Development of automatic control technology for producing a continuous liquid fertilizer

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Swine manure is a mixture of feces, urine and cleaning water and contains high strength of organic matters especially with nitrogen and phosphorus concerning environmental pollution. However, such a waste source can be utilized as fertilizers on arable land through composting process on both solid and liquid fractions. After solid and liquid separation, solid part can be used as compost after composting process with typical method and liquid part contained relatively high nutrients over urine turns to liquid fertilizer with an aerobic process. Most treatment processes to produce liquid fertilizer are operated by the results of calculation with fixed aeration time under constant volume, which may occur the waste of time and power due to the changes of influent characteristics and external environment such as operating temperature. Therefore, the automation of operating process can be a solution.

A lab-scale slurry swine barn and a liquid fertilizer reactor were prepared for this study. Oxidation-reduction potential (ORP), pH and dissolved oxygen (DO) were used as factors to develop automatic control algorithm and monitored for developing automatic liquid fertilizer production process. In this study, ORP, pH and DO were monitored for developing automatic liquid fertilizer production process. A cylindrical shaped liquid fertilizer reactor was made with a surface area of 0.091 m^2 and volume of 30 L. The slurry pit was constructed in a rectangular parallelepiped shape of about 0.058 m^2 width of area (180 mm x 320 mm), 1064 mm depth and 60 L working volume. The liquid fertilizer reactor was operated with 16 h aeration followed by 8 h mixing under 24 h. The variation signals of each factor (ORP, pH, DO) were monitored during 153 days, and track studies were conducted to compare the changes of the internal properties with monitored patterns. A standard sieve with a pore size 0.432 mm^2 and a wire thickness 0.2 mm was used for solid-liquid separation. The amount of swine manure flowing into the reactor was set at 1.2 L / d with the hydraulic retention time (HRT) of 25 d.

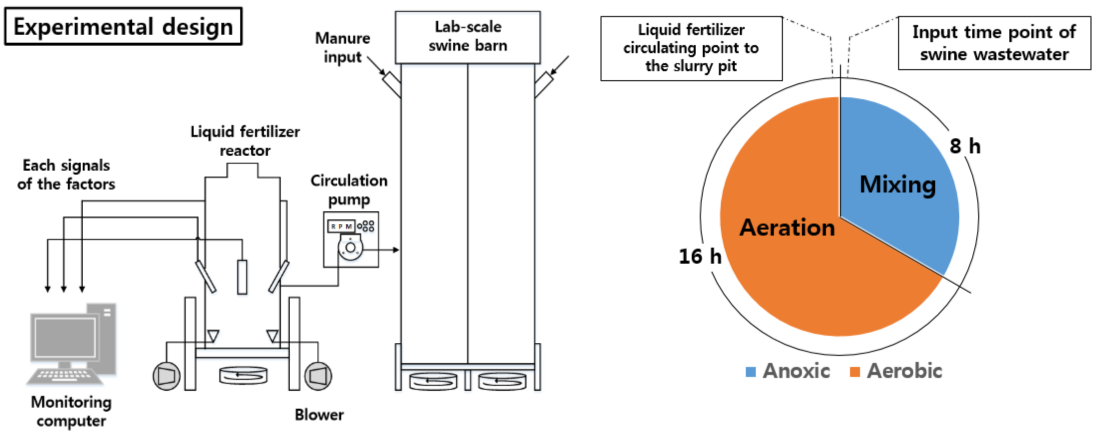

Figure 1. Experimental apparatus and reactor operation for liquid fertilizer

The nitrogen is essential for plant growth, but it is important that the high level of NH_4-N should be properly treated because it can cause odors and sometimes cause toxicity. Figure 2A showed the changes in the nitrogen content and monitoring signals according to the presence or absence of aeration after the influent feeding to the reactor. The nitrate knee point (NKP) representing the end-point of the denitrification was detected with ORP profile. According to previous research, the ORP value was kept constantly until denitrification completion point (Won and Ra, 2011). The Figure 2B shows a slightly different case from Figure 2A. The NH_4-N was increased with feeding of the influent. On the other hands, the NO_X-N was not removed perfectly in the anoxic phase and the ORP value was kept at -110 to -130 mV constantly which was the same as the previous study revealed. In the case of aerobic phase, Figure 2A and 2B has shown that the same pattern of monitoring signals.

When the aeration began, rapid increases in the ORP value were observed in both cases (Figure 2A & B). At the same time, NH_4-N concentration started to decrease and over time, the ORP value slowly increased and suddenly jumped up again. This sudden jumping-up point is expected to be the nitrogen break point (NBP). Although that point cannot exactly be founded at the same time, NH_4-N concentration of that point was near 0 mg/L. The NBP was found in both ORP and DO. The increase of DO is caused by oxygen uptake rate decline after nitrification was completed. Since there is sensitivity of ORP to oxygen, it was expected that the increase of DO was head ORP value jumped up.

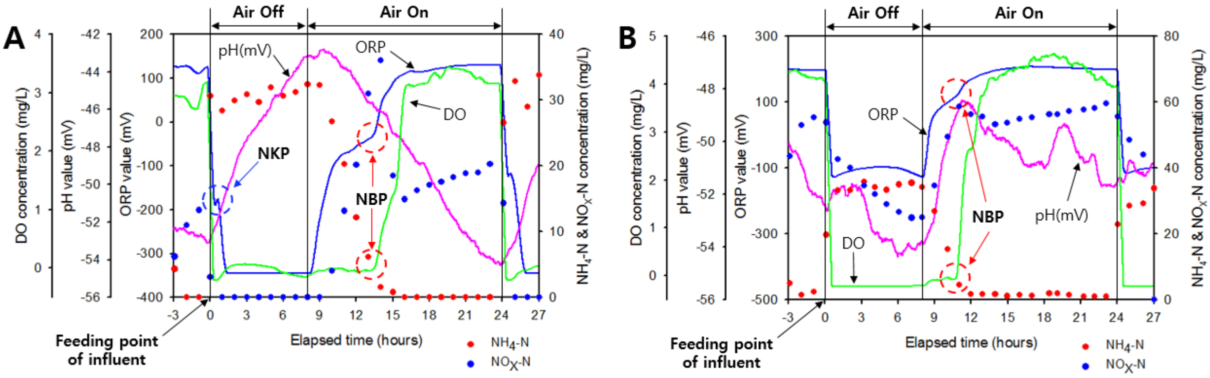

Figure 2. Profiles of each signal and change of nitrogen according to the reactor operation.

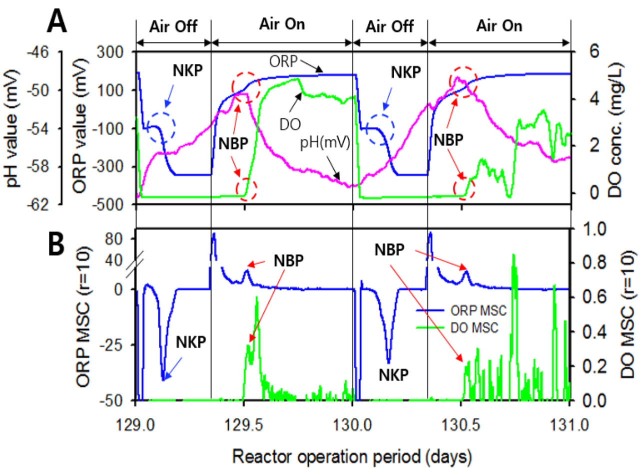

Figure 3. Typical signals patterns according to the presence or absence of aeration.
*MSC, moving slope change

Typical monitoring patterns and automatic control strategies from 129 to 131 days during the study period are shown in Figure 3. The NKP is well detected in ORP profile and NBP is easily found in ORP and DO. Therefore, The Figure 3B shows the moving slope change (MSC) after every 10 minute intervals of the each monitored signal (r=10). It is easy to find a unique point in MSC to detect NKP and NBP, whereby it is possible for developing an automatic control algorithm and connecting with automatically controlled devices to obtain a safe liquid fertilizer NH_4-N converted to NO_X-N. Through ORP and pH profiles monitored the effective operation of liquid fertilizer process is available and now applied in lab-scale liquid fertilizer process.

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Reference

Won, S.G., Ra, C.S.: Biological nitrogen removal with a real-time control strategy using moving slope changes of pH(mV)- and ORP-time profiles. Water Res. 45, 171–178 (2011)