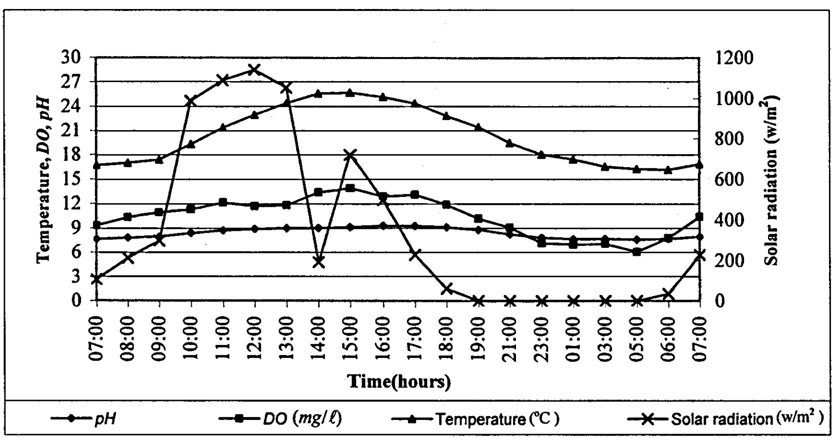

Fig. 9. The daily cyclic variation of *DO*, *pH* and water temperature at the downstream of weir 5 (block 5) in relationship to solar radiation (Apr. 20 & 21, 2004).

the fact that it takes time to transfer the heat energy from solar radiation into water. We also can see that air temperature peaks some hours earlier than (Fig. 7) or about the same time (Fig. 8) as the peak water temperature occurs.

This daily cyclic variation of water temperature also agrees with the result of simulation of water temperature in the Tatara river before (Lap *et al.*, 2005).

The daily cyclic variation of DO

It can be seen from the Fig. 9 that during the day–time from 7 am to 15 pm o'clock,

DO increases steadily and reaches its maximum value of 13.9 mg/ ℓ at 15 pm o'clock. In contrary, from 15 pm to 5 am o'clock of the next day, DO decreases steadily and reaches its minimum value of 6.10 mg/ ℓ. From 5 am to 7 am o'clock of the next day, DO tends to increases again. The reason for this phenomenon can be interpreted by photosynthesis/respiration process.

During the day when there is light, along with the presence of chlorophyll in water, photosynthesis process takes place in the forward direction as follows :

$$6CO_2 + 6H_2O \underset{\textbf{respiration}}{\overset{\textbf{photosynthesis}}{\rightleftharpoons}} 6O_2 + C_6H_{12}O_6$$

That's why DO often increases in the day. At night, due to the lack of light, photosynthesis process does not dominate anymore, instead of that, respiration process will dominate because the organic matter is broken down by organisms and oxygen is consumed in this process. Respiration process takes place in the backward direction as described above. This process causes DO to decrease during night–time.

From the Fig. 9, we also see that the variation of DO seems to be directly proportional to the variation of water temperature. Both water temperature and DO reach their peak at the same time (15 pm o'clock), it is also true for their minimum value (at 5 am o'clock). The directly proportional variation between water temperature and DO seems to be abnormal because it is usual that the ability of water to hold oxygen in solution is inversely proportional to the temperature of water. This phenomenon can be explained that the amount of DO produced by photosynthesis is much higher than that of DO escaping from water due to the increase of water temperature.

In contrary to the phenomenon took place in block 5 above, the variation of DO in block 1 as described in Fig. 10 seems to be insignificant. The variable amplitude of DO during a daily cycle is not large (the maximum value of DO is 12.4 mg/ ℓ at 11 am o'clock, and the minimum value is 11.4 mg/ ℓ at 18pm o'clock). From the Fig. 10 we can see that

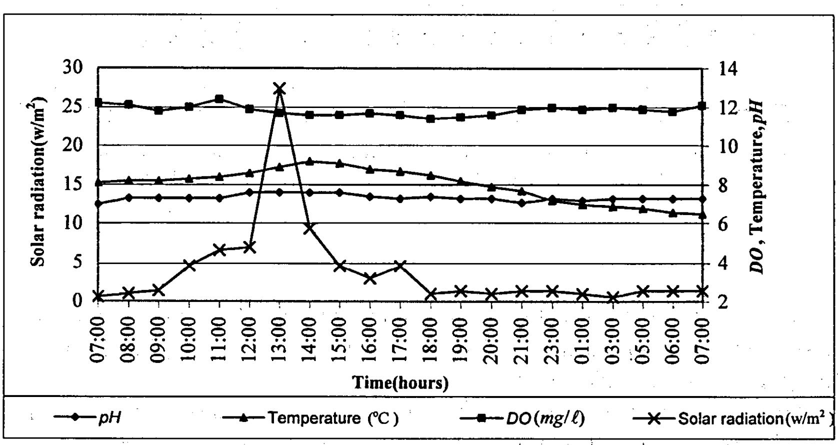

Fig. 10. The daily cyclic variation of DO, pH and water temperature at the downstream of weir 1 (block 1) in relationship to solar radiation (Feb. 2 & 3, 2004).

DO decreases slightly during the time when water temperature increases.

This is normal because the ability of water to hold oxygen in solution is inversely proportional to the temperature of the water.

The difference in variation of *DO* between block 1 and block 5 can be explained that block 1 is in the upstream of the river, it flows through forestal and mountainous area while block 5 is in resident area. Therefore, water in block 1 bears less wastewater as well as algae and aquatic plants than water in block 5. This is the reason that causes the significant variation of *DO* in block 5.

The daily cyclic variation of pH

From the Fig. 9 & 10 and especially in Fig. 11, we can see that the variation of *pH* also seems to be directly proportional to the variation of temperature.

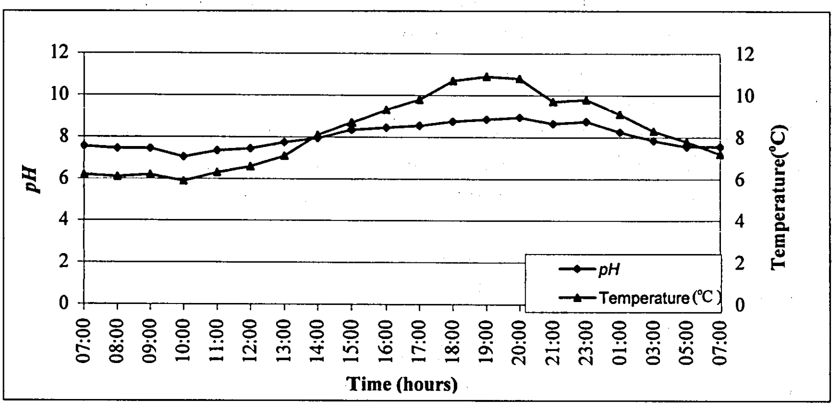

Fig. 11. The daily cyclic variation of *pH* in relationship to water temperature at the upstream of weir 9 (block 8) (Feb. 11 & 12, 2004).

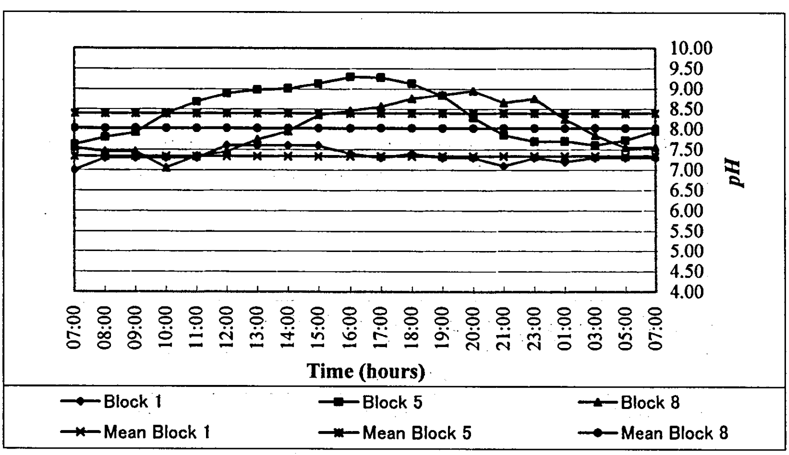

Fig. 12. The daily cyclic variation of *pH* in the blocks 1, 5, 8 and their mean values.

We can see in Fig. 12 during a daily cycle, the *pH* in block 1 remains the most stable, it fluctuates from the minimum value of 7.0 to the maximum value of 7.6. The mean value of *pH* is 7.34. In contrary, the *pH*s in the blocks 5 & 8 fluctuate with a relatively high amplitude.

In block 5, the maximum value of *pH* is 9.30 while the minimum value is 7.61. The mean value of *pH* is relatively high (8.39). Similarly, in block 8, the minimum value of *pH* is 7.05 while the maximum value is 8.95. The mean value of *pH* in block 8 is also high (8.03).

The difference in the range of *pH* fluctuation in each block is a sign of showing water quality in upstream river better than that in downstream blocks.

The daily cyclic variation of conductivity

In general, during a daily cycle, conductivity in different blocks fluctuates very slightly as can be seen in the Fig. 13. The Fig. 13 also shows that water in block 1 has the lowest value of conductivity (the mean value of 23.3 mS/m) while its largest value appears in block 8 (the mean value of 27.42 mS/m).

The daily cyclic variation of T–N

From the Fig. 14, we can see that the variation of *T–N* in different blocks is very random. In general, *T–N* fluctuates with a large amplitude. However, the mean value of *T–N* in block 1 is the lowest (1.077 mg/ ℓ) while this value in block 8 is the highest (1.206 mg/ ℓ).

The mean value of *T–N* in all blocks is higher than Japan's *T–N* standard for fishery and agriculture ($\leq$ 1 mg/ ℓ) (MEJ, 1993).

The daily cyclic variation of T–P

Like *T–N*, *T–P* presented in the Fig. 15 also fluctuates randomly. In block 5, *T–P* has its maximum value of 0.17 mg/ ℓ while its maximum value is 0.31 mg/ ℓ in block 6. As can be seen in Fig. 15, the mean value of *T–P* in block 5 is 0.059 mg/ ℓ, which is higher than that in block 6 (the mean value is 0.052 mg/ ℓ).

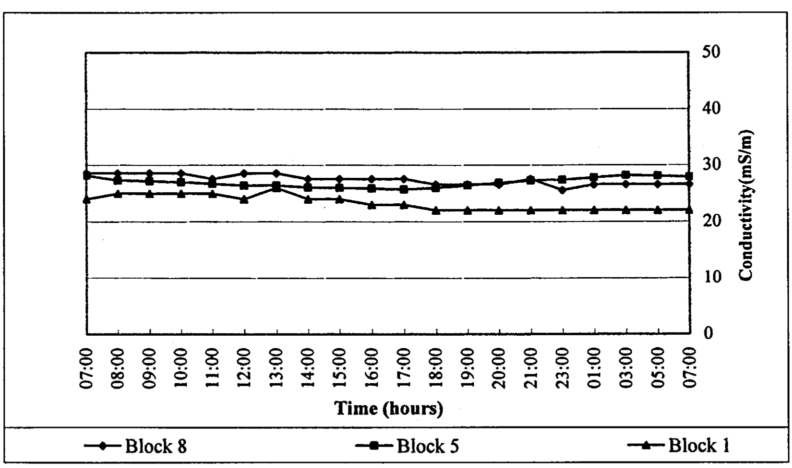

Fig. 13. The daily cyclic variation of conductivity in the blocks 1, 5 and 8.

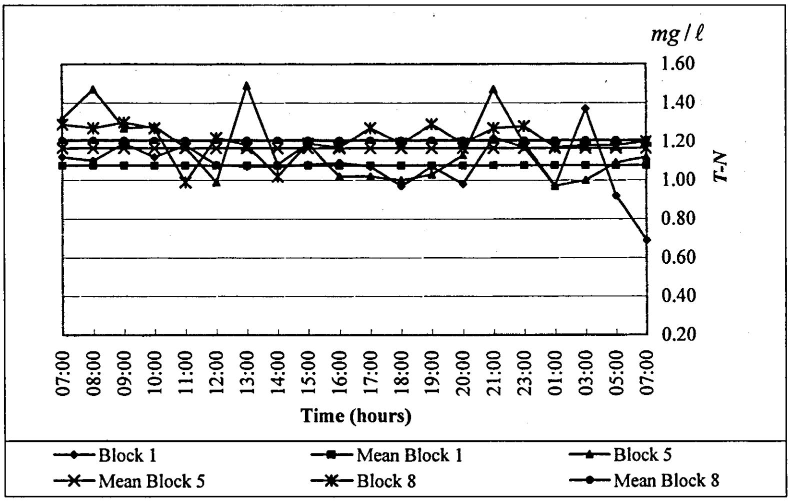

Fig. 14. The daily cyclic variation of *T–N* in the blocks 1, 5 and 8.

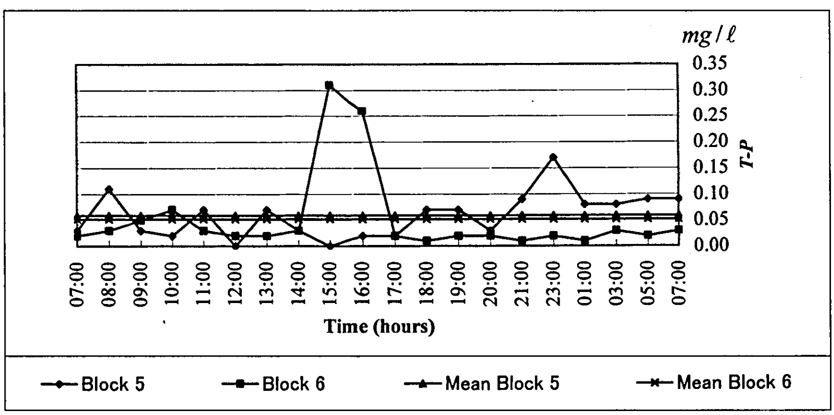

Fig. 15. The daily cyclic variation of *T–P* in the blocks 5 and 6.

CONCLUSIONS

From the data gathered and analyzed above, some characteristics of water quality in the Tatara river would be summarized as follows :

1. Along the river, water temperature varies depending on physical attributes of the river such as the path it flows, width, depth, and velocity as well as depending on the climate conditions of the regions it flows through. In general, at the cross–sections where the ratio (width/depth) is large, water temperature tends to become warmer than at cross–sections with this smaller ratio. During a daily cycle, water temperature in the

river depends closely on air temperature, solar radiation, wind speed and relative humidity.

2. *DO* tends to decrease from upstream to downstream. During a daily cycle, *DO* in the upstream tends to remain more stable than *DO* in the downstream. The reason for this phenomenon is that water in the downstream may contain more alge, aquatic plants and organic matters discharging from paddy fields and resident areas than water in the upstream. In turn, aquatic plants and organic matters affect *DO* concentration in water downstream, and make *DO* more fluctuate in the downstream than in the upstream. However, the mean value of *DO* concentration in the river is relatively high (above 10 mg/ ℓ). It satisfies Japan's Environmental Quality Standards for Conservation of the Living Environment (MEJ, 1993) as *DO* of river water of the class A ($DO \geq 7.5$ mg/ ℓ).
3. Along the river, *pH* fluctuates with a acceptable amplitude (7.47–8.70). However, during a daily cycle, *pH* in water upstream seems to be more stable than *pH* in water downstream. The *pH* downstream fluctuates with a relatively high amplitude (7.61–9.30 in block 5) while the *pH* in block 1 varies only from 7.0 to 7.6. The variation of *pH* seems to be directly proportional to water temperature. Besides, the mean value of *pH* tends to increase from upstream to downstream (can be seen in Fig. 12). In general, the average value of *pH* also satisfies Japan's Environmental Quality Standards for Conservation of the Living Environment (MEJ, 1993) ($8.5 \geq pH \geq 6.5$).
4. Along the river, conductivity tends to increase from upstream to downstream (can be seen in Fig. 3). This is a sign of showing water in the upstream less polluted than water in the downstream. During a daily cycle, conductivity at specific cross–sections varies very slightly.
5. Like conductivity, NO_3^- also tends to increase from upstream to downstream.
6. *T–N* and *T–P* in the river fluctuate randomly both along the river and during a daily cycle. *T–N* seems to be lower in dry season than in rainy season due to the contribution of nitrogen from rain water as well as nitrogen leaching from paddy fields by rainwater to the river. In general, the *T–N* concentration in the river is relatively high (above 1 mg/ ℓ) compared with Japan's *T–N* standard for fishery and agriculture ($\leq$ 1 mg/ ℓ) (MEJ, 1993).

REFERENCES

Chapra, S. C 1997 *Surface water–quality modeling.* McGraw–Hill, New York

Horiba, Ltd. 2001 Multi–Probe W–20XD Series W–22XD.23XD. *Operation Manual.* Kyoto – Japan

Lap, B. Q., K. Mori and E. Inoue 2005 Building a mathematical model for simulating river water quality, a case of study applied to the Tatara river in Fukuoka city. *J. Fac. Agr., Kyushu Univ.*, **50**(1): 175–187

Ministry of the Environment of Japan (MEJ) 1993 Environmental quality standards for water pollution. *in* http://www.env.go.jp/en/lar/regulation/wp.html

Nakasone, H 2003 Runoff water quality characteristics in a small agriculture watershed. *Paddy Water Environ.*, **1**(4): 183–188

UNESCO/WHO/UNEP 1992 Water Quality Assessments – A Guide to Use of Biota, Sediments and Water in Environmental Monitoring–Second Edition. In http://www.who.int/docstore/water_sanitation_health/wqassess/begin.htm#Contents

World Resources Institute (WRI) 1992 World resources 1992–1993. *in* http://www.ciesin.org/docs/006–307/006–307.html