Accumulated nitrogen from organic fertilizer affects river nitrogen pollution

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Abstract
Lake Kasumigaura is the second largest lake in Japan and it is eutrophic. Nutrient loads from agriculture and livestock waste have been identified as a possible cause. Of particular concern are increasing nitrogen concentrations in the Hokota River, where pig farming is a major enterprise. The Japanese government has been advocating conservation measures such as a reduction in the use of chemical fertilizers and synthetic pesticides. As a result, organic forms of nutrients were believed to be good for the environment and less harmful than chemical fertilizers. However, incorrect application of nutrients in any form may contribute to nitrogen pollution. We propose that increasing nitrogen concentrations in Hokota River results from excessive application of swine manure to upland fields, as there has not been an increase in the amount of mineral fertiliser applied. Similarly, increases in nitrogen concentration were observed in spring water (from ground water to surface water) below an upland field that received a large application of horse manure.
In addition, soil core results from an upland field receiving nitrogen inputs for 30 years and subsequently drained in 2011 showed slow movement of residual soil nitrogen from the profile. As a result, residues of nitrogen remain in the soil from historical nitrogen inputs. Nitrogen leaching from the upper portion from rainfall during the last few years was evident, but slow. These results suggest that there was long-term nitrogen leaching potential due to the influence of the accumulated nitrogen. As a result, it was concluded: 1) Livestock waste or organic fertilizer is a likely significant contributor to nitrogen pollution. 2) Nitrogen water quality signatures lag behind the application of organic nitrogen (manure). 3) the infiltration of nitrogen from the soil in upland fields is driven by rainfall.

Key Words
Accumulated nitrogen, Livestock, Organic fertilizer, River nitrogen pollution

Introduction
Lake Kasumigaura is located in the 70km northeast of Tokyo and is the second largest lake in Japan (Figure 1). The lake has a surface area of 219.9 km^2, a basin area of 2,157 km^2, a shoreline of 252 km, a water volume of 0.85 billion m^3, an average of depth 4 m, a maximum depth of 7 m, an annual rainfall of 1,350 mm and a hydraulic retention time of about 200 days. Water from the lake is used for urban consumption, industry, agriculture and recreation, and is an important water resource for the Tokyo area. However, Kasumigaura is eutrophic with algal-blooms since the 1970's. Recently, a lake water quality conservation plan was established for review every five years. Of the three basins that feed the lake, the water quality from the Kitaura basin has not improved, with high nitrogen loads continuing (Figure 2)(IBARAKI pref. 2016).

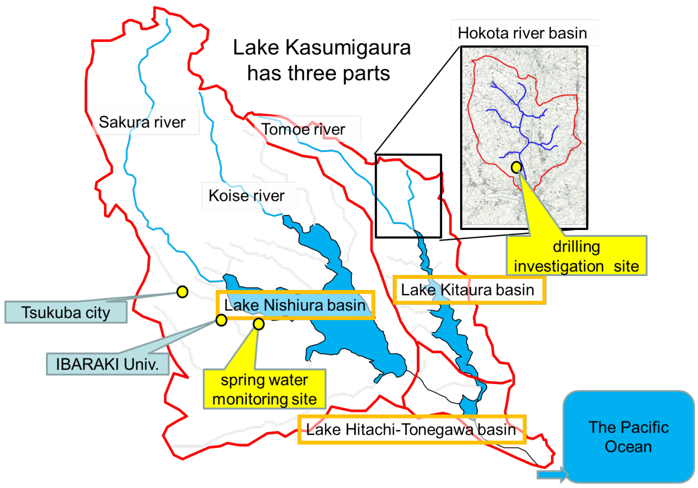

Figure 1. The location of study area is Hokota river basin in Lake Kasumigaura basin (Ibaraki prefecture (2007))

The total nitrogen (TN) concentration of Hokota River is the highest and increasing most rapidly (Figure 2). Intensive agriculture is common in the Hokota River basin including pig farming along with horticultural crops such as melons, strawberries and tomatoes. However, the cause of increasing nitrogen concentrations has not been established, in particular the rapid TN increase from 2004 to 2008 in the Hokota River.

The Japanese government has been advocating conservation measures such as a reduction in the use of chemical fertilizers and synthetic pesticides. As a result, organic forms of nutrients were believed to be good for the environment and less harmful than chemical fertilizers. However, incorrect application of nutrients in any form may contribute to nitrogen pollution. On November 1, 2004, the Japanese government declared the commencement of a management program, "Enforcement of the act on promotion of use of manure management and optimization" mandating that livestock farmers were no longer able to apply livestock waste. Prior to these declaration livestock farmers are likely to have applied large amounts of livestock waste (organic fertilizer) to fields. Therefore, the objective of this study was to identify potential sources of high and increasing TN in the Hokota River at the Kitaura river inflow.

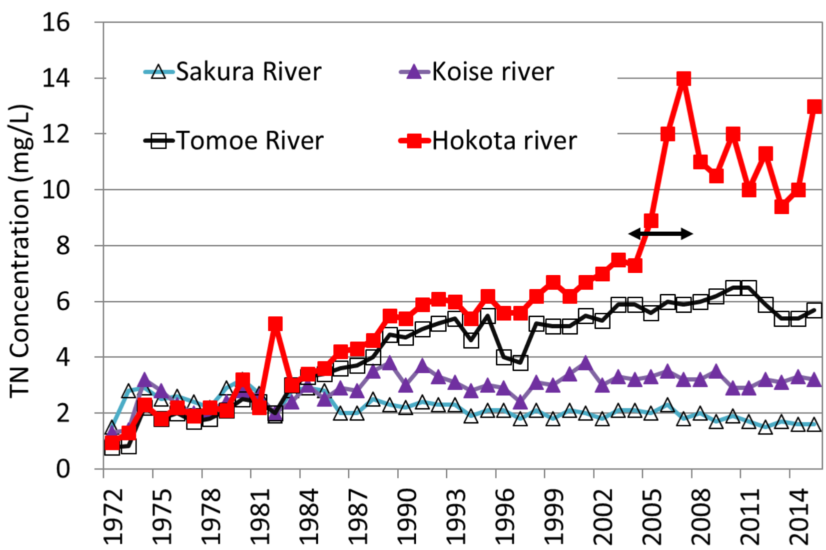

Figure 2. Temporal change in TN concentration of four major rivers (Sakura, Koise, Tomoe and Hokota River) in Lake Kasumigaura basin.

Methods

Organic fertilizer and spring water nitrate nitrogen concentration

An upland field used for the cultivation of chinese cabbage and watermelon had 1269 kg/ha of horse manure applied once in December 1994 and nursery trees were then grown. Two sites 14.1 m apart were established to monitor spring water in the forest above (S6), and below (S4) the upland field. The nitrate nitrogen concentration of spring water from the upland field was measured weekly at these sites from June 25, 1994 to December 5, 1997. Nitrate nitrogen concentration was analyzed using the ion chromatography.

Investigation of soil cores from waste land

We carried out an investigation to reveal the dynamics of nitrogen infiltration into an upland field in the Hokota River basin. On top of this upland fields to about 30 years ago, a swimming pool was built. This pool has been dismantled in 2011. Therefore, this period, rain, did not infiltrated downward. Three years later in 2014 a undisturbed soil core samples were collected by a drilling rig to a depth of 10m, transported to the laboratory, and divided into eight depth increments: 0 - 115 cm, 115 - 290 cm, 290 - 325 cm, 325 - 536 cm, 536 - 640 cm, 640 - 737 cm, 737 - 830 cm, 830 - 1,000 cm (Figure 3). The respective soil texture was heavy clay, heavy clay, sandy clay, loamy sand, sand, heavy clay, sand, loamy sand (Figure 4). The nitrogen concentration in soil water, and denitrifying activity was analysed for each soil layer. Extraction of soil moisture was carried out in a centrifuge. If can not be extracted in a centrifuge was carried out with water extraction.

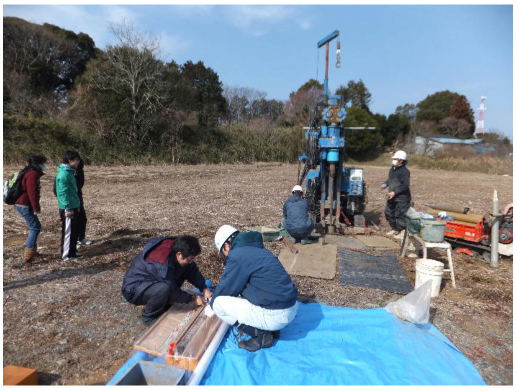

Figure 3. The drilling investigation in the waste land on February 22, 2014.

Figure 4. 10 soil layer samples in the laboratory.

Results and Discussion

Organic fertilizer and spring water nitrate nitrogen concentration

Nitrate nitrogen concentration at S4 increased gradually until June 1995 (Figure 5), after which rapid increases in nitrate nitrogen were seen (Kuroda 2013) . The nitrate nitrogen concentration rise is very similar to the increase in the concentration of Hokota River which rose rapidly over about three years. The concentration rose from 16.04 mg/L to 64.40 mg/L in the period from June 1994 to October 1997. In comparison the nitrate nitrogen concentration of the spring water from the forest site remained stable at 0.3 mg/L during this period. This spring water investigation and the increase in TN concentration in the Hokota River is suggestive that organic manures may contribute to poor water quality.

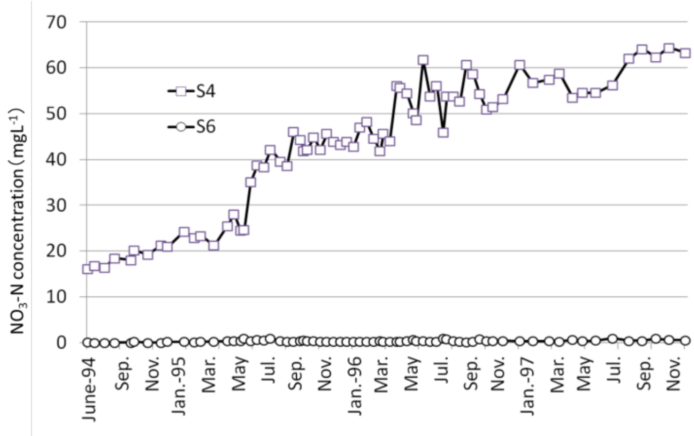

Figure 5. Temporal variation in nitrate nitrogen concentration of two spring water monitoring site from upland fields (S4) and forest (S6).

Investigation of soil cores from waste land

Denitrifying activity (acetylene block method (Hideshige et al, 1994)) was about 0.4 µgN/g-wet/day in the surface layer, about 0.1 µgN/g-wet/day from 115 - 640cm, and 0 µgN/g-wet/day in the lower layers. These value are 1 - 2 orders smaller than the value of the wetland soil (Kitamura et al, 2014). From this it was concluded that in the upland soil denitrification does not occur, and hence changes in residual soil nitrogen could be due only to the action of rainfall and infiltration.

Ammonia nitrogen, nitrite nitrogen, organic nitrogen concentration are all very low (Figure 6). A high nitrate nitrogen concentration was seen below 290cm, however above this nitrate nitrogen was low. The annual infiltration rate in these soils is typically 1m. The depth to low nitrogen concentration at 290cm matches the period of three years of infiltration at 1 m per year. As a result, we concluded that residual soil nitrogen leached from upper soil layers into lower soil layers with rainfall. Further time and infiltration would be required to show the leaching of residual soil nitrogen deeper into the soil profile.

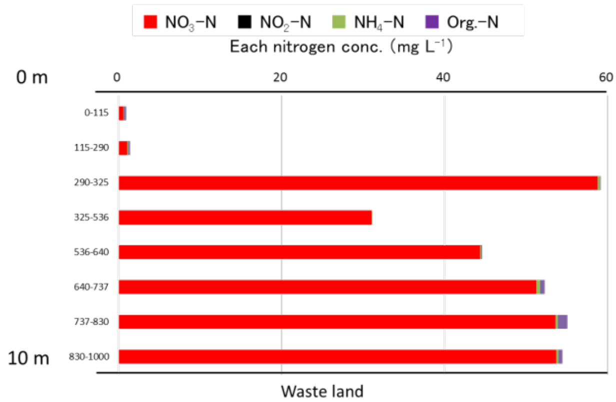

Figure 6. The vertical distribution of soil nitrogen forms.

Conclusion

We investigated nitrogen dynamics in an agricultural area where nitrogen concentration of river and spring waters is high. We concluded:

1. Livestock waste or organic fertilizer is a potential cause of nitrogen pollution.
2. Nitrogen infiltration following the application of organic forms of nitrogen (manure) has a time lag.
3. Nitrogen movement from upland field soils can be driven by rainfall.

Chemical fertilizer is often considered the major source of nitrogen pollution in Japan. However, an overuse of organic forms of nitrogen (manure) may also exacerbate nitrogen pollution. Farmers applying excessive amounts of nutrients in an organic form may contribute significantly over longer time periods because of the slow decomposition of manure. The Japanese government has been advocating conservation measures such as a reduction in the use of chemical fertilizers and chemical synthetic pesticides. As a result, organic forms of nutrients were believed to be good for the environment and less harmful than chemical fertilizers. However, incorrect application of nutrients in any form may contribute to nitrogen pollution. This study suggests that organic forms of nitrogen (manure) may be a significant contributor to nitrogen contamination. A detailed investigation of fertilizers and nitrogen pollution will follow this study. We also propose further work investigating methods to reducing nitrogen contamination from the residual soil nitrogen that now exists in upland fields and will continue to supply high nitrogen levels into waterbodies for many years.

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