EFFECTIVENESS ANALYSIS OF MAINTENANCE FLOW FOR NON-ORGANIC MATTERS IN JAPANESE CLASS-A RIVERS

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ABSTRACT

Normal flow in Japanese Class-A rivers is established with an environmental quality standard that does not consider ammonium nitrogen (NH4-N). In this study, distributions of NH4-N with normal flow were calculated in six representative rivers through an integrated model to estimate NH4-N concentration in rivers. After the calculation, some hydraulic conditions that may cause high NH4-N concentration were extracted. As a result, longitudinal distributions were categorized into five types with hydraulic conditions Especially flow velocity of higher than 0.64m/s and water depth below 0.3m were considered as thresholds. Then, normal flows with corresponding to those conditions were extracted from decision points of normal flow in all Japanese class-A rivers. Almost half of subjective points showed water depth lower than 0.3m, while eight river systems were proved to have a risk of high NH4-N concentration due to flow velocity. Such rivers were Naka river system in Ibaraki, Naka river system in Tokushima, Kushiro river system, Arakawa river system, Tenryu river system, Kurobe river system, Asahikawa river system, and Yodo river systems. Therefore, it is concluded that the state of high NH4-N concentration may occur under the present normal flow standard.

Keywords: Normal flow, ammonium nitrogen, water quality, class-A river, environmental flow

1. INTRODUCTION

More contaminants than rivers' ability of self-cleaning are flowing into rivers through human activities (Kazama and Oki, 2006). The increase of contaminants has a harmful influence on river ecosystems as well as human activities. Environmental quality standards for river environment maintenance is based on such as organic matters without considering non-organic matters. Nitrogen compounds and phosphorus compounds represent nutrient salts in rivers. Especially in nitrogen compounds, ammonium nitrogen (NH4-N), nitrite nitrogen (NO2-N), and nitrate nitrogen (NO3-N) are included together with organic nitrogen. NH4-N is nitrified and changes to NO2-N with enough oxygen in the process of wastewater treatment. Under high concentrations of NH4-N, it is harmful to both river biology and water utility by a human. River creatures are damaged by a deficiency of oxygen when algae grow too rapidly because of eutrophication. On the other hand, as human water utility, NH4-N reacts with chlorine, which is used to disinfect tap water (Seimiya, 2017). The reaction produce chloramine which consume more chlorine as known as break point, then water quality deteriorates.

Environmental flow, as well as wastewater treatment, is one of the ways to improve water quality in rivers. Environmental flow is defined as follows; "Environmental flows describe the quantity, timing, and quality of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being" (Arthington et al., 2003). Although there are a few rivers that introduced environmental flow in Japan, normal flow is defined in most of the Japanese class-A rivers which are maintained by Japanese government. Normal flow means necessary flow to maintain proper function of flow water (Ministry of Land, Infrastructure, Transport and Tourism, 2007) and is considered in the combination of flow for water use and maintenance flow. Normal flow should be kept in rivers and should not be withdrawn.

There are eight targets to identify normal flow referring to the Guideline of Normal Flow Setting (Ministry of Land, Infrastructure, Transport and Tourism, 2007). The normal flow considers water quality as "maintenance of water qualification." In the guideline, maintenance of water qualification is indicated that evaluation is based on BOD. Besides, nutrient salts such as NH4-N should be considered if necessary. However, all class-A rivers whose normal flows are dominantly affected by the maintenance of water qualification refer to environmental quality standards. Thus NH4-N might not be taken into consideration for those normal flows. That is to say, present normal flows possibly do not satisfy with the river environment from the viewpoint of NH4-N.

Therefore, this research focuses on multiple class-A rivers whose normal flows are decided by the maintenance of water qualification. For those rivers, hydraulic conditions that affect the high concentration of NH4-N are revealed concentration to calculate NH4-N concentration with normal flow. The hydraulic conditions refer such as water depth and velocity. At first, focus on distributions of NH4-N concentration with flowing constant normal flow for the whole year in several rivers. Then hydraulic conditions among rivers are compared, and conditions relating to the high concentration of NH4-N are identified. Material cycle sub-model and ecosystem sub-model in integrated model (Mizoguchi, 2016) are applied for analysis since it can calculate substance concentration, such as NH4-N considering absorption and emission from organisms. Based on extracted conditions, evaluate normal flows all over Japan if they satisfy NH4-N concentration.

2. METHOD

2.1 Computation model

In this research, two sub-models in the Mizoguchi's integrated model are utilized. This model figures out the number of organisms or water quality represented by substance concentrations longitudinally. The hydraulics sub-model, the material cycle sub-model, and the ecosystem sub-model are components of the integrated model. Hydraulics sub-model supplies such as flow velocity and water depth to the other two sub-models as determination conditions for substance concentrations and amount of organisms. Besides, the material cycle sub-model and ecosystem sub-model interact with each other in every time step. NH4-N, which is the primary purpose of this research, is computed by the material cycle sub-model shown in Eq. (1). Variables and coefficients in the Eq. (1) are described in Table 1.

$$\begin{aligned}\frac{\partial(NH_4)}{\partial t}+U\frac{\partial(NH_4)}{\partial x}=&-\frac{\alpha_N}{H}\phi_A G_A+\frac{1-\sigma_{Het}}{\sigma_{Het}}\frac{\alpha_N}{H}G_H+\frac{\alpha_N}{H}k_{ae}(B_A+Het+FPOM\times H)+\frac{\alpha_N}{H}k_{an}(Het-Het_A)\\&+\frac{\alpha_N}{H}r_{dec}+\frac{\alpha_N\alpha_{DNP}}{H}k_{mic}(CPOM\times H+Se_{CP})+\alpha_N\left(k_{pe}-\phi_P\mu_P\right)PP+\alpha_N k_{ze}ZP+\frac{\alpha_N}{H}(\alpha_{Bi}-g_{Bi})C_{Bi}\\&+\frac{\alpha_N}{H}B_{Fi}\{C_{Fi}(D_{Fi}+U_{Fi})+R_{Fi}h_{Ri}(T_w)\}+\alpha_{NC}k_{DOC}DOC-k_{NH_4}NH_4\\&+\frac{\partial}{\partial x}\left(Dis\frac{\partial(NH_4)}{\partial x}\right)+\frac{Q_S}{A_S H}(NH_{4S}-NH_4)\end{aligned} \quad (1)$$

Table 1. Variables and coefficients in Eq. (1)

U	Velocity	σ_{Het}	Yield of attached heterotroph
NH_4	Concentration of NH4-N	G_H	Growth rate of attached heterotroph
$CPOM$	Concentration of coarse particle organic matter	Het	Amount of attached heterotroph
$FPOM$	Concentration of fine particle organic matter	Het_A	Maximum amount of attached heterotroph in aerobic layer
DOC	Concentration of dissolved organic matter	k_{DOC}	Rate of DOC mineralization
Se_{CP}	Amount of sedimented coarse particle organic matter	r_{dec}	Amount of aerobic and anaerobic metabolism
α_{DNP}	Ratio of nutrient salts generation in leaching and biodegradation of coarse particle matter	k_{mic}	Rate of nutrient salts generation in leaching and biodegradation of coarse particle matter
k_{ae}	Rate of metabolism	k_{NH4}	Rate of NH4-N nitrification
k_{an}	Rate of anaerobic decomposition	α_N	Content ratio of nitrogen in biomass
G_A	Growth rate of attached algae	g_{Bi}	Total growth ratio of attached heterotroph
φ_A	Ratio of non-organic nitrogen in attached algae	α_{Bi}	Assimilation efficiency of benthic invertebrate
B_A	Amount of attached algae	C_{Bi}	Growth rate of attached heterotroph
k_{pe}	Respiration rate of phytoplankton	B_{Fi}	Amount of fish
φ_P	Ratio of non-organic nitrogen in phytoplankton	$h_{Ri}(T_w)$	Limiter function of water temperature for fish respiration
μ_P	Specific growth rate of phytoplankton	C_{Fi}	Consumption rate of fish
PP	Concentration of phytoplankton	D_{Fi}	Fish behavior
k_{ze}	Total respiration rate of zooplankton	U_{Fi}	Excrement ratio of fish
ZP	Concentration of zooplankton	R_{Fi}	Respiration rate of fish
α_{NC}	Ratio of nitrogen to carbon	Dis	Dispersion coefficient
Q_S	Discharge from lateral inflow	H	Water depth
A_S	Mesh size	NH_{4S}	NH4-N concentration of lateral inflow

Each term on the right side of the equation shows biological, chemical, or physical reaction: the first term shows intake by attached algae along with growth; the second terms stands for growth of attached heterotroph; the third stands for metabolism or decomposition, the fourth stands for anaerobic decomposition by attached heterotroph; the fifth stands for anaerobic decomposition in sediment; the sixth stands for microbial degradation of coarse particle organic matter; the seventh stands for phytoplankton; the eighth stands for zooplankton; the ninth stands for benthic invertebrate growth; the tenth stands for fish growth; the eleventh stands for mineralization of dissolved organic carbon; the twelfth stands for nitrification of NH4-N; the thirteenth stands for dispersion; and the fourteenth stands for inflow from outside of mainstream.

Because the output of the hydraulics sub-model is not regulated by the material cycle sub-model and ecosystem sub-model, only the material cycle sub-model and ecosystem sub-model are applied in this research. Parameters that would be supplied by the hydraulic sub-model are replaced with measured values. Longitudinal transition, but the cross-sectional transition is considered. Calculation cells have the same longitudinal distance as 100m and are the same concentration of substances and amount of organisms in initial conditions.

2.2 Data setting for representative river calculation

Representative rivers for calculation are extracted if the necessary flow from "maintenance of water purification" is the largest among the eight categories. From the corresponded rivers, calculation was conducted in the following six rivers: Shinano river, Maruyama river, Kita river, Hiji river, Yoshinogawa river, Kumano river. Upstream end of the calculation section is a closest measurement point of water quality to the determination point of normal flow. Downstream end of the section is upstream of a tidal area. The downstream end of Shinano river and Yoshinogawa river are the diversion points of Okozu diversion channel and Kyu-Yoshinogawa river respectively to reduce calculation load.

Boundary conditions for all variable water quality in representative rivers were given by measured value from the Water Information System (Ministry of Land, Infrastructure, Transport, and Tourism) in the most upstream measurement point with NH4-N or NO3-N. Although dissolved organic carbon (DOC) is calculated as concentrations of organic matter in the sub-model, only BOD and COD are measured. In previous research, DOC can be converted from BOD with an equation (Kamiya et al., 2015). In the majority of representative rivers, water quality was measured four times in a year at almost same intervals (Ministry of Land, Infrastructure, Transport and Tourism). Therefore, boundary conditions were switched every three months beginning from January. As an example, boundary conditions in Maruyama river are shown in Table 2. Initial conditions of the number of organisms were set, referring to field observations in Japan (e.g., Ito and Nikaido, 1966).

Table 2. Boundary condition in Maruyama river

Substance/ organism	Concentration [mg/L]			
	1/1～3/31	4/1～6/30	7/1～9/30	10/1～12/31
Coarse particle organic matter	0.06	0.28	0.18	0.07
Fine particle organic matter	1.14	5.32	3.42	1.24
Dissolved organic matter	1.29	1.35	1.53	1.41
Ammonium nitrogen	0.03	0.04	0.02	0.04
Nitrite nitrogen	0.003	0.005	0.004	0.005
Nitrate nitrogen	0.54	0.46	0.12	0.46
Phosphate phosphorus	0.029	0.060	0.013	0.032
Dissolved oxygen	12.00	9.90	7.90	9.70
Phytoplankton	0.70	0.70	0.70	0.70
Zooplankton	0.01	0.01	0.01	0.01

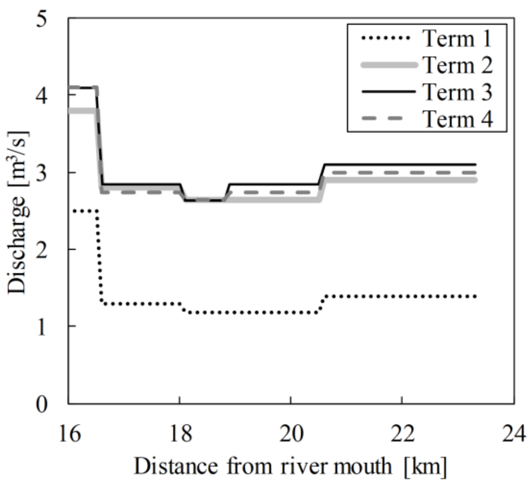

Figure 1. Normal flow in Maruyama river
Term 1: January to March, Term 2: April and September to December, Term 3: May to June, Term 4: July to August

Longitudinal distributions in a day before flow alteration were evaluated with flowing the amount of normal flow from 1st January to 31st December. Each representative river was established own normal flow fluctuation with one or more terms in a year. Normal flow in Maruyama river is shown in Figure 1 as an instance. This includes water intake. Preconditioning term was one year, which means the duration of calculation was two years, including evaluation duration for the latter one year. Boundary conditions and water temperatures were provided every 24 hours; thus, hourly fluctuation was not considered. Water temperatures were converted from moving average of air temperatures for 15 days, including the objective day.

The calculation was conducted in the sub-models of 100m of the cell length with 0.2-second time step.

3. RESULT

3.1 Distribution in each river

The longitudinal distribution of NH4-N in representative rivers are shown in Figure 3-8. Those can be categorized into following five types from shapes of distributions: Shinano/ Kita river type which has the highest concentration in downstream end; Maruyama river type which shows almost the same concentration in evaluation section; Hiji river type which has local maximum and minimum; Yoshinogawa river type which increases rapidly in a specific point; and Kumano river which has the high concentration in upstream end. However, there are some exceptions. The result of 20th May in Yoshinogawa river did not increase dramatically; thus, this was not categorized into Yoshinogawa river type. The NH4-N concentrations on 14th October and 29th November showed the distribution of Shinano/ Kita river type, although ones on 30th January and 29th June were categorized as Kumano river type. As the next step, hydraulic conditions that cause a relatively high concentration of NH4-N were discovered, focusing on points with a high concentration of NH4-N.

At first, about Shinano/ Kita river type, an increase of NH4-N concentration was affected by NH4-N production from metabolism or decomposition of attached algae and fine particle organic matter (FPOM) (Figure 2, Figure 3). Compared to attached algae and FPOM, decomposition of FPOM produced more NH4-N. The concentration of FPOM was longitudinally almost equal; thus, nearly the same amount of NH4-N was produced in the evaluation section. Therefore, the concentration of NH4-N would increase linearly from upstream to downstream; however, the concentration in downstream was lower than expected. This decrease was caused by nitrification, whose amount increases directly proportional to the concentration of NH4-N.

On the other hand, attached algae had more influence on NH4-N production in Kita river. Although the evaluation length of Kita river was shorter than that of Shinano river, the rate of NH4-N increase to longitudinal distance was much higher in Kita river. The reason of the high concentration was the lower water depth in Kita river, which caused more solar radiation arriving at attached algae and high condensation due to low discharge. This type was named as “standard type,” and compared with the other rivers.

Secondly, one of the features in Maruyama river was an equivalent concentration in the longitudinal direction (Figure 4). The concentrations on 29th October and 29th June were similar, 30th March was lower than them, and 30th August was the lowest. Differences in boundary conditions occurred these differences.

As the same as Shinano river, standard type, decomposition of FPOM influenced an increase of NH4-N concentration, and nitrification influenced a decrease of NH4-N concentration. A lower concentration of FPOM caused the reason for the smaller difference between upstream and downstream compared to standard. In comparison to the lowest concentration of FPOM in Shinano river (12.1mg/L on 29th December in the downstream end), the highest concentration in Maruyama river (5.2mg/L on 29th April in the upstream end) was less than half. It means, due to low concentrations of FPOM, the amount of NH4-N produced less, and then the concentration of NH4-N became almost even longitudinally. Thus, rivers with low concentrations of FPOM are categorized into Maruyama river type, which shows almost the same NH4-N concentration longitudinally.

Thirdly, Hiji river type shows the local maximum and local minimum. From Figure 5, the distribution of NH4-N concentration on 2nd February indicated local maximum and minimum. The local maximum located at 18.0km and local minimum located in 20.0km from the downstream end. At the local maximum point, the metabolism of the attached algae affected dominantly to NH4-N increase. The number of attached algae increased from 20.0km to 18.0km, where their growth rate was also high. The growth rate is defined by such as the concentration of nutrient salts, and the intensity of solar radiation varies according to water depth. Water depth was low at the local maximum point and high at the local minimum point. The threshold was almost 0.3m for an increase of NH4-N. Therefore, rivers with a water depth of lower than 0.3m are categorized into Hiji river type, which has a local maximum.

type.

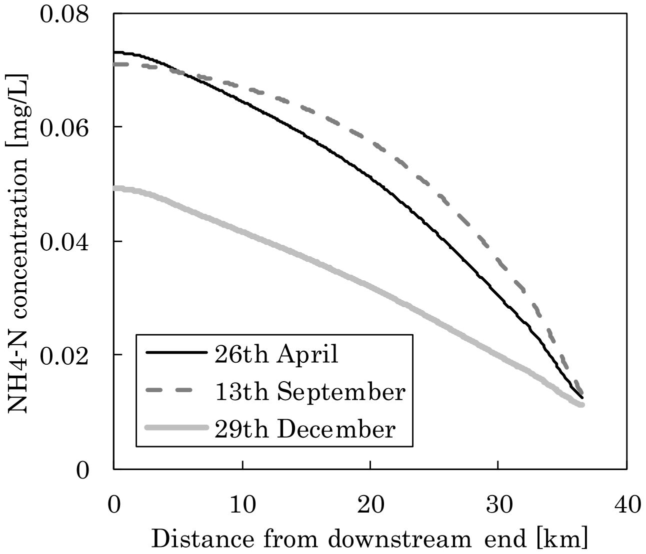

Figure 2. NH4-N distribution in Shinano river

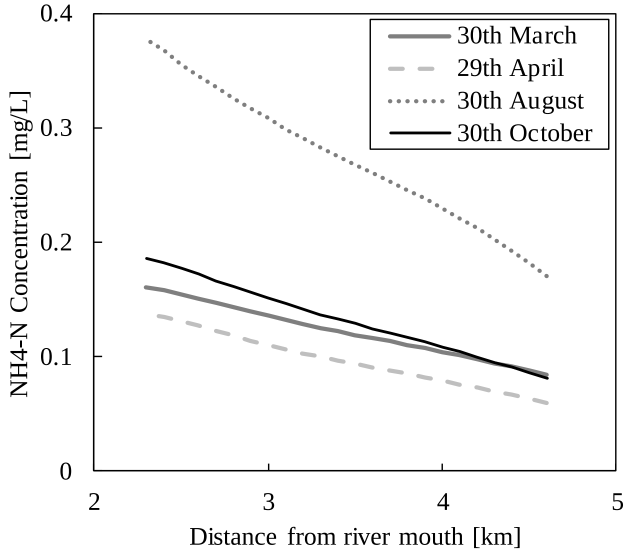

Figure 3. NH4-N Concentration in Kita river

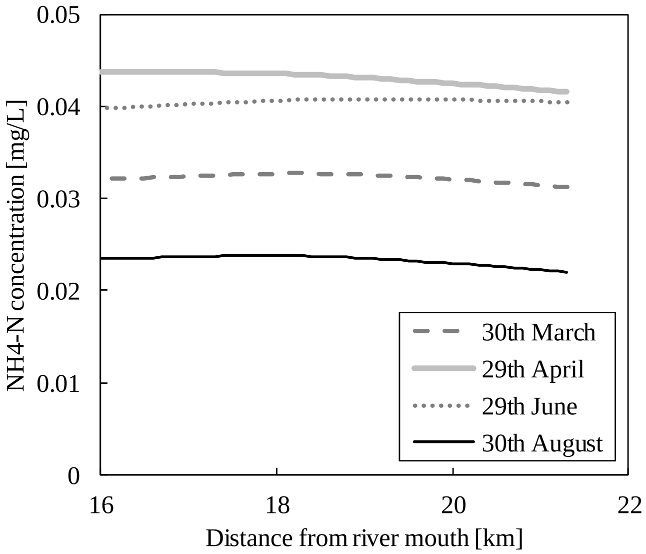

Figure 4. NH4-N distribution in Maruyama river

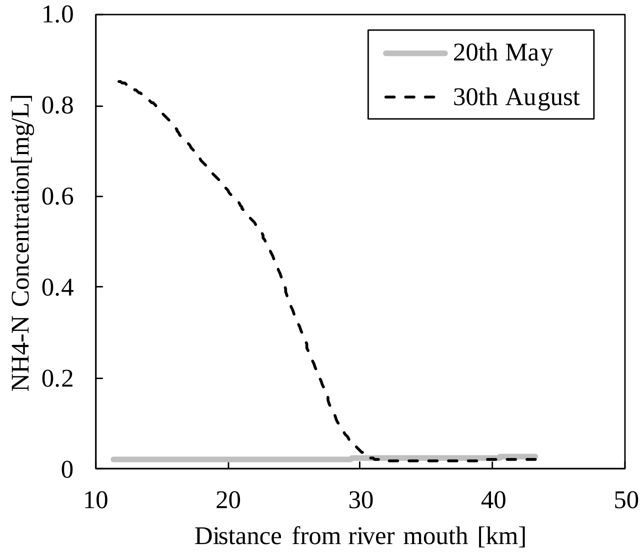

Figure 5. NH4-N distribution in Hiji river

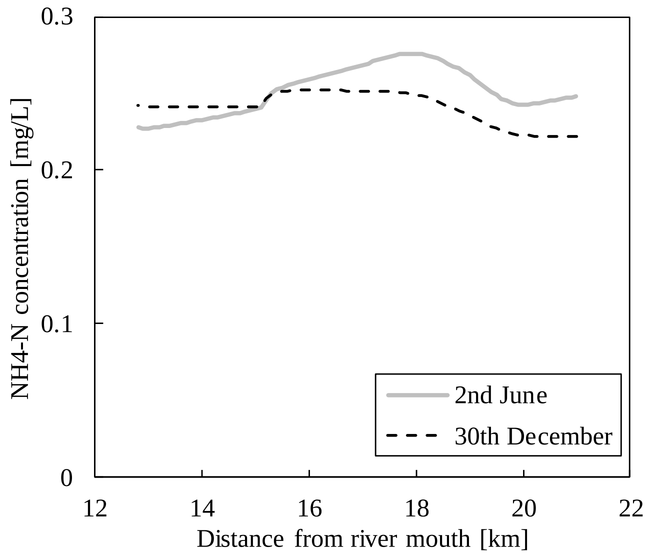

Figure 6. NH4-N distribution in Yoshinogawa river

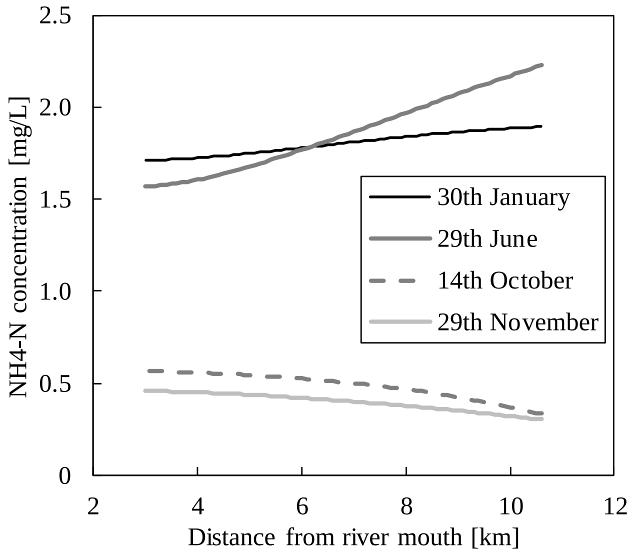

Figure 7. NH4-N distribution in Kumano river

Fourthly, Yoshinogawa river type has characteristics of the rapid increase section. As shown in Figure 6, an obvious NH4-N increase occurred on 30th August around 30km. In this section, NH4-N was mainly produced by the decomposition of FPOM. The concentration of FPOM increased between 33km to 27.2km, which locates upstream of the rapid increase section. An increase of FPOM concentration was caused to stir up sedimented FPOM. Stirring is related to shear force mainly defined by water depth and flow velocity. Dimensionless shear force increased in almost the same section as the increase of the amount of the stirring. Since the sheer force cannot be measured directly, shear force is less useful for an indicator of river evaluation. The high flow velocity was observed approximately from 35km to 25km from the downstream end. The flow velocity, which covers the section with much stirring of sedimented FPOM, was equal to or more than 0.64m/s. The sections with equal or more than 0.64m/s were from 33.7km to 27.2km. Although more upstream than 42.8m also showed more than 0.64m/s, the amount of stirring FPOM was not increased since there was little sedimented FPOM. In conclusion, rivers with a high flow velocity, equal or more than 0.64m/s, are categorized in Yoshinogawa river

Finally, Kumano river type has the highest concentration in the upstream end and relatively high concentration whole along the river (Figure 7). Among longitudinal distribution of NH4-N concentration in Kumano river, 30th January and 29th June corresponded to Kumano river type. The increase of NH4-N was dominantly caused by metabolism of attached algae and decomposition of FPOM in this type of river. The decease of NH4-N was mainly caused by nitrification in this type of river. Boundary conditions were exceedingly high, for example, 1.9mg/L on 30th January and 2.3mg/L on 29th June compared to 0.01mg/L in Shinano river. Therefore, amount of nitrification which increases proportionally to concentration of NH4-N possibly exceeded that of production. For this reason, NH4-N concentration decreased along the flow direction of a river.

As for the other two days in Kumano river, the boundary condition was 0.27mg/L on both 15th October and 29th November. It was higher than that of in Shinano river although it was lower than the other boundary conditions in Kumano river. The behavior in those days did not correspond to Kumano river because the amount of increase from metabolism and decomposition exceeded that of nitrification with a high middle concentration of NH4-N. The threshold value was estimated between 0.27mg/L to 1.9mg/L, however, the exact value could not be figured out from the results of this research. Thus, rivers with a high NH4-N concentration in boundary conditions are categorized in Kumano river type, and the highest concentrations are observed in the upstream end.

3.2 River categorization and hydraulic conditions

River types were categorized into five from distribution of NH4-N concentration: Shinano/ Kita river type, Maruyama river type, Hiji river type, Yoshinogawa river type, and Kumano river type. Shinano/ Kita river type is considered as the primary type, which shows the highest concentration in the downstream end. Maruyama river type has a low concentration of FPOM and almost the same NH4-N concentration whole along the river. Hiji river type includes sections with water depth lower than 0.3m, whose concentration becomes local maximum. Rivers categorized to Yoshino river type flows faster than 0.64m/s as flow velocity in some sections, and NH4-N concentration bursts into high in those sections. Rivers with high concentrations as boundary conditions correspond to Kumano river type, and the highest concentration can be seen in the upstream end.

The following four conditions may be regarded as the significant factors to lead high NH4-N concentrations. As hydraulic conditions, the flow velocity is equal or more than 0.64m/s, and water depth is lower than 0.3m. For other conditions, FPOM concentration is low, and the boundary condition of NH4-N is high.

These conditions were shown in Figure 8 as a flowchart. Because the highest boundary condition of NH4-N was in Kumano river among the representative rivers in this search, the first condition is a high boundary condition. The lowest concentration of FPOM in the evaluating section was observed in Maruyama river; the second branch connects to Maruyama river. Sections with a flow velocity equal or higher than 0.64m/s were Yoshinogawa river and upstream of Shinano river. Due to the high boundary conditions of FPOM concentration in Shinano river, the attached algae did not grow much. Then Shinano river did not behave as same way as Yoshino river type. This exception is considered a less critical and outcoming condition in this flowchart. Thus the third branch is to Yoshinogawa river. There were several rivers with water depth lower than 0.3m; Hiji river, Kita river, Kumano river, Maruyama river, and Yoshinogawa river. Kumano river, Maruyama river, and Yoshinogawa river are already categorized previous conditions; thus, Hiji river and Kita river correspond to this branch. The left river, Shinano river, has the highest concentration in the downstream end. Besides, Kita river also has sections with water depth of more than 0.3m and the highest concentration in the downstream end; therefore, Kita river belongs to Shinano river type.

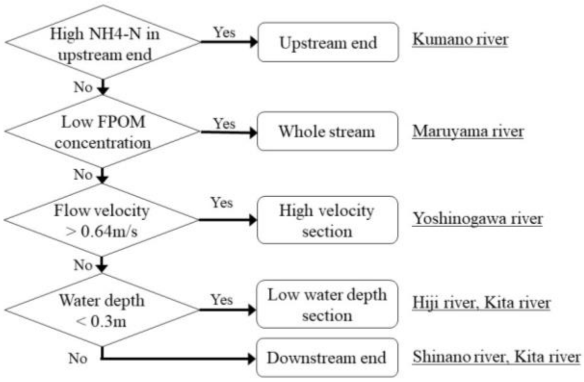

Figure 8. Flow chart of river categorization

4. DISCUSSION

4.1 Equations

From the calculation result of six representative rivers, hydraulic condition either water depth lower than 0.3m or flow velocity more than 0.64m/s may be the conditions of a high concentration of NH4-N. To extract rivers with those hydraulic conditions, river evaluation in terms of high NH4-N concentration is potentially possible. Thus, class-A rivers whole in Japan with the possibility to become high NH4-N is selected to calculate water depth and flow velocity in the case of flowing normal flow in decision points of the flow.

To reduce the NH4-N concentration that may cause water quality deterioration, it is also essential to control the source of domestic waste and contaminants flowing to the river. However, the purpose of this study is to investigate the effect of environmental flow. Therefore, we focus on the relationship between the hydraulic conditions (flow velocity and water depth) and the NH4-N concentration that can be controlled by the amount of river discharge.

Followings were investigated referring to The Fundamental river management policy in Japan and other associated materials: control points of normal flows, and discharge and bed slope in the points. If there are multiple points and terms to be defined as normal flows, all points and terms were considered as long as those were in mainstreams. Then, location information, latitude, and longitude of the decision points were investigated from the Water Information System (Ministry of Land, Infrastructure, Transport, and Tourism). Width of water surface were scaled from GSI Maps (Geospatial Information Authority of Japan). Rivers and points lacking more than one items of information were removed from object rivers.

Water depths and flow velocities were calculated applying the Manning equation with an assumption of energy slope equal to bed slope. Rivers with the potential to be high NH4-N concentration were extracted, referring to the water depths and the flow velocities.

113 points were analyzed. Statistical data of the water depths and the flow velocities were shown in Table 3.

More than the half of all points (60 points) have water depth lower than 0.3m. Even though water depth is higher than 0.3m under the ordinally condition, it is possible to become lower than 0.3m discharging normal flow, which is often categorized as drought. The relation between the scale of water depth and NH4-N concentration under lower water depth than 0.3m was not figured out by the analysis. Thus, those 60 points could not be ranked by the possibility of high concentration.

Subsequently, 16 points were extracted as rivers corresponding to equal or more than 0.64m/s of flow velocity (Table 4). Those rivers were integrated into 8 river systems; Naka river system in Ibaraki, Naka river system in Tokushima, Kushiro river system, Arakawa river system, Tenryu river system, Kurobe river system, Asahikawa river system, and Yodo river systems. Arakawa, Asahikawa, and Naka (in Tokushima) river systems had decision points with a flow velocity lower 0.64m/s. In other words, all points or terms in other river systems were supposed to show a high concentration of NH4-N. More evaluation for NH4-N concentration is required, such as longitudinal and seasonal investigation in those river systems. Even though Tenryu river system establishes normal flow in two different points, high concentrations of NH4-N were expected in both cases.

Table 3. Statistical data at control points of normal flow

	Normal flow [m^3/s]	Width of water surface [m]	Water depth [m]	Flow velocity [m/s]
Average	19.1	86	0.37	0.46
Maximum	180	405	2.66	0.95
Minimum	0.1	10	0.05	0.12
Median	9	73	0.29	0.46

Table 4. Points with flow velocity equal or higher than 0.64m/s

River system	Points	Normal flow [m^3/s]	Flow velocity [m/s]
Naka river in Ibaraki	Noguchi	23	0.65
		31	0.73
Naka river in Tokushima	Wajiki	16	0.65
		19	0.70
		30	0.83
		31	0.84
		32	0.85
Kushiro river	Shibecha	18	0.68
Arakawa river	Yorii	23	0.71
Tenryu river	Miyagase	25	0.76
		28	0.79
	Kashima	86	0.88
Kurobe river	Aimoto	4.5	0.76
Asahikawa river	Makiyama	26	0.78
Yodo river	Takahama	170	0.93
		180	0.95

5. CONCLUSIONS

Focusing on rivers whose normal flows are determined by "maintenance of water purification," NH4-N concentrations were calculated under the condition that the only normal flow flows in the river channel throughout a year. Flow velocity over 0.64m/s or water depth less than 0.3m is the hydraulic condition to make the NH4-N concentration high. Based on those hydraulic conditions, the class-A river systems in Japan with the possibility of high NH4-N concentration were extracted. More than half, 60 out of 113, river systems were estimated to high NH4-N rivers according to water depth.

Flow velocity over 0.64m/s was observed in 8 river systems; Naka river system in Ibaraki, Naka river system in Tokushima, Kushiro river system, Arakawa river system, Tenryu river system, Kurobe river system, Asahikawa river system, and Yodo river system. All control points and terms show a flow velocity higher than 0.64m/s in Naka (in Ibaraki), Kushiro, Tenryu, Kurobe, and Yodo river systems. Tenryu river systems consider multiple normal flow depending on location and season; however, in all cases, flow velocity exceeds the threshold for high concentration. The result of the analysis indicates that the NH4-N concentration shall be taken into account in the normal flow evaluation in many rivers.

REFERENCES

Arthington, A. H., Bhaduri, A., Bunn, S. E., Jackson, S. E., Tharme, R. E., Tickner, D., Young, B., Acreman, M., Baker, N., Capon. S., Horne, A. C., Kendy, E., McClain, M. E., Poff, N. L., Richter, B. D., and Ward, S., (2018). The Brisbane Declaration and Global Action Agenda on Environmental Flows. *Frontiers in Environmental Science*, 6, 45:1-15.

Ito, T., and Nikaido, K. (1966). Quantitative distribution of fishes in the upstream and downstream of a reservoir. *Japanese Journal of ichthyology*, 13, 4/6:145-155.

Kamiya, H., Ohshiro, H., Nakashima, Y., Sato, S., Nojiri, Y., Esumi, T., Sishi, M., Fujihara, A., Godo, T., Sugahara, S., and Yamamuro, M. (2015). The relationship between water temperature and dissolved organic carbon concentration in Lake Shinji. *Japanese Journal of Limnology*, 75:225-229.

Kazama, S., and Oki, T. (2006). The effects of climate change on water resources. *Global Environmental Research*,10, 2:201-206.

Ministry of Land, Infrastructure, Transport and Tourism. Water Information System. (http://www1.river.go.jp/)

Ministry of Land, Infrastructure, Transport and Tourism. (2007). Guideline for normal flow.

Mizoguchi, Y. (2016). Development of integrated model of hydraulics, material cycle and ecosystem along a river, *Nagoya university*.

Seimiya, Y. (2017). Study on chlorine-consuming substances in water source. *Journal of the National Institute of Public Health*, 66, 2:189-190.