**Effect of Livestock Liquid Manure Released at a Rice Field on Quality of Soil and Water in the Saemangeum Watershed**

가축분뇨 액비 살포가 새만금우역에서의 논토양과 수질에 미치는 영향

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**ABSTRACT**

The Saemangeum watershed is required to manage water pollution effectively but the effect of liquid manure (LM) on soil and water quality in the basin is not clearly identified as yet. This study aims at assessing the effect on soil of a rice field and water quality of water bodies near the rice field during rice-crop time period to find out the effect of LM, the effect of rainfall, and the effect of rice-crop environment on soil and water quality by analyzing data of nitrogen components. As a result of the LM distribution, NO₃-N was much higher than other N components in the entire soil layers and it was accelerated by rainfall right after the LM distribution. Compared to chemical fertilizer (CF), LM was slightly affected but still influenced on the surface water quality. During weak rainfall, low nitrogen concentration in topsoil was resulted as NH₃-N decreased and Org-N and NO₃-N increased. NO₃-N concentration in the water of irrigation canals increased with time. During intensive rainfall, NO₃-N and Org-N of the soil were measured highly in the submerged condition, while the water quality of the rice field was lower due to flooding into the irrigation canal as well as the growth of the rice plants. Also, total nitrogen was increased more than 7 times and it showed serious water quality deterioration due to LM and excessive fertilizer distribution, and rainfall during all rice-crop processes. The effect of LM on water quality should be studied consistently to provide critical data while considering weather condition, cropping conditions, soil characteristics, and so on.

**Key words:** Livestock night-soil, Manure, Nitrogen, TN, Soil, Water quality.

**1. Introduction**

Fate of nitrogen components in a cycle has been studied by researchers related to impacts of agricultural activities on environmental media in experimental studies and model simulation studies. To understand fate of nitrogen and carbon in the vadose zone under transitory anaerobic conditions, Cannavo et al.(2004) conducted in situ and laboratory measurements of seasonal variations in aerobic respiratory and denitrifying activities and a field experiment in a bare...
soil with four soil layers for over 7 months beginning just after maize harvest and incorporation of maize crop residues. In situ microbial activity concurred with Laboratory measurements of potential activities in natural environmental conditions and semi-potential denitrifying activities were strongly limited by NO$_3^-$ than denitrifier density in the soil profile. Several previous experimental studies examined nitrogen contamination of soil and water from agriculture. In cooperation with the University of Georgia, the Southeast Watershed Research Laboratory (SEWRL), the United States Department of Agriculture-Agricultural Research Service (USDA-ARS), leaded a research for the long-term implications over the past 20 years to determine effect factors of nitrogen fate in the southeastern Coastal Plain (Hubbard et al., 2004). Prasad et al. (2004) evaluated soil surface nitrogen loads to describe the geographical distribution of agricultural nitrogen contributions from different regions of India and found the average nitrogen loads for India were higher than those for European countries. A major percentage of total nitrogen inputs were livestock manure (44.06%) among other inputs including inorganic fertilizer (32.48%), atmospheric deposition (11.86%) and nitrogen fixation (11.58%). Renck and Lehmann (2004) examined rapid water flows observed the high N losses from the topsoil of a highly aggregated tropical soil of central Amazonia in Brazil and the large nitrate accumulation in the deep soil to a depth of at least 5 m. Effects of near-surface hydraulic gradients on N loss in surface runoff from soil pans at 5% slope were evaluated under simulated rainfall (Zheng et al., 2004) and resulted that artesian seepage could make a significant contribution to water quality problems. Dominguez et al., (2004) investigated the effect of earthworms on leaching of water and nitrogen in corn agroecosystems in a long-term (6-year) field experiment in Wooster, Ohio, USA. Earthworms did not influence on concentrations of N, while they caused to increase leachate volume significantly and earthworm population density was positively correlated with total N leaching flux. When the effects of agricultural practices on dissolved N and P leaching from topsoil to subsurface soil after crop harvest had been evaluated for groundwater quality management, the dissolved N and P leaching were affected more by the type of fertilizer applied than tillage or cropping practices (Jiao et al., 2004).

The Nitrogen Risk Assessment Model for Scotland (NIRAMS) had been developed for prediction of streamwater N concentrations draining from agricultural land in Scotland (Dunn et al., 2004a) and described how the principal hydrological controls at a catchment scale (Dunn et al., 2004b). The results demonstrated the high variability in N leaching across Scotland. In the areas with greatest residual N, the losses of N coincided with lower rainfall but were not directly proportional to the amount of residual N. Er et al. (2004) determined important factors affecting biosolid nitrogen mineralization in soils. The mineralization rate in the final model was significantly controlled by several factors including biosolid application rate, biosolid C:N ratio, and temperature but effect of soil organic N content and time on the biosolid N mineralization variability had insufficient evidence. Also, transport and reduction of nitrate in a typically macroporous clayey till were examined at variable flow rate and nitrate flux by Jorgensen et al. (2004). The denitrification (reduction of nitrate) and resulting flux of nitrate observed during variable flow rate from the columns were considerably regenerated by simulations using a calibrated discrete fracture matrix diffusion model (DFMD). Royer et al. (2004) conducted simulations for transport and fate of nitrate in headwater agricultural streams in Illinois using the nutrient spiraling model, presented most NO$_3^-$N in these headwater sites appeared to be exported to downstream water bodies rather than denitrified annually. Shah et al. (2004) conducted simulations using a physically-based, field-scale model for the fate of subsurface-banded N. The model was very sensitive to soil pH and Freundlich distribution coefficient, but it was not matched well with field data, which were not enough to describe distribution of subsurface-banding N in soil.

Based on previous studies, natural-type nitrogen includes nitrogen gas (N$_2$), organic-nitrogen (Org-N), and inorganic-nitrogen such as ammonia (NH$_4^+$-N or NH$_3$-N), nitrite (NO$_2^-$-N), and nitrate (NO$_3^-$-N). The natural-type nitrogen exists with changing types in the nitrogen cycle process. The Org-N compound is converted into NH$_4^+$-N or NH$_3$-N by biological degradation and NH$_4^+$-N or NH$_3$-N is converted into NO$_3^-$-N by the nitrification process (Wetzel, 2001).
\[
\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-
\]
\[
2\text{NH}_4^+ + 3\text{O}_2 \rightarrow 2\text{NO}_2^- + 4\text{H}^+ + 2\text{H}_2\text{O}
\]
\[
2\text{NO}_2^- + \text{O}_2 \rightarrow 2\text{NO}_3^-
\]

NO\textsubscript{3}^- - N is reduced to nitrogen gas (N\textsubscript{2} gas) in an anoxic condition. This is the biological nitrification-denitrification process and representative microorganisms of these processes are *Nitrosomonas* and *Nitrobacter*. These microorganisms are sensitive due to pH. For example, maximal effect indicates in pH ranges 7–8 for *Nitrosomonas* and 7.7–8.1 for *Nitrobacter* (Grunditz and Dalhammar, 2001).

Discharge load from livestock industries in the Saemangeum watershed forms 25% of the entire discharge loads and around 89% of them in Jellabuk-do of South Korea, are converted into compost and liquid manure to spread on agricultural lands (JRETDC, 2014). Due to the overall prohibition of ocean dumping in 2012, the Korean government has established various policies for the transformation of the livestock night-soil into compost and liquid manure so that businesses supporting livestock night-soil treatment facilities can create business bases for treating the entire quantity of livestock night-soil on land, the total amount of nourishment introduced by regional units for inducing proper nourishment supply, vitalization of natural recycling agriculture as supporting working expenses, and so on. For controlling algal blooms and the eutrophication management of lake and coastal water as creating the retention watershed on the lower water system of Jellabuk-do according to the Saemangeum land reclamation project, especially, the management of inorganic nutrients (nitrogen, N, and phosphorous, P) is magnified as one of important issues and the livestock night-soil is focused on one of the most important emission source of N and P. Act on the livestock night-soil has various management systems but in reality the livestock night-soil attracts public attention because it still influences on water quality in the form of non-point pollution and in the application of compost and liquid manure. Development of the resource recovery system is required to solve such a realistic problem. In the form of the compost and liquid manure, the resource recovery system should be much more effective than existing fertilizers, possible to be used by residents (farmers), and able to minimize effect on water quality.

Compared to studies on resource recovery system such as the compost and liquid manure, however, an environmental study such as effect on water quality of the lower river is insufficient as yet when the compost and liquid manure are spread on the farmlands. Thus, this study aims at assessing effect on soil of a rice field and effect on water quality of water bodies near the rice field during the period of rice cropping from early in May to early in November of 2013 after the liquid manure distribution. To reach the purpose of this study, soil and water have been sampled total six times according to the rice cropping schedule. Sampling has been conducted for soil in a rice field from three layers in depth, upper soil (US) layer (up to 10cm), middle soil (MS) layer (10cm ~ 30cm), and lower soil (LS) layer (30cm ~ 50cm) and for water body in a rice field and in irrigation canal. This study analyzes data of nitrogen component variable measured by Agriculture and Food Safety Research Center of Jeonju University based on Official Test Method of Soil and Water Pollution.

### 2. Methodology

#### 2.1 Background of N component fate during Rice-Cropping

Based on previous studies mentioned above, Fig. 1 summarizes fate and mechanisms of Ammonia coming from the liquid manure in environmental media (air, water, soil, and rice plants) during the periods of rice cropping. Crops imbibe lots of nutrient from the soil. Nitrogen, mainly inorganic-N such as NH\textsubscript{4}^+-N and NO\textsubscript{3}^- -N, is imbibed as one of important issues and the livestock night-soil is focused on one of the most important emission source of N and P. Act on the livestock night-soil has various management systems but in reality the livestock night-soil attracts public attention because it still influences on water quality in the form of non-point pollution and in the application of compost and liquid manure. Development of the resource recovery system is required to solve such a realistic problem. In the form of the compost and liquid manure, the resource recovery system should be much more effective than existing fertilizers, possible to be used by residents (farmers), and able to minimize effect on water quality.
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2.1 Fate of Ammonia

Ammonia, a major component of livestock manure, is released during the nitrification process. Passing 1~2 weeks in the submerged condition, the water body in the rice field is divided into two layers, an oxidized layer with oxygen-rich water and a reduced layer with oxygen-poor water. As shown in Fig. 1, the nitrification occurs in the oxidized layer and the denitrification process is very important when the soil is saturated with water because the microorganisms of the denitrification process act only in waterlogged soil without oxygen. The loss of the denitrification process is significantly occurred by frequent rainfall during late springtime and early summertime. The denitrification progresses regardless of the manure and fertilizer or source of NO₃-N such as degradation. Other factors of the denitrification acceleration includes crop residue to be used as a carbon source, warm soil, pH (neutral to alkalinity), and so on.

2.2 Sampling and Measurement

Schedule of the rice crop is presented in Table 1 with details from plowing the rice field (early in May) to harvesting (around the end of October). Important factors of the rice crop are to apply manures (or fertilizer) and to irrigate a paddy. Four different manures are applied during the rice crop; basic manure (liquid manure) when harrowing the field first, chemical fertilizer within 15 days after transplanting the rice, topdressing at young ear formation stage around 25 days before heading ear emergence, and fertilizer right after the heading ear emergence. However, the last fertilizer is this study applied another fertilizer after harvesting and before sowing the field with barley instead of the last fertilizer during the period of rice crop. When irrigating the paddy, water-level is various due to growth of the rice but this study uses a constant water-level, 10 cm. Also, drainage from the paddy and drying of the paddy are conducted toward the beginning of division after taking the root, at a zenith of division, and around 15 days before harvesting.

**Rainfall Events:** Weather is an important factor for the growth of rice and also affects on water quality significantly. During this study, total number of raining days was 65 days and overall rainfall was 750.5 mm, and maximum rainfall 66 mm was happened between the periods of the 4th sampling and the 5th sampling. All sampling periods except the 4th period are influenced by rainfalls. Among them, the 5th period is a representative wet period and the 4th period indicates a dry period. The overall rainfall, maximum rainfall, and raining days during the sampling periods are presented in Table 1.

**Manure Distribution:** During the researching period, manures including LM and CF were added for 4 times as marked in Table 1. First of all, total 40 tones of the LM were applied into the targeted area (4200 m²) on May 10th in 2013 based on the scattering standard of livestock liquid manure (LM, 10 ton per 1000 m²). Component content of the LM consists of nitrogen 1.9%, phosphoric acid 0.1% and potassium 0.28%. Considering only nitrogen component among the swine liquid manure, total nitrogen (TN) includes 42% organic-N, 35% NH₃-N, 19% NO₂-N, and 4% NO₃-N, and concentration of TN is 1603 mg/L as shown in Fig. 2. Secondly, chemical fertilizer (CF) contained with nitrogen 23%, phosphoric acid 19%, and potassium 9%. was distributed about 40kg on total field area 4200 m² according to the scattering standard amount 10 kg per 1000 m². For ear dressing, the chemical fertilizer contained with nitrogen 45% was distributed at the ear formation stage in the submerged condition. Finally, the field after the autumn harvest had been made even and distrusted the LM before sowing the field with barley.
Samplings: Sampling of soil in the rice field and water in the irrigation canal and in the rice field had been done on 6th, 18th, and 29th of May, June 17th, July 18th, and November 11th due to a farming plan as presented in Table 1. Water in the rice field had been taken for the 4th and 5th sampling periods and water in the irrigation canal was sampled for the remained periods. The 1st sampling (Soil 1 and Water 1) was done for an initial soil condition before distributing the LM and the 2nd one (Soil 2 and Water 2) was performed after drained off water from the paddy when rice plants started division after done for irrigating a paddy, harrowing the field and planting the rice. The 3rd sampling (Soil 3 and Water 3) had been tried after the chemical fertilizer was distributed in the submerged condition. Also the 4th sampling of the dry season (Soil 4 and Water 4) was conducted in the submerged condition after the chemical fertilizer contained with nitrogen 45% was distributed at the ear formation stage. Finally, the 6th sampling of the dry season (Soil 5 and Water 5) was done after spraying agricultural pesticide twice, maintaining the submerged condition until 15 days before the harvest when the growth of rice was ripe, draining off the water completely and dried the soil of the rice paddy, and distrusting the LM before sowing the field with barley.

Measurement: The samples were measured at Jeonju University-affiliated safety research center of agriculture products and food (Water quality test organization 2012-01) in accordance with Standard Method of soil and water pollution. As shown in Fig. 3, five spots for the soil sampling were taken within 3m × 3m a part of the entire rice field 100 m × 42 m near a drain in the field and soils from
### Table 1. Sampling and measurement conditions due to rice crop’s schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Mechanism</th>
<th>Activity and condition</th>
<th>Reference</th>
<th>Water-level (cm)</th>
<th>Number of rain (Rainfall)</th>
<th>Etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>May06</td>
<td></td>
<td>1st sampling for initial soil and water quality (Soil1 and Water 1)</td>
<td></td>
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<tr>
<td>May10</td>
<td></td>
<td>Plowing a rice field</td>
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<td></td>
<td></td>
<td>1st manure (LM as basic manure)</td>
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<tr>
<td></td>
<td></td>
<td>Irrigating a paddy</td>
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<tr>
<td></td>
<td></td>
<td>Harrowing the field</td>
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<tr>
<td></td>
<td></td>
<td>Rice planting</td>
<td></td>
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<tr>
<td></td>
<td>Sprout</td>
<td>For 7~10 days from rice planting to taking roots</td>
<td></td>
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<tr>
<td></td>
<td>Taking roots</td>
<td>Drainage from the paddy</td>
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<tr>
<td>May18</td>
<td>2nd Sampling</td>
<td>(change after applying liquid manure, LM) (Soil 2 and Water 2)</td>
<td></td>
<td>4(20.5mm)</td>
<td></td>
<td>Vegetation period (Sprout—Just before division of young ears) Requirement of much N, P, and K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irrigating a paddy</td>
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<tr>
<td></td>
<td></td>
<td>2nd manure (chemical fertilizer, CF)</td>
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<tr>
<td>May20</td>
<td>3rd Sampling</td>
<td>(change after the 2nd manure)</td>
<td></td>
<td>5(69.5mm)</td>
<td></td>
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<tr>
<td>June17</td>
<td>4th Sampling</td>
<td>(change at the submerged condition before drainage temporarily after a zenith of rice plant’s division) (Soil 4 and Water 4)</td>
<td></td>
<td>4(4.5mm)</td>
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<tr>
<td>June20</td>
<td></td>
<td>After a zenith of rice plant’s division</td>
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<tr>
<td>June22</td>
<td></td>
<td>Starting to create an ear of rice</td>
<td></td>
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<tr>
<td>July16</td>
<td></td>
<td>3rd manure (topdressing) at young ear formation stage</td>
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<tr>
<td>July18</td>
<td>5th Sampling</td>
<td>(change of submerged condition after topdressing at young ear formation stage)</td>
<td></td>
<td>14(177mm)</td>
<td></td>
<td>Reproductive stage (maturity—division of young ears) Less requirement of N and P Lots of K and Si requirements</td>
</tr>
<tr>
<td>Aug10</td>
<td>heading ear</td>
<td>Enough irrigating</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>emergence</td>
<td>heading ear emergence (around 20 days before and after heading ear emergence)</td>
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<td></td>
<td>anthesis</td>
<td>3~5 days after heading ear emergence, height of rice around 1m</td>
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<tr>
<td>Aug15</td>
<td></td>
<td>1st pesticide application</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Aug22</td>
<td></td>
<td>2nd pesticide application</td>
<td></td>
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<tr>
<td>Oct05</td>
<td></td>
<td>Drainage completely and drying</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct22</td>
<td></td>
<td>Harvesting</td>
<td></td>
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<tr>
<td>Oct26</td>
<td></td>
<td>LM before sowing the field with barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nov11</td>
<td></td>
<td>6th Sampling (change after completing all rice crop processes) (Soil 6 and Water 6)</td>
<td></td>
<td>38(479mm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
three different layers of each spot were sampled; upper soil layer, US (up to 10cm), middle soil layer, MS (10~30cm), and lower layer soil, LS (30~50cm). Measurement and analysis items were related to nitrogen components (NH$_3$-N, NO$_2$-N, NO$_3$-N, TN, and organic-N calculated using the measured N’s) and pH. Measurement unit is mg per 1Kg of dried soil and mg per 1L of water and unit of the LM is mg L$^{-1}$. Before analyzing N components and pH in soil, soil samples were pretreated to separate solid and liquid by submerging in water for 24 hours as controlling pH with HCl. The extracted water from soil and the water sampling were used to analyze N components and pH in accordance with Standard Method of water pollution. The ammoniac nitrogen was measured by the Indophenol method, nitrate nitrogen and nitrite nitrogen were analyzed by Ion Chromatography (IC), the total nitrogen (TN) was used ultraviolet absorptiometric analysis (alkaline potassium-persulphate method) and pH was measured using the pH meter.

3. Results and Discussion

3.1 Nitrogen Measurements

This study considers pH measurement instead of DO observation to examine nitrogen compound change. Change of pH in water was more sensitive than those in soil. In water, pH was changed from weak acidity to weak alkalinity with time passes, while pH in soil was various depending on the soil layers but maintained near 6.5 because soil samples were extracted by water under controlled pH condition using HCl when analyzing soil samples. If NH$_3$ gas stripping was happened, it might be by volatilization when spreading LM with pH 9.3. In the water layers and US layer, NH$_4^+$-N was reduced and NO$_2^-$-N was increased by nitrification and also denitrification in soil controlled N-component change.

Sampling was performed due to a farming plan as presented in Table 1 and the nitrogen components had been analyzed based on the distribution of liquid manure (LM) or chemical fertilizer (CF) with or without rainfall events. Unlike TP (total phosphorous) having adsorptive characteristic on topsoil, TN was flown or discharged in ground water and surface water. Componential changes of nitrogen were presented in Fig. 4 for temporal distribution and for vertical distribution in accordance with the farming plan. Fig. 4(a) ~ 4(e) presented the temporal (left panels) and vertical spatial (right panels) distribution of TN, Org-N, NH$_3$-N, NO$_2$-N, and NO$_3$-N. In Fig. 4, the N components were influenced by the LM or CF distribution and by rainfall events. In the soil, the N components were rich at the topsoil (US) compared to the deep soil (MS or LS). All N components except Org-N at the topsoil were increased rapidly as much as the amount of LM but they except NO$_3$-N were slightly decreased in the deep soil. Scooping on effects of the CF after the LM, the decrease of the N components in all layers of soil were presented at the 3$^{rd}$ period (Soil 3), they were increased consistently until the 5$^{th}$ period (Soil 5), and then decreased again at the 6$^{th}$ period (Soil 6) except Org-N in the US and MS layers.

During the dry season and without CF distribution, the N components at the 4$^{th}$ period (Soil 4) might be consumed by the rice plants in accordance with a zenith of rice plant’s division but TN as a function of NO$_3$-N at Soil 4 was still increased. The biggest change was happened at Soil 5 during the wet season and after the CF distribution. Especially, the MS layer of Soil 5 indicated the largest change for all N components. The decrease of the N components at Soil 6 was caused by cumulated processes such as rainfall phenomena during the summer rainy season, complete growth of the rice, and consumption by the barley sown the field after the rice harvest. The vertical profiles of all N components except NH$_3$-N for Soil 6 were distributed differently compared to other profiles for Soil 1 ~Soil 5.

The N components were increased in water (Water 1~Water 6) in accordance as they were decreased in the soil. However, TN was decreased rapidly depending on NO$_3$-N at Water 5 in the middle of the summer rainy season and increased very much as a function of NH$_3$-N at Water 6. It might be occurred because the soil particles with plenty of nutrients were flown into the irrigation canal when water from the rice field was drained off completely due to the farming plan and run over by the rainfall phenomena during the farming period.
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Fig. 4. Temporal distribution and vertical spatial distribution of N components.
3.2 Effect of Liquid Manure

This study examined the nitrogen component change before and after LM distribution (Soil 1 and Soil 2) as shown in Fig. 5(a) and 5(b). Soil 1 indicated the initial soil condition before LM distribution and Soil 2 described the soil condition after the LM distribution. In Soil 1, Org-N was the major component in all soil layers and was measured higher at the topsoil than at the deep soil. The next dominant component was NO$_3$-N, which had twice more at the topsoil than in the deep soil. It might be happened because of advection from other places, dry and wet deposition in springtime, and the LM distribution. Constituent of LM was Org-N, NH$_3$-N, NO$_2$-N, and NO$_3$-N in order and most of LM were Org-N and NH$_3$-N. TN of LM was marked as 1.9% (1900ppm or 1900mg/L) on the LM certified material test report but it was measured as 1603mg/L. Difference 297mg/L was regarded as a loss of NH$_3$-N by volatilization during the LM distribution. As a result of Soil 2 measurement after the LM distribution, NO$_3$-N was much higher than other N components at the entire soil layers and it was accelerated by 17mm rainfall right after the LM distribution. Unlike NH$_3$-N, NO$_3$-N wasn’t adsorbed on the soil particles and tended to move along the soil water currents. Thus, the NO$_3$-N loss was caused by the leaching phenomena. Unlike results of Soil 1 and Soil 2, Water 1 and Water 2 were analyzed to evaluate water quality of the irrigation canal near the rice field before and after the LM distribution as shown in Fig. 5(c) and 5(d). Water 1 included Org-N (45%), NO$_3$-N (32%), NH$_3$-N (17%), and NO$_2$-N (6%) orderly. As shown in the topsoil analysis in Figure 5(a) and 5(b), respectable amounts of NO$_3$-N were caused by the dry and wet deposition from the atmosphere. Water 2 at a distance of time, 12 days, contained NO$_3$-N (40%), Org-N (29%), NH$_3$-N (27%), and NO$_2$-N (4%).

Soil 1 and Water 1 of the 1st period and Soil 6 and Water 6 of the 6th period were used to examine the N component change during the entire rice cropping. Soil 1 and Water 1 indicated the initial condition of soil and water respectively before foundation LM distribution. Soil 6 and Water 6 presented the final condition after completion of all rice-crop
processes and sowing the field with barley. Until the 6th period, manure or/and fertilizer had been distributed four times. Soil 1 and Soil 6 were compared for the N component change in soil and Water 1 and Water 6 were analyzed for that in water of the irrigation canal. Soil 1 and Soil 6 were obtained by adding the concentrations of US layer and MS layer as shown in Fig. 6. For both of Soil 1 and Soil 6, major N component was Org-N and NO3-N was the next. Excessive Org-N and NO3-N in Soil 6 might be caused by the last CF distribution before the 6th sampling period. The N component change in soil tended to be connected with the water quality change of N component. Water 1 contained Org-N and NO3-N as major components but Water 6 included dominant NH3-N about 80% and some NO3-N about 12% as shown in Fig. 6(b). Difference of TN from Water 1 to Water 6 was increased more than 7 times and it showed serious water quality deterioration due to excessive manure or/and fertilizer distribution and rainfall during all rice-crop processes.

3.3 Effect of Rainfall

The effect of rainfall was examined using two cases (Case A and Case B) as shown in Fig. 7. Case A for weak rainfall events compared the 2nd period (Soil 2 and Water 2) with 20.5 mm rainfall and the 3rd period (Soil 3 and Water 3) with 69.5 mm rainfall including daily maximum 40 mm. Case B for strong rainfall events compared the 4th period (Soil 4 and Water 4) as the dry season and the 5th period (Soil 5 and Water 5) as the wet season having the rainfall (total 177 mm and 60 mm daily maximum). Results of Case A between Soil 2 and Soil 3 indicated that the rainfall was possible to leach NO3-N of LM. To examine the effect of rainfall alone was difficult because various activities such as irrigating the rice field, rice-planting, the rice field drainage, chemical fertilizer input, and so on, had been done during the period between Soil 2 and Soil 3. When comparing to Soil 2, Soil 3 had low nitrogen concentration at the US layer although the chemical fertilizer was distributed. Case B compared Soil 4 of the dry season and Soil 5 of the wet season. For Soil 4 at the submerged condition before drainage temporally after a zenith of rice plant’s division, intake by the rice plants and the loss by leaching changed the N components. For Soil 5 of the wet season, the N components, especially NO3-N and Org-N, were measured highly for a great quantity of rain in the submerged condition after topdressing (with chemical fertilizer) at young ear formation stage of the rice.

To evaluate the water quality before and after the rainfall, Fig. 8 presented results of two cases; Case A for Water 2 and Water 3 measured water in the irrigation canal near the rice field and Case B for Water 4 and Water 5 measured water in the rice field. Water 3 of Case A and Water 5 of Case B dealt with water quality affected by flooding and compared with Water 2 of Case A and Water 4 of

![Graph](image1.png)

![Graph](image2.png)

**Fig. 6.** Environment effect during farming period on quality of soil and water.
Case B. When comparing to Water 2, the N concentration in water (Water 3) of the irrigation canal was increased because water in the rice field after the chemical fertilizer distribution was flooded into the irrigation canal near the rice field by the rainfall. It might act as a non-point pollution source to deteriorate the water quality.

Fig. 8(a) showed the nitrogen components for Water 1–3 measured in water of the irrigation canal. Based on Water 1, Water 2 indicated the effect of LM and CF and Water 3 was influenced by the rainfall. By the rainfall, NH₃-N
was decreased and Org-N and NO\textsubscript{3}-N were increased. Nitrification at the topsoil converted NH\textsubscript{3}-N into NO\textsubscript{3}-N, which dissolved in the water of the rice field and discharged into the irrigation canal when draining the water of rice field or/and flooded by the rainfall. It caused NO\textsubscript{3}-N concentration in the water of irrigation canal increased with time. To compare the dry season and the wet season, Water 4 the dry season and Water 5 of the wet season in Fig. 8(b) measured and analyzed water quality of the rice field. As opposite to Soil 5, the water quality for Water 4 was higher than that for Water 5 although the topdressing had been done during the period between Water 4 and Water 5. It might be occurred because Water 5 was diluted by the plenty of rainfall as flooding into the irrigation canal as well as growth of the rice plants.

### 4. Conclusions

To find out effect of LM and effect of rainfall on soil and water quality, this study measured data of N components including NH\textsubscript{3}-N, NO\textsubscript{2}-N, NO\textsubscript{3}-N, Org-N, and TN and results are as follow:

1) This study considers pH measurement instead of DO observation to examine nitrogen compound change. The pH of LM was 9.3 and pH of water was weak alkalinity in the range of 6.9 to 8.8. Because the soil pH was controlled by HCl when pretreating for measurement, the exact pH of soil was not measured, thus it might be in alkalinity near 8 or over 8.

2) During the rice-crop, LM was spread in the beginning of the rice-crop as the basic manure, chemical fertilizers were distributed twice until rice harvesting, and the final manure (LM) was performed after harvesting the rice and before sowing the field with barley. LM as the basic manure was slightly affected compared to CF but it still influenced on surface water quality around 1.26 times for TN depending on NH\textsubscript{3}-N (2 times) and NO\textsubscript{3}-N (1.6 times), while TN was increased more than 7 times and it showed serious water quality deterioration after spreading the final LM.

3) For weak rainfall, NH\textsubscript{3}-N was decreased and Org-N and NO\textsubscript{3}-N were increased. It was guessed that nitrification at the topsoil converted NH\textsubscript{3}-N into NO\textsubscript{3}-N, which dissolved in the water of the rice field and discharged into the irrigation canal when draining the water of rice field or/and flooded by the rainfall. It caused NO\textsubscript{3}-N concentration in the water of irrigation canal increased with time depending on pH change. For intensive rainfall, the N components (especially NO\textsubscript{3}-N and Org-N) of the soil were measured highly in the submerged condition after topdressing (with chemical fertilizer). As opposite to soil quality, the water quality of the rice field was lower because it was diluted by the intensive rainfall as flooding into the irrigation canal as well as growth of the rice plants.

4) If NH\textsubscript{3} gas stripping was happened, it might be by volatilization when spreading LM. In the water layers and US layer, NH\textsubscript{4}+-N was reduced and NO\textsubscript{3}--N was increased by nitrification and also denitrification in soil controlled N-component change.

Further studies about effect of LM on water quality should be continued as considering weather condition (rainfall cycle, rainfall intensity, rainfall, etc.), cropping conditions, soil characteristics, and so on, to provide critical data in establishing Pollutants Control Act based on effective and detailed limitation of total emission volume of water pollutants. The government may use the critical and useful data to get aggressive alternative that natural recycling agriculture optimizes natural environment and agricultural environment.

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### References


