International Journal of GEOMATE, June 2019, Vol.16, Issue 58, pp.76 - 81
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2019.58.8162
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

ROLE DIFFERENCE AMONG RIVERS AFFECTED BY VOLCANIC ACTIVITIES OF MT. ONTAKE FOR WATER QUALITY OF THE NIGORIGAWA RIVER

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*Corresponding Author, Received: 25 Oct. 2018, Revised: 26 Dec. 2018, Accepted: 14 Jan. 2019

ABSTRACT: To understand the influence of volcanic activities of Mt. Ontake on the Nigorigawa River, the distribution of elements contained in the water of the Nigorigawa was examined. The Nigorigawa has several tributaries such as the Akagawa River, the Shirakawa River, the Denjogawa River, and small streams. Sampling stations were located in the Nigorigawa and upstream rivers of it. These water samples were analyzed by the ICPE. The Akagawa and the Denjogawa show anomalous water quality. The amounts of elements in the water of the Akagawa are far more than those in other rivers (ex. S: 138 mgL^{-1}, Fe: 34 mgL^{-1}, Al: 33 mgL^{-1}). The water quality of the Akagawa shown above is consistent with characteristic features in the volcanic zone. In contrast, the water of the Denjogawa contains large amounts of Na (46 mgL^{-1}). It is likely due to dissolution from the sediment of Mt. Ontake, because the Denjogawa has a source in the Ontake Landslide, which was caused by the 1984 Nagano Prefecture Earthquake. It was found that the Akagawa and the Denjogawa play a role different from each other for forming the water quality of the Nigorigawa (the Akagawa: eruption, the Denjogawa: earthquake).

Keywords: Distribution of elements, Nigorigawa River, Mt. Ontake, Volcanic activity, Ontake Landslide

1. INTRODUCTION

Mt. Ontake (altitude 3,076m) is located across Nagano Prefecture and Gifu Prefecture. Mt. Ontake often has shown volcanic activities. Since recorded history, it erupted on a medium scale for the first time in 1979. Thereafter, small-scale eruptions occurred in 1991 and 2007, and a medium-scale eruption happened again in 2014 [1]. All of them were phreatic eruptions [2], [3]. Also, the Western Nagano Prefecture earthquake (M6.8) occurred in 1984, which caused the sector collapse at Mt. Ontake, i.e., the Ontake Landslide.

Mt. Ontake has several rivers, one of which is the Ohtakigawa River flowing in the southern side of it. Generally, it is known that volcanic activities affect the water quality of the surrounding rivers and change their water quality [4]. Actually, the Ohtakigawa is reported to be affected by the eruption [5], [6]. In addition, it was found that in the Ohtakigawa after the junction with the Nigorigawa, pH was low, the electric conductivity was high, and biota was less [7]-[9]. Recently, Usami et al. [10] have progressed the above research and have shown the formation process of anomalous water quality of the Ohtakigawa from a viewpoint of elements.

The previous works shown above have revealed that the water quality in the Ohtakigawa is significantly affected by the Nigorigawa. In order to recover the Ohtakigawa environment damaged owing to the volcanic activities, however, we need more information to further comprehend the formation process of the water quality of the Nigorigawa.

In this work, to further approach the cause of the characteristic water quality of the Nigorigawa, we surveyed the upstream of the Nigorigawa. We observed elements in water of the Nigorigawa and upstream rivers of the Nigorigawa to clarify the relation between the rivers.

2. METHODS

2.1. Study Site

Figure 1 shows a map of sampling stations. We selected ten stations as the sampling stations in tributaries of the Ohtakigawa River (the Nigorigawa River, the Shimokurosawa River, the Shirakawa River, and the Uguigawa River) and in upstream rivers of the Nigorigawa River (the Nigorisawagawa River, the Denjogawa River, the Akagawa River, the Shirakawa River, and branches of the Denjogawa and the Nigorisawagawa). Here, it is noted that the Ohtakigawa and the Nigorigawa have a different tributary with the same name “Shirakawa”. Hereinafter we call the Shirakawa of the Ohtakigawa

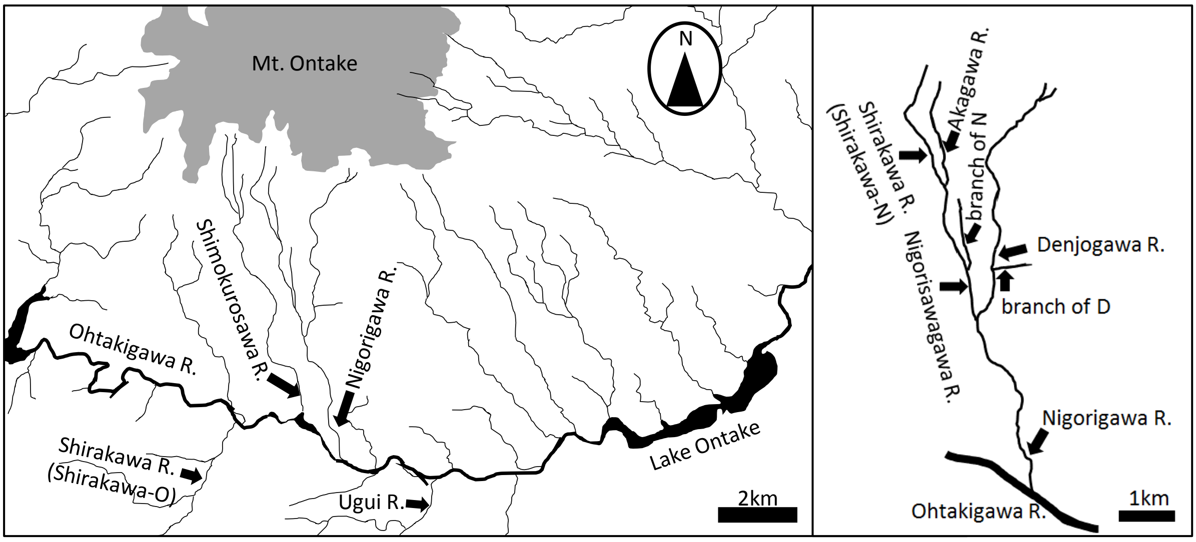

Figure 1 Sampling stations in the Ohtakigawa watershed. The left panel is a map which shows sampling stations in tributaries of the Ohtakigawa. The right panel is an enlarged map focusing on the Nigorigawa and upstream rivers of it, sampling stations in which rivers are displayed.

"the Shirakawa-O" and the Shirakawa of the Nigorigawa "the Shirakawa-N."

Investigations were carried out from October 10, 2015, to November 25-26, 2017 as shown in Table 1.

2.2 Sampling and Analysis

2.2.1 pH

Samples obtained from the survey on November 25-26, 2017 were brought back to the laboratory and pH was measured by using a pH meter (Mettler Toledo Portable pH Meter Pro2Go).

In the investigation from October 10, 2015 to November 4, 2017, pH of the sample was measured by a pH meter (RISEPRO ph-900).

2.2.2 Elements

Samples were filtered. Filtration was carried out with a teflon filter paper (PTFE, 0.5μm, φ 47mm), and the samples were separated into dissolved and suspended matters.

The filtrate samples were added to aqua regia (HNO_3: HCl=1:3), and the suspended particle matter on the teflon filter was decomposed in aqua regia. Elements contained in them were analyzed and 21 element species (Na, Mg, Al, Si, P, S, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Sn) were measured by using the ICPE.

In this work, nine element species: Na, Mg, Al, Si, S, K, Ca, Mn and Fe, which generally are the main components of volcanic ejecta [11],[12], and actually demonstrated high concentrations, are exhibited in detail.

Table 1 Sampling stations and sampling dates. The circles indicate that water was sampled at the corresponding station and date. "Upstream rivers of the Nigorigawa" means the sampling stations in the Nigorisawagawa, the Denjogawa, the Akagawa, the Shirakawa-N, and branches of the Denjogawa and the Nigorisawagawa.

Sampling station	Upstream rivers of the Nigorigawa	Nigori gawa	Shira kawa-O	Shimo kuro sawa	Ugui gawa
Oct. 10, 2015		○	○	○	
Sep. 17, 2016		○	○	○	○
Oct. 29, 2016		○	○	○	○
Mar. 4, 2017		○	○	○	○
May 6, 2017		○	○	○	○
Jun. 24, 2017		○	○	○	○
Aug. 5, 2017		○	○	○	○
Nov. 4, 2017		○	○	○	○
Nov. 25-26, 2017	○	○			
Investigation frequency	1	9	8	8	7

3. RESULT

3.1 Concentrations

3.1.1 The Nigorigawa

Figure 2 shows the concentrations of the nine element species at each sampling station. First, the water quality of the Nigorigawa is overviewed; S, Na, Ca and Si have high concentrations (40, 32, 30 and 26 mgL^{-1}, respectively). In addition, the concentrations of all the nine elements are 6-158 times higher than those in other tributaries of the Ohtakigawa (the Shimokurosawa, the Shirakawa-O and the Uguigawa rivers). Thus, it is confirmed as reported by [10] that the water quality of the Nigorigawa is anomalous enough to dominantly affect the water quality of the Ohtakigawa.

3.1.2 The Nigorisawagawa and the Denjogawa

Next, the water quality of the Nigorisawagawa and the Denjogawa, into which the upstream of the Nigorigawa bifurcates, are compared. The concentrations of S, Al and Fe in the Nigorisawagawa (S: 68 mgL^{-1}, Al: 10mgL^{-1}, Fe: 6 mgL^{-1}) shows quite high values compared with those in the Denjogawa (S: 7 mgL^{-1} , Al: 0 mgL^{-1} , Fe: 0 mgL^{-1}). In contrast, the concentration of Na in the Denjogawa (46 mgL^{-1}) is much higher than that in the Nigorisawagawa (19 mgL^{-1}). From these results, it is clearly seen that the high concentration of S in the Nigorigawa is caused by the Nigorisawagawa and the high concentration of Na in the Nigorigawa is due to effects of the Denjogawa.

3.1.3 The Akagawa and the Shirakawa-N

The upstream of the Nigorisawagawa further bifurcates into the Akagawa and the Shirakawa-N. First, let us discuss S, Ca and Si, which show a high ratio in the Nigorisawagawa. The concentrations of S, Ca and Si are high both in the Akagawa and in the Shirakawa-N. It is consequently found that the high concentrations of S, Ca and Si in the Nigorisawagawa are caused by both of the Akagawa and the Shirakawa-N. Next, let us observe Al and Fe, whose concentrations in the Nigorisawagawa is much higher than those in other tributaries of the Ohtakigawa. The Al and Fe concentrations in the Akagawa are extremely high compared with those in the Shirakawa-N (16 times and 229 times higher, respectively). From this result, it is found that the high concentrations of Al and Fe in the Nigorisawagawa are almost due to the Akagawa.

3.1.4 Branches of the Denjogawa and the Nigorisawagawa

In branches of the Denjogawa and the Nigorisawagawa, the concentrations of the nine elements are sufficiently small as in other tributaries of the Ohtakigawa (Figure 2) and thus their influence on the Nigorigawa, can be ignored.

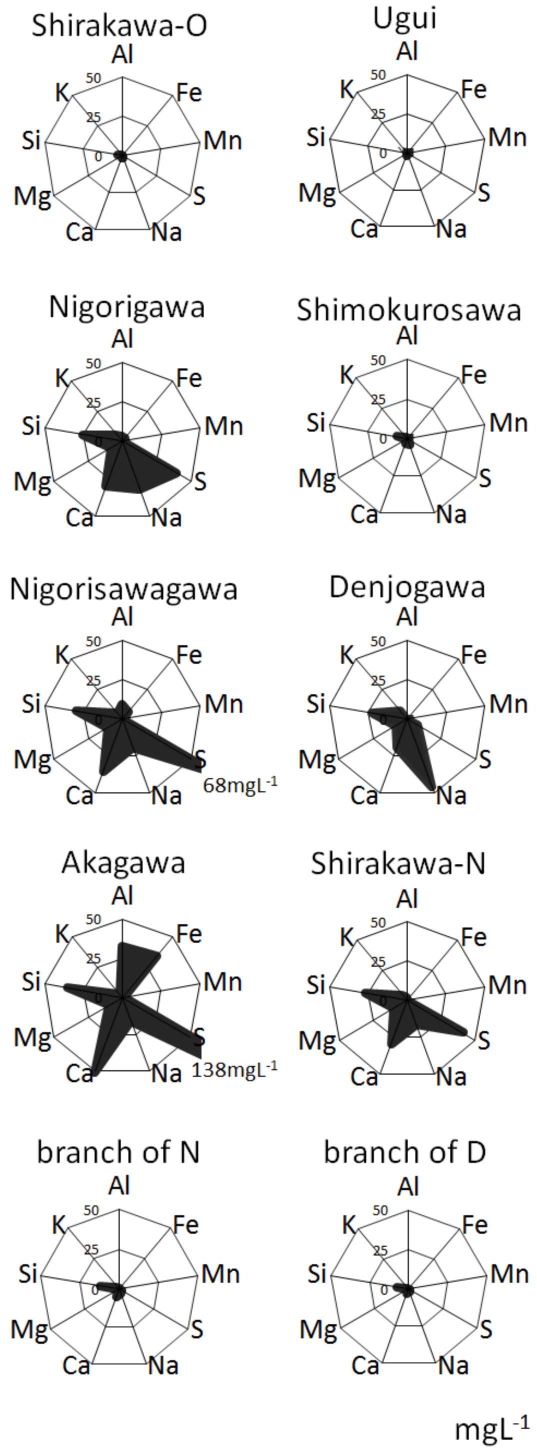

Figure 2 Concentrations of the nine element species at each sampling station.

3.2 Speciation

The speciation of S, Na, Ca and Si, which show high concentrations in the Nigorigawa, is investigated. They are in a dissolved state in all the rivers including the Nigorigawa. That is, they exist as sulfate ion, sodium ion, calcium ion and silicon oxide, respectively.

In addition, the speciation of Al and Fe, whose concentrations are high especially in the Akagawa, is shown in Figure 3. Rivers are arranged from the top panel to the bottom panel in ascending order of pH. Al and Fe have a property to dissolve in acid water. Indeed, Al and Fe exist as dissolved matters (aluminum ion and iron ion) in the Akagawa, where pH is 2.9. In the Nigorisawagawa (pH=3.7), the downstream of the Akagawa, 10% of Fe exists in the suspended state, and in the Nigorigawa (pH=5.9), the downstream of the Nigorisawagawa, ratios of suspended matters of Al and Fe are 44 % and 28%, respectively. This implies that pH rises owing to the influence of other rivers, the Shirakawa-N and the Denjogawa, and the dissolved matters are gradually changed to the suspended matters.

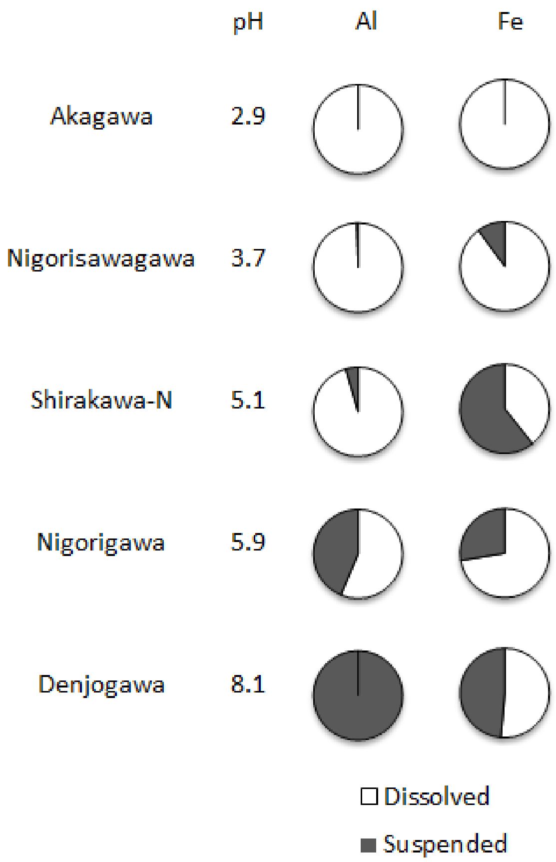

Figure 3 Speciation of Al and Fe in the Nigorigawa and upstream rivers of it.

3.3 Change in the Two Years

The Nigorigawa has been surveyed nine times during the two years from October in 2015 to November in 2017. It is noted that the surveys have been taken one year later the eruption on the September 2014. The concentrations of the nine element species at the nine surveys are shown in Figure 4. Each concentration does not have a clear tendency to change.

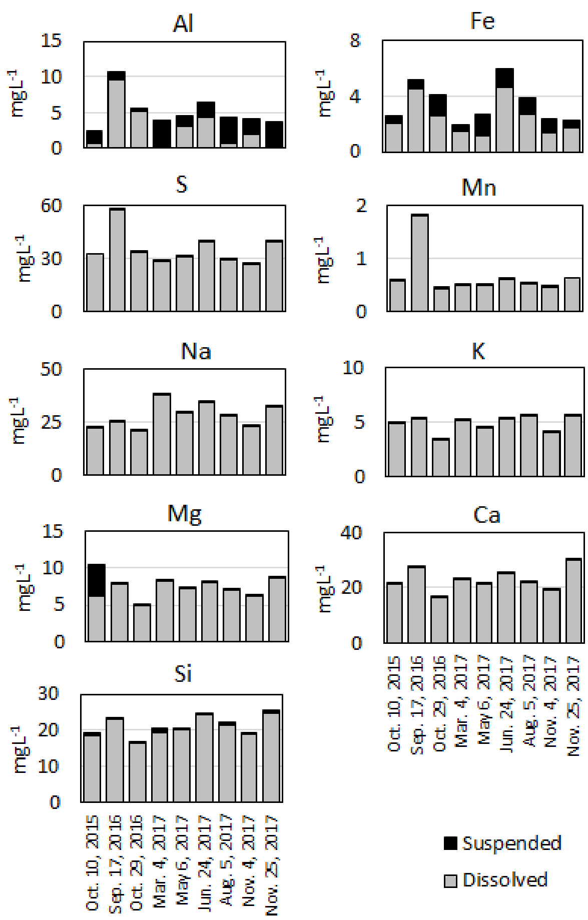

Figure 4 Concentrations of the nine element species at the nine surveys from October in 2015 to November in 2017

4. CONCLUSION AND DISCUSSION

In this work, it has been found that the characteristic water quality of the Nigorigawa is formed mainly by both of the Akagawa and the Denjogawa, which play different roles, respectively.

Here, it is discussed how water quality is formed in the Akagawa and the Denjogawa, respectively. First, we consider what causes the high concentrations of S, Al and Fe in the Akagawa. The Akagawa has a source in the vicinity of craters that erupted in 1979 and 2014 [13]. This implies that the water in the Akagawa is acidified by the solution of SO_2 contained in the volcanic gas and the oxidation of FeS contained in the volcanic ejecta [14]-[16], and consequently, Al and Fe contained in soil and rock are eluted in acid water. Next, we discuss the cause of the high concentration of Na in the Denjogawa. The Denjogawa has a souse on the site of the sector collapse (the Ontake Landslide in 1986), where soil and rock are exposed. It is inferred that Na elutes from the soil and rock by weathering process [17], and inflows into the Denjogawa.

In the Akagawa, Al and Fe are in the dissolved state. The speciation of Al and Fe is changed to the suspended state as pH rises due to the influence of the Shirakawa-N and the Denjogawa. Through the process of the speciation change, the water quality of the Nigorigawa is formed.

Suspending Al and Fe has positive and negative aspects of living things there. A positive aspect is that these elements are removed from the river water by suspending process, because Al and Fe with high concentrations are poisonous to living things [18], [19]. On the other hand, a negative aspect is that the suspended elements eventually precipitate on the surface of the river bed, and adversely affects periphyton [20]-[22].

The change in the element concentrations in the Nigorigawa has not shown noticeable tendencies for the two years from 2015 to 2017. It is inferred that the Nigorigawa continues to affect the water quality of the Ohtakigawa. In addition, as described above, the Nigorigawa is affected mainly by the two upstream rivers, the Akagawa and the Denjogawa. Thereby, it is implied that the water quality of the Akagawa and the Denjogawa also does not significantly change.

5. ACKNOWLEDGMENTS

The authors are grateful to Kiso District Forest Office, Chubu Regional Forest Office, Forest Agency of Japan for giving the permission to use forest roads for the access to the survey sites. They thank Kentaro NOZAKI of Sugiyama Jogakuen University, Takashi TASHIRO of Nagoya University, and Yukio ONODA of the Aqua Restoration Research Center for cooperation in the field survey and valuable suggestions. They thank students of Aichi Institute of Technology for their helping in this work. This research was supported by a Grant from the Water Research Environment Center (No.2017-05: representative: Yoshitaka Matsumoto). The analysis in this work is performed on “ICPE-9000” (SHIMADZU) which supported by 2012 Ministry of Education Private University Research Facilities Maintenance costs subsidies.

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