CHARACTERIZATION OF LIVESTOCK WASTEWATER AT VARIOUS STAGES OF WASTEWATER TREATMENT PLANT

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Abstract

A characterization study has been conducted at Gongju Livestock Wastewater Treatment Plant, Gongju, South Korea. It is owned and operated by the government with treatment capacity of 250 tons per day. Livestock wastewater was collected from individual farmer and treated at the treatment plant. The centralized livestock wastewater treatment plant has various treatment processes namely pre-treatment, anaerobic digestion, nitrification, de-nitrification, chemical treatment, sand filtration and ozonation. The livestock wastewater was characterized by high COD, SS, T-N and T-P with concentration of 20,600 mg/l, 6933 mg/l, 2820 mg/l and 700 mg/l, respectively. After the wastewater has undergone various treatment processes it was discharged to waterways with concentration of COD, SS, T-N and T-P at 105mg/l, 73 mg/l, 2.1 mg/l and 9 mg/l, respectively. This is part of the study to investigate the potential of irradiation to be applied at the centralized livestock wastewater treatment plant. Although livestock wastewater can be potentially applied to crop as source of nutrients it also affect the water quality due to runoff and leaching. When the wastewater applied at the rates in excess of crop uptake rates, the excess wastewater could potentially enter surface and groundwater and polluted them.

Abstrak

Kajian pencirian telah dijalankan di loji rawatan sisa air ternakan yang terletak di Gongju, Korea Selatan. Loji tersebut mempunyai kapasiti rawatan sehingga 250 tan sehari dan beroperasi serta dimiliki sepenuhnya oleh kerajaan Korea Selatan. Sisa air ternakan dari penternak-penternak akan dikutip dan dibawa ke loji rawatan berpusat untuk dirawat. Loji rawatan berpusat mempunyai pelbagai proses rawatan iaitu pra-rawatan, anaerobik, nitrifikasi, nyah-nitrifikasi, rawatan kimia, filtrasi dan proses ozon. Parameter untuk COD, SS (Jumlah Pepejal Terampai), T-N (Jumlah Nitrogen) dan T-P (Jumlah Fosforus) yang dianalisa untuk sisa air ternakan tanpa rawat masing–masing mencatatkan kepekatan sebanyak 20,600 mg/l, 6933 mg/l, 2820 mg/l dan 700 mg/l. Selepas dirawat menerusi pelbagai proses rawatan, kepekatan untuk COD, SS, T-N, T-P masing – masing adalah 105 mg/l, 73 mg/l, 2.1 mg/l dan 9 mg/l. Kajian ini adalah sebahagian daripada penelitian potensi aplikasi sinaran untuk merawat sisa air ternakan di logi berpusat tersebut. Walaupun sisa air ternakan biasa digunakan sebagai baja kepada tumbuhan, ia tetap menjejaskan kualiti air kesan daripada larian dan larut lesap. Apabila kadar pemberian sisa air ternakan melebihi kadar pengambilan oleh tumbuhan, lebihan sisa air ternakan berpotensi tinggi untuk mencemarkan air semulajadi.

Introduction

Animal manure could affect water quality if it was discharged to natural water bodies. The impact will be greater if the volume and frequency of the discharged are high. Livestock wastewater is a potential source of nutrients and can be potentially applied as nutrients for crop. However if the wastewater is applied at rates in excess of crop uptake rate, the excess wastewater could enter surface and groundwater. Thus it is important to treat the livestock wastewater. Most of the water used in Malaysia is taken from surface water sources but the quality of the water is deteriorating. Many factors have contributed to this, for example industrial wastewater, sewage and domestic wastewater, livestock wastewater and others [1]. Heavy contamination of livestock wastewater is characterized by high suspended solids, high COD, high BOD and high nitrogen, which affected the surface water if it is not treated [2]. In Malaysia the requirement to treat livestock wastewater (independent farmers) has started recently otherwise it was discharged directly to river or natural water body. However, many developed countries such as South Korea have regulation to control the release of untreated livestock wastewater to the river. Raw livestock wastewaters are required to be treated at Livestock Wastewater Treatment Plants. It is usually owned and operated by the government. Individual livestock farmers are required to pay reasonable fees for wastewaters generated at their farms to be collected and treated at the treatment plants. The objectives of this paper were to compare the situation in South Korea with Malaysia in handling the livestock wastewater and to give an overview of the impact of livestock wastewaters if they were discharged to natural water bodies without treatment.

Methodology

Location and Sampling

The sampling was conducted at Gongju Livestock Wastewater Treatment Plant, Gongju, South Korea. The treatment plant has a capacity of treating 250 tons of raw wastewaters per day. Truck tankers were used to transport livestock wastewater from individual livestock farms. Wastewater samples were collected after each treatment stage at Gongju Livestock Wastewater Treatment Plant with 2 duplicates per point. Samples collected were preserved in refrigerator at $4^{o}C$.

Sample analysis

Samples collected were analyzed for Total Nitrogen, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, Total Phosphorus, COD, BOD, Suspended Solids and pH. pH was measured using pH meter (Hach) after calibrated. BOD was measured using WTW OxiTop® measuring system. SS was measured according to APHA standard [3]. Total Nitrogen, $N\text{-}NH_4^+$, $N\text{-}NO_3^-$, $N\text{-}NO_2^-$, Total Phosphorus, COD were measured by a calorimetric method using Hach spectrophotometer model DR4000 [3].

Results and Discussion

Livestock wastewater at Gongju Livestock Wastewater Treatment Plant contained high concentrations of Total Nitrogen (T-N), Total Phosphorus (T-P), Chemical Oxygen Demand (COD) and suspended solid (SS) (Figure 1 and 2). The concentrations of T-N, T-P, COD and SS for raw wastewater were 2820 mg/l, 700 mg/l, 20600 mg/l and 6933 mg/l, respectively. After undergoing various treatment stages the concentration of T-N, T-P, COD and SS were reduced to 9 mg/l, 2.1 mg/l, 105 mg/l and 73 mg/l, respectively (Figure 1 and 2) and these were then discharged to the drain.

The concentrations of other species of nitrogen such as $N\text{-}NH_4^+$, $N\text{-}NO_2^-$ and $N\text{-}NO_3^-$ at the final stage was discharged to drains at 15 mg/l, 0.17 mg/l, <0.05 mg/l, respectively (Figure 1). Concentration of $N\text{-}NH_4^+$ for raw livestock wastewater was 2880 mg/l. After undergoing various treatment processes $N\text{-}NH_4^+$ was reduced to 15 mg/l (Figure 1). This was translated as being a 99.5% removal of $N\text{-}NH_4^+$.

The removal rates (%) of pollutants from influent to effluent for T-N, T-P, COD and SS were translated as 99.7%, 99.7%, 99.5% and 98.9%, respectively. It is not a simple process but involved various treatment processes in order to achieve above 98% removal efficiency.

The treatment process at Gongju Livestock Wastewater Treatment Plant was divided into eight stages namely Screening (Raw), Chemical treatment (Polymer), Anaerobic Digestion, Nitrification, Sequencing Batch Reactor Processes (SBR), Chemical Treatment (Coagulant), Fenton and Ozone (which include activated carbon/sand filtration). Figure 3 showed the contribution of each process to reduce the pollutants by above 98 % of pollutants removal. Livestock wastewater contained high concentrations of organic wastes. From Figure 3, it can be seen that anaerobic digestion contributed significantly to the reduction of the T-N, T-P, COD and SS from previous processes (polymer) with percentage removal rate of 83%, 66%, 87% and 74%, respectively.

Substantial amount of methane gas generated from the anaerobic digestion was used to generate heat and supplied back to maintain the temperature at $32\text{-}35^{o}C$ as required in the anaerobic digestion. The heat was also supplied to the Nitrification process. It was needed especially during the winter season where the temperature recorded was below $0^{o}C$.

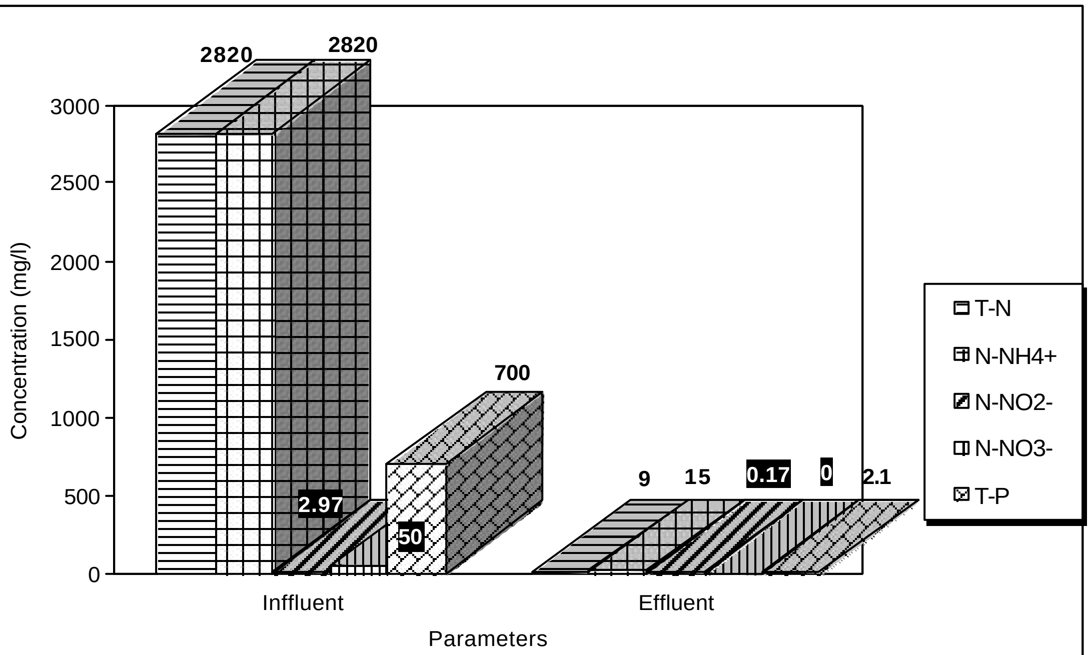

Figure 1: Concentration of Nitrogen and Phosphorus before and after the treatment at Gongju livestock wastewater treatment plant

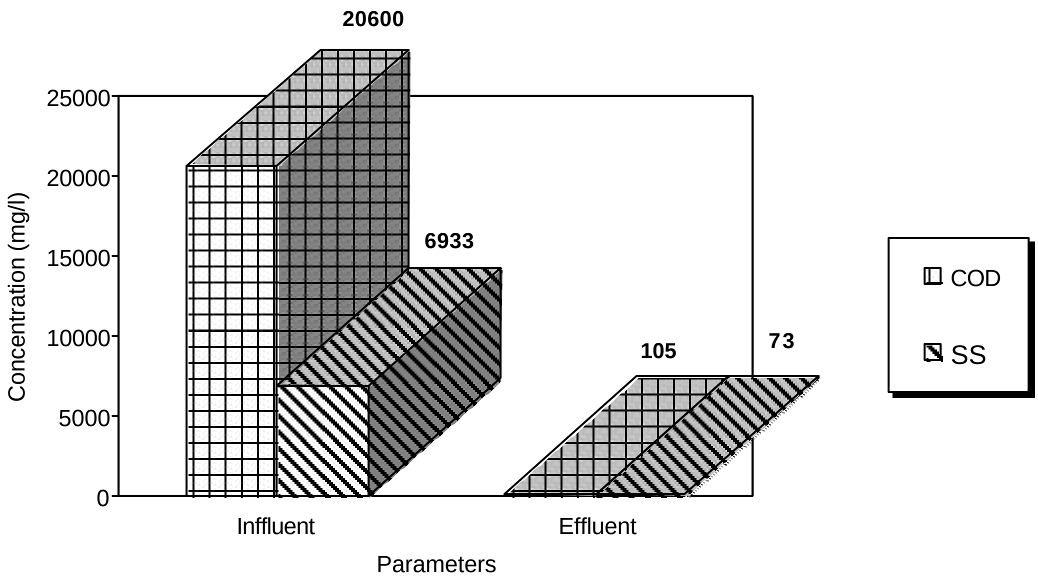

Figure 2: Removal of COD and Suspended Soilds (SS) before and after the treatment at Gongju livestock wastewater treatement

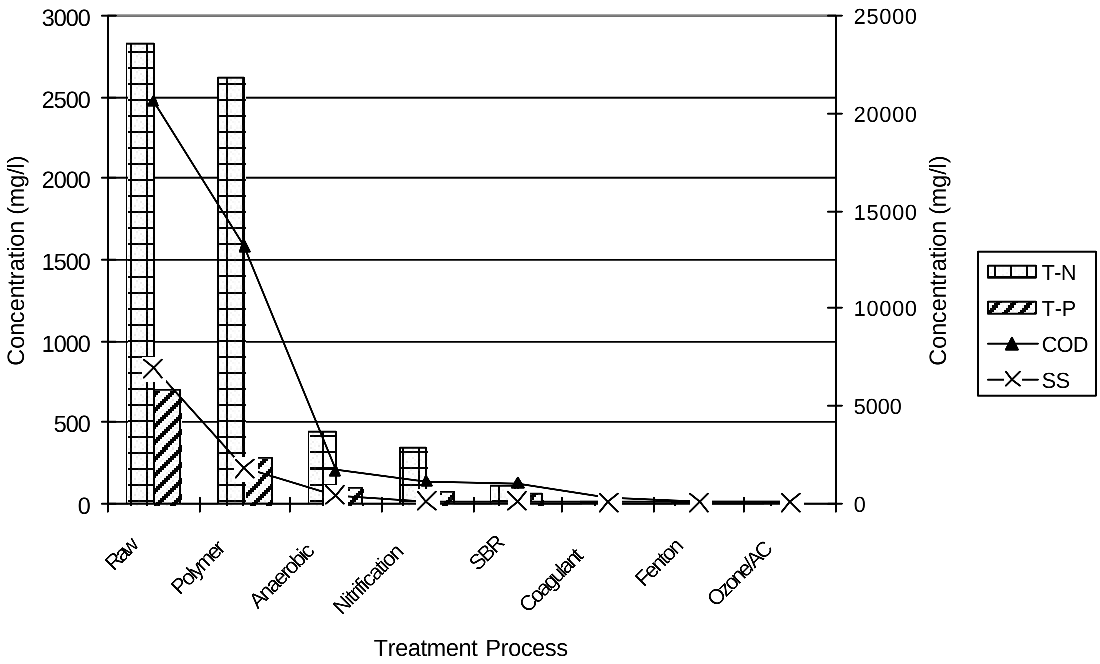

Figure 3: Removal of pollutants in different stages during the treatment at Gongju livestock wastewater treament

Livestock wastewater has high concentrations of inorganic and organic nitrogen and other nutrients. Because of high concentrations of organic matter and nitrogen, complicated processes of wastewater treatment were needed. Although complicated processes were required, the efforts by the Korean government to provide the facility to treat livestock wastewater could be understood. Should the effluent from individual livestock farm was allowed discharged directly to natural water bodies, this will significantly degrade the water quality.

Livestock wastewaters were also commonly used as fertilizers and applied onto cropped fields. However, excessive application as fertilizer represents a potential source of pollution to the groundwater in the affected area.

Therefore if the handling of livestock wastewater was not managed properly it will cause potential health problems such as exposure to bacteria and chemical contaminations.

After anaerobic digestion, the wastewater was treated at nitrification stage where $N\text{-}NH_4^+$ was converted to $N\text{-}NO_3^-$ by bacteria. This explained the increase of $N\text{-}NO_3^-$ concentration for the effluent (Figure 4). Therefore main composition of nitrogen before nitrification was $N\text{-}NH_4^+$ (Influent). While after the nitrification, main composition of nitrogen was $N\text{-}NO_3^-$ (Effluent) (Figure 4).

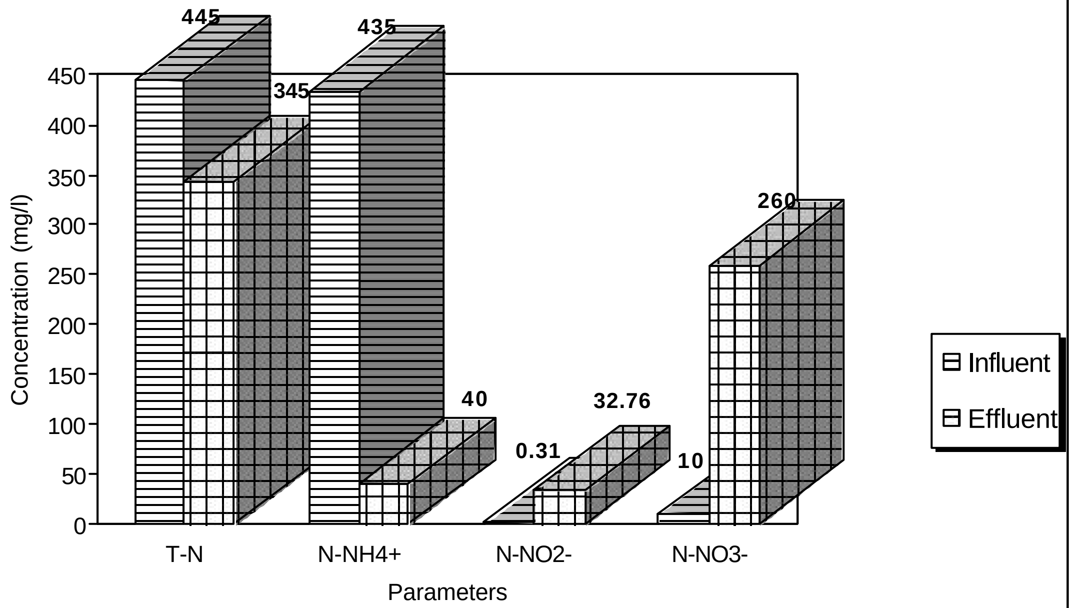

Figure 4: Nitrification Process at Gongju livestock wastewater treatment plant

At the de-nitrification stage N- NO_3^- was converted to nitrogen gas. This explained the decrease of N- NO_3^- after de-nitrification process (Figure 5). As N-NO_3^- was part of the T-N, the removal of N-NO_3^- to nitrogen gas also resulted in the reduction of T-N for effluent after de-nitrification process (Figure 5).

Therefore before the de-nitrification process the main composition of nitrogen was N-NO_3^- (influent) which was approximately about 75 % of Total Nitrogen.

The pH recorded at all treatment stages was ranging from 6.42-9.01. Each treatment process has different pH with the lowest pH of 6.42 recorded at chemical treatment (Alum/polymer). The regulation requirement of South Korea government for treated livestock effluent for COD, SS, T-N and T-P were below 50 mg/l, 30 mg/l, 60 mg/l and 8 mg/l, respectively. Data obtained from this study for COD, SS, T-N and T-P were 105 mg/l, 73 mg/l, 9 mg/l and 2.1 mg/l, respectively.

Malaysia as developing country perhaps is still far away in terms of treating the livestock wastewater compares to South Korea – developed country. However the situation in Malaysia has improved gradually resulting from the need and awareness to conserve the natural water bodies by various parties such as government, farmer and public as well. The outbreak of Nipah disease in 1998/1999 for instance, has caused significant changes on the pig industry in Malaysia. Pig farming will only be allowed in Pig Farming Area, identified by Ministry of Agriculture and Agro-based Industries [4]. Proper wastewater treatment at the farm are also required and regulated by the Veterinary Services Department. The effort by Agriculture and Agro-based Industries Ministry to study the possibility to set up centralize livestock farming activities will contribute significantly on the management of the livestock wastewater in the country (*The Star, May 19, 2006*). With centralized livestock farming, the wastewater will be treated and monitored effectively before discharged to natural waterway.

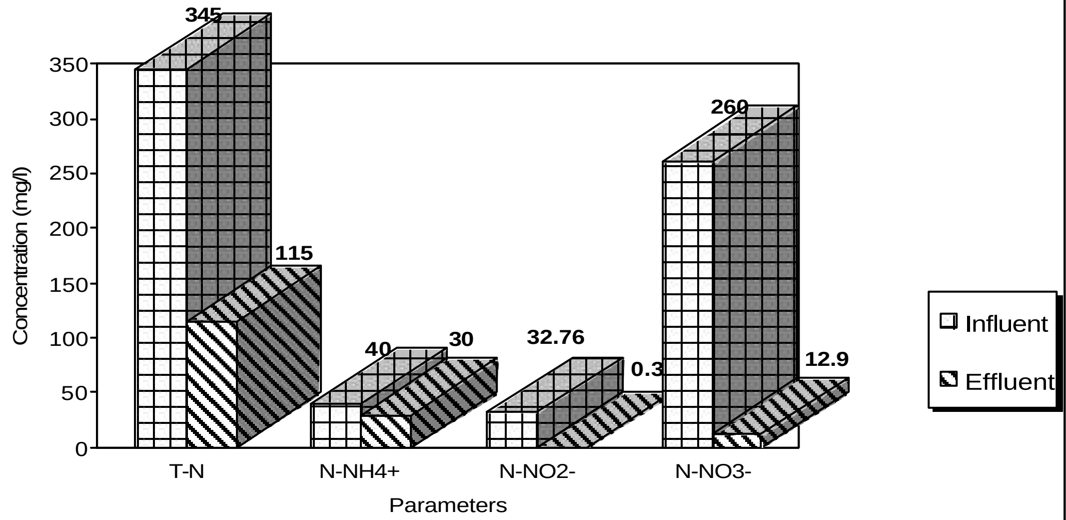

Figure 5: Denitrification process at Gongju livestock wastewater treatment plant

Conclusions

The Gongju livestock wastewater treatment plant consists of various treatment process. Each stage has installed for specific purposes to remove target pollutants. For example, anaerobic digestion process was used to reduce organic matters and nutrients. Because of high concentrations of pollutants that were present in livestock wastewater these must be managed properly to avoid direct dis charge to the natural water bodies. The centralized livestock wastewater treatment has been in operation for more than 5 years. The success of this centralized livestock wastewater treatment was contributed to the effort by i) government -providing the service, ii) farmer -willing to pay the minimal service fee, iii) farmer -aware of their responsibility to the environment and preserve the natural fresh water. Direct discharged of untreated livestock wastewater to natural water bodies indeed will pollute it significantly. Although the handling of livestock wastewater in South Korea is well ahead of us, Malaysia has also started taking various efforts to preserve the freshwater.

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