International Journal of GEOMATE, June, 2016, Vol. 10, Issue 22, pp. 2043-2049
Geotec., Const. Mat. &Env., ISSN: 2186-2982(Print), 2186-2990(Online), Japan

DISTRIBUTION CHARACTERISTICS OF THE ANNUAL NITROGEN LOAD IN YAMATO RIVER BASIN IN 2011

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ABSTRACT: Although there was not enough data to calculate the amount of nitrogen load in the Yamato River basin, some estimation methods were applied for calculation. The estimation of flow rate was made using a calculation of the cross section and velocity using a new method to estimate velocity from cross section and water level values based upon the modified Manning equation. The estimation of total nitrogen concentration was calculated using EC and water level values or flow rate. As a result, the annual total nitrogen load at Kashiwara, Fujii, Itahigashi, Hota, Shintatsuta, Nukatabetakabashi, and Kamihanda stations and the Nara sewage treatment plant were estimated to be 1856, 1793, 751, 498, 260, 188, 83 and 481t/year in 2011. The amounts of total nitrogen load from two sewage treatment plants reached 900t/year, about 45% of those at the Yamato River basin. The annual total nitrogen load at Kashiwara Station under flood conditions with over 24m^3/sec of flow rate and excluding flood conditions were calculated to be 835 and 1021t/year in 2011. The annual total nitrogen load at Fujii Station was calculated to be 1013t/year under flood conditions with over 22m^3/sec of flow rate and excluding flood conditions to be 780t/year in 2011.

Keywords: the Yamato River, nitrogen load, flow rate, distribution, flood

1. INTRODUCTION

The Yamato River had problems with water quality during its high growth period in the 1970s. In recent years, the water quality has been improved by the installation of a sewage system in the whole of the Nara Basin. However, total of nitrogen load in the Yamato River did not decrease and the river water was still in eutrophication.

Nitrogen load under flood conditions is high because precipitated soil at river floor and riverbed includes nitrogen and some soil sediment flows out by flooding. Measurement under flood conditions is necessary for the estimation of nitrogen load, although measurement in flood conditions is dangerous and there are few data at automatic observing stations. Resultingly, there was not enough data to calculate the amount of nitrogen load in the Yamato River basin[1]. Therefore flow rate was calculated from the cross section and velocity using a new method to estimate velocity from cross section and water level values based upon the modified Manning equation. Total nitrogen concentration was calculated using EC and water level values or flow rate. The research object is to analyze distribution of total nitrogen at the Yamato River basin.

2. RESEARCH AREA AND METHOD

Fig.1 shows land use map of the Yamato River basin. The map was produced from data of land numerical information released by Ministry of Land, Infrastructure and Transport in 2006[2]. Green, yellow, pale blue and purple colors show forests, orchards, rice fields and housing sites. The area of the Yamato River basin is 1070km^2. The population of the basin is about 2 million people. The basin has big cities in its upper stream, and the population of the Nara Basin is 1 million people. Population increased significantly in high-growth period. The sewage system has been in use since 1970s. The cover area of the sewage system was 7.4% in 1975, 33% in 1990, 58.7% in 2000 and 85.3% in 2013[3].

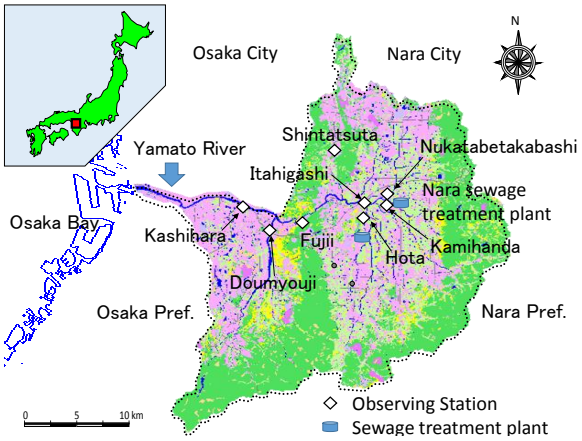

Fig. 1 Land use of the Yamato River basin

The analysis of nitrogen load was performed using data for the water information system of Ministry of Land, Infrastructure and Transport.

However there was not enough data to calculate the amount of nitrogen load in the Yamato River basin, so some estimation methods were applied for making this calculation[4]. The river cross section was measured at the field to apply estimation method.

3. TIME SERIES OF FLOW RATE AND NITROGEN LOAD IN REAL DATA

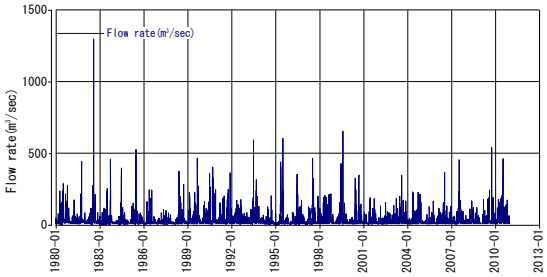

Fig. 2 Daily flow rate at Fujii Station (lowest stream in the Nara Basin)

Fig.2 shows daily flow rate at the Fujii observation station which is located at the lowest stream in the Nara Basin. At the observing station water level, flow rate, and water quality values were measured. The maximum flow rate was about 1300m^3/sec in 1982 while on the other hand, the normal flow rate on a fine day was only about 13m^3/sec.

The daily flow rate was calculated from daily automatic water level data and published by Ministry of Land, Infrastructure and Transport. However data for water level in 2011 was just published and then daily flow rate was calculated from the automatic daily water level data.

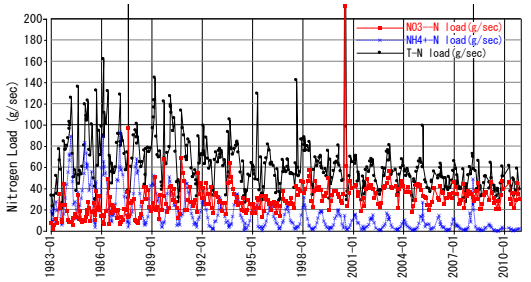

Fig. 3 Daily total nitrogen, NO_3-nitrogen and NH_4-nitrogen loads at Fujii Station.

Fig.3 shows daily total nitrogen, NO_3-nitrogen and NH_4-nitrogen loads at Fujii Station. The sampling for analyzing total nitrogen, NO_3-nitrogen and NH_4-nitrogen concentrations was performed once at a month. Usually the sampling day for nitrogen was not on a rainy day and sampling was not performed in particular under flood conditions because of safety. Therefore, the daily nitrogen load was calculated from daily flow rate and monthly nitrogen concentration. Therefore, nitrogen load data did not include rainy days and flood conditions. Subsequently, the daily total nitrogen load on fine days varied, decreasing from 80 to 50g/sec since 1986. Similarly, NH_4-nitrogen load on fine days varied, decreasing from 40 to 3g/sec since 1986. However, daily NO_3-nitrogen load on fine days increasing 5 to 35g/sec since 1983. During this period, the covering area of the sewage system in the Yamato River basin increased 7 to 85%[5] .

4. FLOW RATE AND TOTAL NITROGEN LOAD AT FUJII

The Fujii Station data is important in calculating the total load of the Nara Basin because it is the lowest point in the Nara Basin. However there was no flow rate data at Fujii Station in 2011 so it was necessary to estimate the flow rate. Flow rate in 2011 had to be calculated from water level value using relation between water level and flow rate values.

Flow rate can be estimated from water level, river cross section and velocity. River velocity is calculated by the following equation[6].

$$v = \frac{1}{n} a^{\frac{1}{2}} H^{\frac{1}{6}} \qquad (1)$$

v:velocity, *n*:Roughness coefficient, *a*:Eigenvalue of observatory, *H*: average water depth

Water level is different from average water depth. Average water depth can be calculated from cross section and water level values. This equation was derived from the Manning equation. In the Manning method, Hydraulic radius(*R*) can be replaced by *H* in general in big rivers. Then, the Manning equation can be modified into the following equation.

$$v^2 = \frac{1}{n^2} H^{\frac{1}{3}} H^{\frac{3}{3}} I^{\frac{2}{2}} \qquad (2)$$

$$a = HI \qquad (3)$$

I:Hydraulic gradient

Equation (2) is made by substituting equation (3) into the equation (1). From equation (3), *HI* (multiplication between average water depth and hydraulic gradient) is a stable value. Then fig.4 shows the relation between average water depth and Hydraulic gradient (*I*).

The parameter *a*,eigenvalue of observatory at Fujii Station was calculated to be 0.034 from data as shown in fig.4. Hydraulic gradient was 0.034 divided with average water depth at Fujii Station and then velocity could be calculated from average water depth. Average water depth at Fujii Station

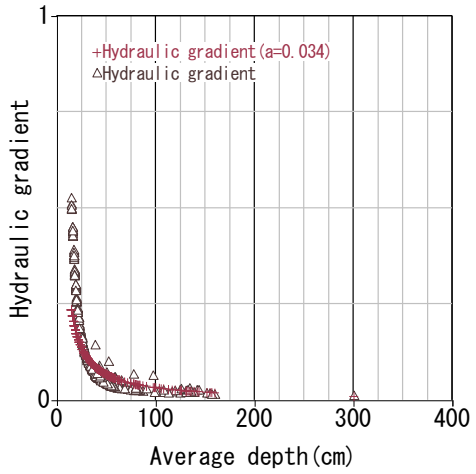

Fig.4 Relation between average water depth and hydraulic gradient (*I*) at Fujii Station in 2010

in 2011 could be calculated from cross section measured by our work before measurement and water level value measured by Ministry of Land, Infrastructure and Transport. The roughness coefficient, n is generally 0.100 for the natural river. Therefore, flow rate at Fujii Station in 2011 was calculated from both average water depth and velocity values determined by water level value measured by Ministry of Land, Infrastructure and Transport. Fig.5 shows the calculated daily flow rate at Fujii Station in 2011.

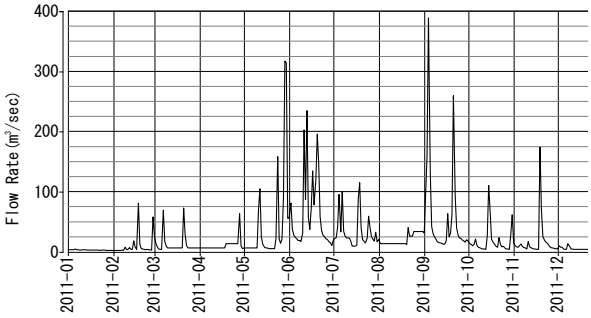

Fig.5 Calculated daily flow rate at Fujii Station in 2011

Fig.6 shows the relation between daily water level and EC values in 2011 at Fujii Station. The EC value decreased with water level value. The regression line between water level and EC value was shown by the following equation.

$$EC = \frac{24.147}{WL} \qquad (4)$$

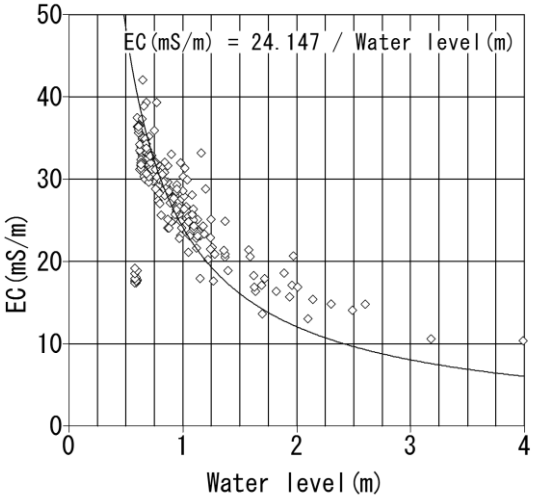

Fig. 6 Relation between daily water level and EC values at Fujii Station in 2011

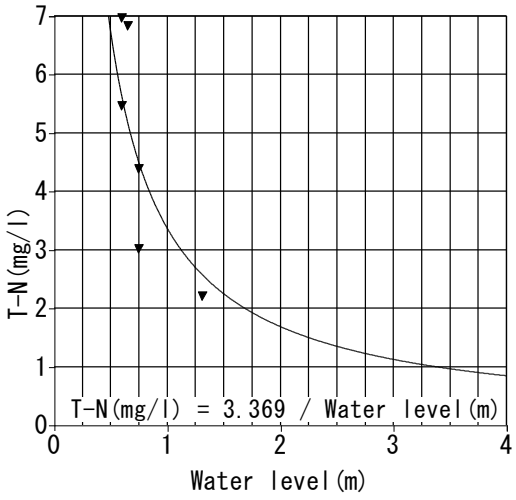

Fig. 7 Relation between monthly water level value and total nitrogen concentration in 2011 at Fujii Station

Fig.7 shows relation between monthly water level value and total nitrogen concentration in 2011 at Fujii Station. The total nitrogen concentration also decreased with water level value. The regression line between water level and EC value was shown by the following equations.

$$TN = \frac{3.369}{WL} \qquad (5)$$

$$TN = 0.140EC \qquad (6)$$

Equation (6) is made by substituting equation (4) into equation (5).

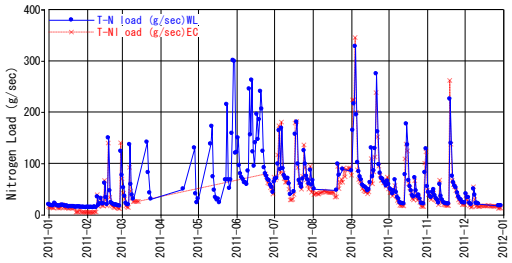

Fig.8 Daily total nitrogen load at Fujii Station in 2011

Fig.8 shows two kinds of daily total nitrogen load at Fujii Station calculated from water level and EC values in 2011. The annual total nitrogen load at Fujii Station was calculated to be1793t/year based on the daily calculated data. The annual total nitrogen load at Fujii Station under flood conditions with over 22m^3/sec of flow rate was calculated to be 1013t/year and average load was 126g/sec in 2011. The annual total nitrogen load excluding flood conditions was 780t/year and average load was 33g/sec. Therefore the total nitrogen load at Fujii Station increased with flow rate and the total nitrogen load under flood conditions was important because 56% of the total load was derived from under flood conditions.

5. FLOW RATE AND TOTAL NITROGEN LOAD AT KASHIWARA

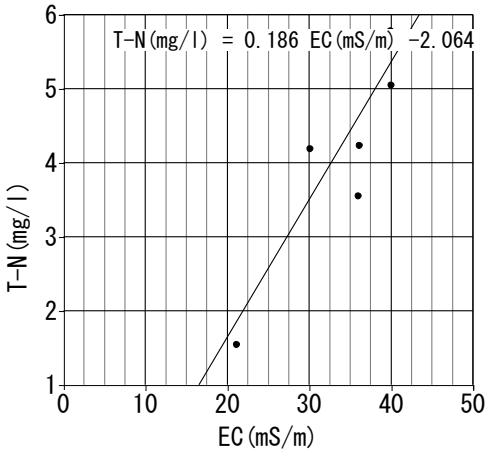

Fig. 9 Relation between EC and T-N concentration (mg/l) at Kashiwara Station in 2011

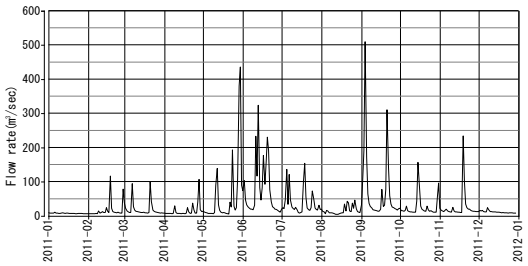

Fig.10 Daily flow rate at Kashiwara Station in2011

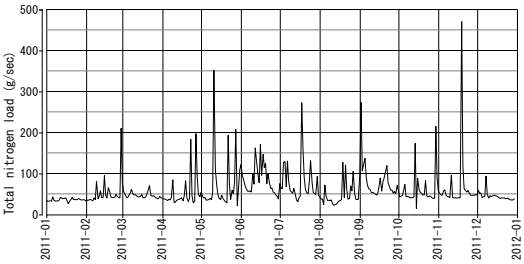

Fig.11 Daily total nitrogen load at Kashiwara Station in 2011

The Kashiwara observing station is located at the middle stream in the Yamato River (Fig.1) and downstream of Fujii Station. At Kashiwara Station daily flow rate, daily EC and water level data were measured by Ministry of Land, Infrastructure and Transport however total nitrogen concentration was only measured once a month in 2011. Then total nitrogen concentration was estimated from EC value as well as Fujii Station. Fig.9 shows the relation between total nitrogen concentration and EC value which was on the one line in 2011. The relation between total nitrogen concentration and EC value was shown by the following equation as well as Fujii Station.

$$TN = 0.186 \times EC - 2.064 \qquad (7)$$

The calculated total nitrogen load at Kashiwara Station was shown as in fig.10 based upon equation (7). Maximum nitrogen load in rain day was extremely high 480g/sec however less than 60g/sec on fine days from fig.10. The annual total nitrogen load at Kashiwara Station was calculated to be 1857t/year in 2011. The annual total nitrogen load at Kashiwara Station under flood conditions with over 24m^3/sec of flow rate was calculated to be 835t/year and average load was 108g/sec in 2011. The annual total nitrogen load excluding flood conditions was 1021t/year and average load was 43g/sec. Therefore the total nitrogen load at Kashiwara Station increased with flow rate and the total nitrogen load under flood conditions was important because 45% of the total load was derived from under flood conditions.

6. FLOW RATE AND TOTAL NITROGEN LOAD AT THE UPSTREAM OF FUJII

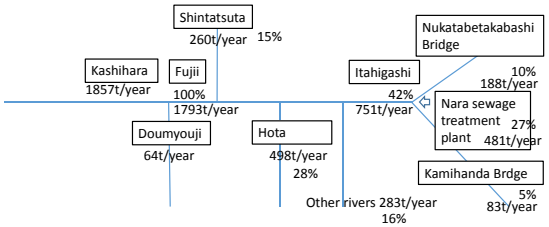

Fig.12 Distribution the total nitrogen load of the Yamato River system

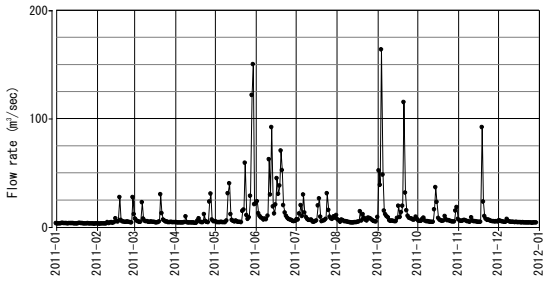

Fig.13 Daily flow rate at Itahigashi Station in2011

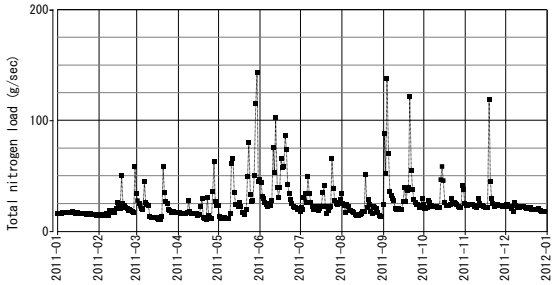

Fig.14 Daily total nitrogen load at Itahigashi Station in 2011

There are Itahigashi, Hota, and Shintatsuta stations at the upstream of Fujii Station and the Nara sewage treatment plant and Nukatabetakabashi and Kamihanda stations at the upstream of Itahigashi Station as shown in fig.11.

Daily flow rate was measured at Itahigashi observing station shown in fig.13 however total nitrogen concentration and EC were not measured as well as Kashiwara Station. Then the total nitrogen load at Itahigashi Station was determined from flow rate at Itahigashi Station comparing with flow rate at Fujii Station shown in fig.14. Fig.15 shows relation between the flow rate at Fujii and Itahigashi Stations in 2011. The total nitrogen load was calculated from ratio of the flow rate at Fujii and Itahigashi. The flow rate at Itahigashi Station was 42% of that at Fujii Station in 2011 and then the total nitrogen load was assumed to be rate with flow rate. The total nitrogen load at Itahigashi Station was calculated to be 751t/year.

There were very limited data about flow rate and nitrogen concentration and only flow rate data at Hota Station between 1997 and 1999. Then fig.16 shows the relation between the flow rate at Fujii and Hota stations between 1997 and 1999. As well as Itahigasi Station the total nitrogen load was calculated from ratio of the flow rate at Fujii and Hota stations. The flow rate at Hota Station was 28% of that at Fujii Station between 1997 and 1999 and then the total nitrogen load was assumed to be rate with flow rate. The total nitrogen load at Hota Station was calculated to be 498t/year.

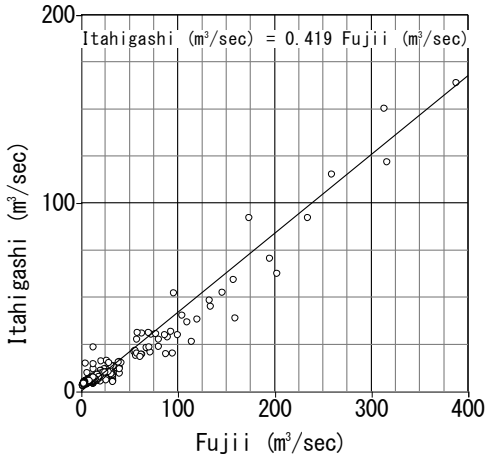

Fig. 15 Relation between the flow rate at Fujii and Itahigashi stations in 2011

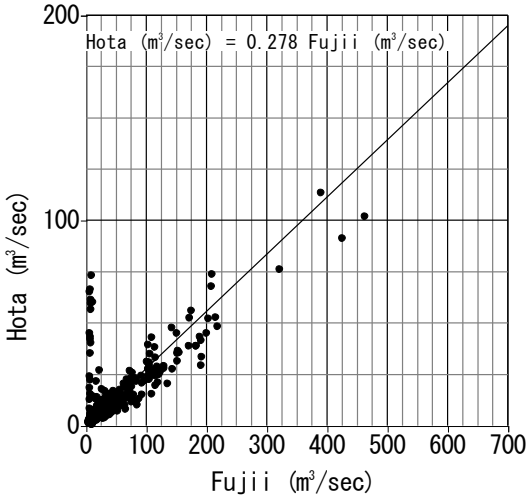

Fig. 16 Relation between the flow rate at Fujii and Hota stations from 1997 to1999

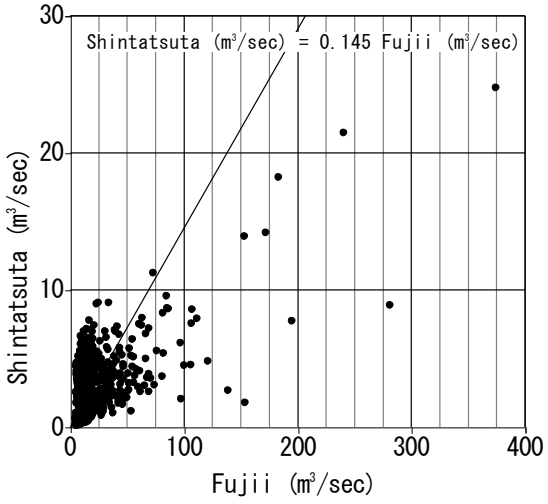

Fig. 17 Relation of flow rate at between Fujii and Shintatsuta stations from 1986 to1989

There were very limited data about flow rate and nitrogen concentration as well as Hota Station and only flow rate data at Shintatsuta Station between 1986 and 1989. Then fig.17 shows the relation between the flow rate at Fujii and Shintatsuta stations between 1986 and 1989. As well as Hota Station the otal nitrogen load was calculated from ratio of the flow rate at Fujii and Shintatsuta stations. The flow rate at Shintatsuta Station was 15% of that at Fujii Station between 1986 and 1989 and then the total nitrogen load was assumed to be rate with flow rate. The total nitrogen load at Shintatsuta Station was calculated to be 260t/year.

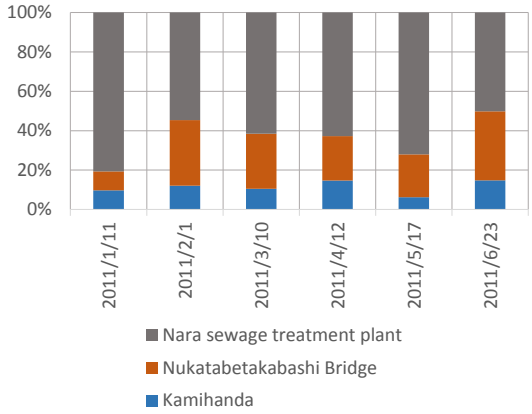

Fig. 18 Ratio of flow rate at the upstream of Itahigashi

Next, the total nitrogen load at the upstream of Itahigashi was estimated however there were very limited data about flow rate and nitrogen concentration. Flow rate at the upstream of Itahigashi Station was measured just 6 times in 2011. Flow rate at upstream of Itahigashi Station was sum of those at Nukatabetakabashi and Kamihanda stations and the Nara sewage treatment plant. Fig.18 shows the ratio of flow rate at the upstream of Itahigashi based upon 6 measured flow rate values. Flow rate at the Nara sewage treatment plant was over 50 % of that at Itahigashi Station. The total nitrogen load at Itahigashi Station was 751t/year and each total nitrogen load was calculated based on the flow rate ratio among them. As a result, the total nitrogen loads at Nukatabetakabashi and Kamihanda stations and the Nara sewage treatment plant were 188, 83 and 481t/year.

The difference of the total nitrogen load between Kashiwara and Fujii stations was derived from that at Doumyoji Station and 64t/year. Ratio of the total nitrogen load in the Yamato River basin in 2011 was shown in Fig.19.

There is another sewage treatment plant at the upstream of Hota Station and the total nitrogen load at Hota Station was high, 498t/year relative to the Yamato River basin. Therefore the total

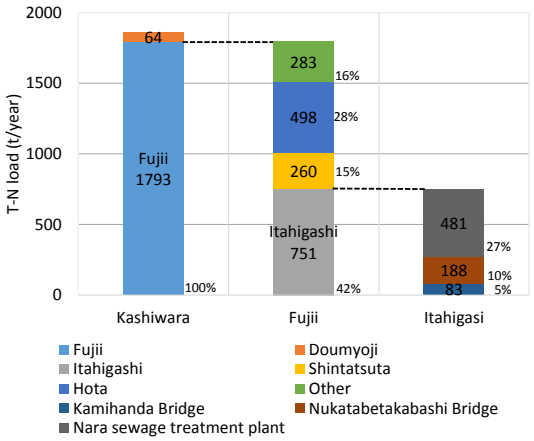

Fig. 19 Ratio of the total nitrogen load in the Yamato River basin in 2011

nitrogen load of two sewage treatment plantswas estimated about 979 t/year and the amounts of total nitrogen load from two sewage treatment plants reached about 52 % of those at the Yamato River basin.

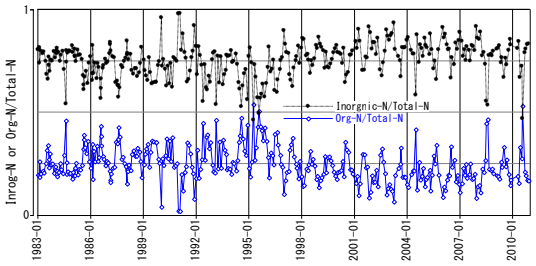

Fig. 20 Ratios of organic nitrogen and inorganic nitrogen loads per the total nitrogen load at Fujii Station from 1983 to 2010

Ratios of organic nitrogen and inorganic nitrogen loads per the total nitrogen load at Fujii Station from 1983 to 2011 were shown in Fig.20. Average ratios of organic nitrogen and inorganic nitrogen loads per the total nitrogen load were about 25% and 75%.

7. CONCLUS ION

The amount of nitrogen load was estimated and the distribution of nitrogen load was analyzed in the Yamato River basin. Although there was not enough data to calculate nitrogen load in the basin, some estimation methods were applied for calculation. At Fujii Station, flow rate data was calculated with cross section and velocity using a new method to estimate velocity from cross section and water level values based on the modified Manning equation. Only cross section and water level data were necessary for calculation.

At Fujii Station total nitrogen concentration was also estimated using EC and water level value. Then daily total nitrogen load was calculated at Fujii Station and the annual total nitrogen load at Fujii Station was calculated to be 1793t/year based on the daily calculated data. The annual total nitrogen load at Fujii Station under flood conditions with over 22m^3/sec of flow rate was calculated to be 1013t/year and average load was126g/sec in 2011. The annual total nitrogen load excluding flood conditions was 780t/year and average load was 33g/sec.

Similarly at Kashiwara Station, total nitrogen concentration was also estimated using EC. The annual total nitrogen load at Kashiwara Station was calculated to be 1857/year in 2011. The annual total nitrogen load at Kashiwara Station under flood conditions with over 24m^3/sec of flow rate was calculated to be 835t/year and average load was 108g/sec in 2011. The annual total nitrogen load excluding flood conditions was 1021t/year and average load was 43g/sec. At Itahigashi, Hota, Shintatsuta, Nukatabetakabashi, and Kamihanda stations and the Nara sewage treatment plants, the total nitrogen load was estimated using flow rate. The annual total nitrogen load at Itahigashi, Hota, Shintatsuta, Nukatabetakabashi, and Kamihanda stations and the Nara sewage treatment plant were estimated to be 751, 498, 260, 188, 83 and 481t/year in 2011. There were two sewage treatment plants at the upstream of Itahigashi and Hota stations. Therefore the amounts of total nitrogen load from two sewage treatment plants reached about 52% of those at the Yamato River basin.

8. REFERENCES

[1] Masanobu Taniguchi, Hiroyuki Ii, Tatemasa Hirata, Analysis of organic nitrogen compound in domestic sewage in Yamato River using a social experimental test, 2010, vol. 30, Part 10, p. 1587–1590, Stuttgart, April 2010

[2] Ministry of Land, Infrastructure and Transport, Japan, Water information system, http://www1.river.go.jp/

[3] Yamato River construction office, http://www.yamato.kkr.mlit.go.jp/YKNET/index.html

[4] Masanobu Taniguchi, Hiroyuki Ii, Tatemasa Hirata, The development of water resource system – The Water balance of Yamato River basin, Environmental Engineering Research Papers Vol. 48, 2011.

[5] Isamu Munemiya, Hiroshi Tsuno: Environmental Water Quality Studies, KoronaSya, in Japanese, p48, 2001.

[6] Mikio Hino: Clear hydraulics, p138-152, in Japanese, 1983

International Journal of GEOMATE, June, 2016, Vol. 10, Issue 22, pp. 2043-2049

MS No. 5322 received on June 13, 2015 and reviewed under GEOMATE publication policies.

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