Influence of the pig manure-based liquid fertilizers on the water quality properties in an agricultural catchment with different land uses

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Abstract
A wide diversity of liquid fertilizers and composts produced by the livestock manure in Korea are commonly applied to agricultural lands as alternative chemical fertilizers. However, their effects on the crop production and environmental impacts are unknown. The current study was conducted to understand the effects of the pig manure-based liquid fertilizer on water quality. Cultivated paddy rice and upland plots located in Gyeong-gi province, Korea were treated with two liquid fertilizers, SP (Liquid fertilizer with storage process) and SCB (Liquid fertilizer with slurry composting and bio-filtration process). Plots with no fertilizer (control A) and chemical fertilizer (control B) were also prepared for comparison. Nutrient concentrations in streams were monitored from May through June, which is the dry and early cultivation period in Korea. During this period, there were a lot of nutrient inputs to agricultural lands and this caused the higher concentrations of nutrients in May and June. The nutrient concentrations were dramatically changed during the rainy season, July through August, which resulted from the major problem in streams, such as eutrophication. The losses of N and P to the surface drainage water from paddy rice plots treated with SP and SCB were higher than the ones from the control plots (A and B). In addition, the losses of N and P through the runoff water from upland plots with SP and SCB treatment were higher than for control plots (A and B). The nutrient outflow from paddy rice fields and uplands with application of liquid pig manure was lower than for control plots (A and B). Particularly, the outflow from uplands may directly affect water quality in neighbouring streams. Therefore, it is necessary to establish proper management practices to prevent nutrient losses from agricultural fields and pollution of water environments. The long-term effect of the continuous treatment with manure-based liquid fertilizer will be determined in a successive study.

Key Words
Compost, liquid fertilizer, livestock manure, water quality, SCB.

Introduction
Traditionally, the livestock manure-based composts have been used for agricultural purposes because the composts contain a wide range of nutrients and ameliorate soil properties. In 2008, 42 million tons of livestock manures were generated in Korea, and 84% of the total livestock manure was used for compost and liquid fertilizer productions. In spite of ever-increased usage of livestock manure in the agricultural areas, its environmental impact on neighbouring streams is not well known. Therefore, the present study was conducted to provide understanding of effect of the liquid fertilizer treatment on water quality.

Methods
Experimental site
The experimental plots in paddy rice fields and cultivated uplands were located in GyeongGi province, Korea. Soils for paddy rice field and upland were all sandy loam, and soil pH ranged between 6.1~6.7 and 6.2~6.7, respectively. The organic matter contents were within the range of 34~42 and 24~30 g/kg, respectively.

Treatment
Two pig manure-based liquid fertilizers were applied in this study, which were from a bio-filtration process (SCB) and storage process (SP). They were applied to the separate experimental plots (20x36 m in a paddy rice field and 2.7x10 m in upland). The amount of N required was pre-calculated for the crop needs. For comparison, the experiment plots also included no fertilization plots (control A) and chemical fertilization plots (control B). Following the treatment, paddy rice (*Oriza Sativa* L.) was transplanted into each experimental plot at the spacing 15x30 cm and grown for five months, and corn (*Zea mays* L.) was sown in each experimental plot at the spacing of 20x60 cm and grown for three months.

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Sampling and analyses
Water sampling was carried out from paddy rice fields and uplands to monitor the changes of water quality analysis during the cultivation period. All samples were refrigerated at 0 to 4℃ soon after collection until analysis. Water samples were shaken to obtain homogeneous aliquots for N and P analysis. Nitrogen and phosphorus concentrations in the drainage and runoff waters were analysed. The NH_4-N and major anions were analysed using the indophenol-blue method (Bremmner and Mulvancy 1982) and an ion chromatography (DX-320, Ion Chromatograph, Dionex Corp.), respectively. Total N was analysed by the standard methods according to the FWPCA manual (USDI 1971), and total P determination was made by the isobutanol extraction method described by Golterman and Glymo (1969).

Results
Table 1 shows the concentrations of N and P in surface drainage waters from paddy rice fields during the cultivation period. The soluble salt (SS) concentrations in water samples were ranged from 0.01 to 0.07 mg/L for all treatments. The concentrations of T-N and T-P in drainage water samples were 1.85~3.88 and 0.18~0.44 mg/L, respectively. Losses of N and P including EC to the drainage waters were higher from SP and SCB treated plots than the ones from controls, such as control A (no fertilization) and control B (chemical fertilization).

Table 1. Water quality properties in the drainage waters from paddy rice fields.

Treatment	SS (g/L)	EC (dS/m)	NH_4-N (mg/L)	NO_3-N (mg/L)	T-N (mg/L)	PO_4-P (mg/L)	T-P (mg/L)
No fertilization	0.01±0.01	0.07±0.09	0.07±0.13	1.22±1.01	1.85±0.95	0.01±0.02	0.18±0.07
CF	0.01±0.02	0.09±0.11	0.09±0.12	2.14±1.75	2.28±0.64	0.03±0.02	0.39±0.03
SP	0.07±0.05	0.16±0.16	0.17±0.13	3.45±2.20	3.88±2.65	0.05±0.03	0.44±0.20
SCB	0.03±0.04	0.08±0.12	0.16±0.15	1.64±1.10	2.63±2.06	0.01±0.01	0.21±0.18

CF; Chemical fertilization, SP; Liquid fertilizer with storage process, SCB; Liquid fertilizer with slurry composting and bio-filtration process

Table 2 shows the observed concentrations of N and P in runoff waters from uplands during the experiment period. The SS concentrations in water samples ranged from 1.0 to 1.7 mg/L for all treatment. The T-N and T-P concentrations in runoff waters were 6.07~8.45 and 1.39~3.02 mg/L during the rainfall events. Losses of N and P including EC to the runoff waters were higher from SP and SCB treated plots than for the control plots (A and B). The losses of N and P in runoff waters from SP and SCB treated plots were larger than for the control plots (A and B). Particularly, the loss of nitrate-nitrogen was larger than for ammonium-nitrogen, and this can be explained by the nitrification process after liquid manure was applied.

Table 2. Water quality properties in run-off water with application of liquid pig manure at the study upland.

Treatment	SS (g/L)	EC (dS/m)	NH_4-N (mg/L)	NO_3-N (mg/L)	T-N (mg/L)	PO_4-P (mg/L)	T-P (mg/L)
No fertilization	1.7±2.0	0.03±0.02	0.41±0.02	1.45±0.52	6.07±2.23	0.56±0.22	1.39±1.36
CF	1.0±0.7	0.04±0.03	0.47±0.16	1.66±1.11	6.15±0.89	0.61±0.26	2.58±1.25
SP	1.6±1.0	0.10±0.06	0.43±0.29	2.47±2.21	8.45±4.16	1.15±0.50	3.02±3.06
SCB	1.0±0.9	0.04±0.02	0.47±0.32	1.84±0.68	8.09±3.80	0.68±0.32	2.82±0.51

CF; Chemical fertilization, SP; Liquid fertilizer with storage process, SCB; Liquid fertilizer with slurry composting and bio-filtration process

Figure 1 shows the change of nutrient concentrations in stream waters near the experimental sites. A lot of nutrient inputs were applied to agricultural land, particularly in May through June, which caused the higher concentration of nutrients in the drainage waters. Therefore, the concentrations of COD, T-N and T-P in May through June were higher than the ones in July through August, which is the rainy season. Nutrient concentrations showed the dramatic changes during the rainy season and this caused the major eutrophication problem in neighbouring stream waters.

Conclusion
Losses of N, P and EC to the drainage and runoff water samples from paddy rice fields and uplands treated with SP and SCB were higher than for no fertilizer and chemical fertilizer. The nutrient outflow from paddy rice fields and uplands was lower than for control plots (A and B). The outflow from uplands could directly affect the stream water quality near agricultural fields. The nutrient concentrations in stream waters near the

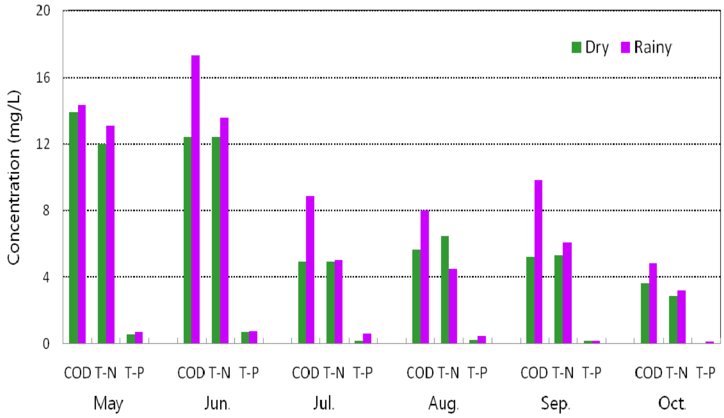

Figure 1. Concentrations of COD, T-N and T-P concentrations in stream waters nearby paddy rice fields and uplands during the crop cultivation period.

experimental sites in May and June (dry and early cultivation period) were higher than in July and August (rainy season). This is because there were a lot of nutrient inputs applied to the agricultural lands. Nutrient concentrations were changed dramatically during rainy season, and it caused the eutrophication problem in streams. Similar results were found in a previous study by Kim *et al.* (1999). Their study indicated that nitrogen and phosphorous concentrations in the drainage waters were relatively high depending on application type and amount of fertilizer during the cultivation period. Therefore, it is necessary to establish the proper management practices to prevent the loss of nutrient from agricultural fields and pollutants entering water. Moreover, it is essential to encourage the utilization of liquid fertilizer with an assurance of water quality. Long-term monitoring is recommended for sustainable water environments in association with continuous application to the agricultural soils.

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