RESEARCH ARTICLE

Advanced Science Letters
Vol. 23, 2586–2588, 2017

Reversible Anaerob-Evapotranspiration Process for Removal of High Strength Ammonium in Leachate from Tropical Landfill

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This paper figured out the better system between anaerobic-evapotranspiration system (AES) and evapotranspiration-anaerobic system (EAS) for ammonium removal in leachate from landfill. Hence, three different species plants namely *Eleusine indica* (L.) Gaertn (R-1), *Alocasia macrorrhiza* Schott (R-2), and *Fimbristylis globulosa* (Retz) Kunth (R-3) were compared. Jatibarang landfill were located on Semarang, Central Java, Indonesia. The experiments were conducted to measure ammonium removal efficiency. The results show by the time of reactor operation, the ammonium removal efficiency increases gradually for all systems. EAS system give better performance compare EAS. The influence of different type of plants is not significance. The ammonium removal efficiency (%) in R-1, R-2, and R-3 are 87.91, 85.24, and 89.69 for AES system, and 87.30, 86.15, and 87.44 for EAS system, respectively.

Keywords: Ammonium, Leachate, Landfill, Anaerobic Process, Evapotranspiration Reactor.

1. INTRODUCTION

Biological processes was very effective in removing organic and nitrogenous matter. Nitrogenous wastes component that pollute the receiving water are ammonium ions (NH_4^+), nitrite ions (NO_2^-), and nitrate ions (NO_3^-).[1–3] Leachates with high $NH_4^+ \pm N$ content are generally difficult for conventional biological treatment processes, it has several limitations such as leachate toxicity and low biodegradability.[4,5] More attractive method is combined anaerobic and aerobic systems for simultaneous removal of ammonium. Therefore, this treatment system was needed to be developed and modified.[6] Phytotechnology by using plants was a promising system for treatment ammonium in leachate because ammonium is a central nitrogen compound in all organisms. Evapotranspiration therefore might be used in soil-plant systems for landfill leachate treatment.

This study was combined anaerobic and evapotranspiration system to remove high ammonium concentration in leachate by using three plants alternative species namely Goosegrass (*Eleusine indica* (L.) Gaertn, Giant taro plant (*Alocasia macrorrhiza* Schott) and hydrophyte plant (*Fimbristylis globulosa* (Retz) Kunth.

2. EXPERIMENTAL DETAILS

Artificial leachate was made by added of diammoniumsulphate into raw leachate were collected from the Jatibarang landfill, Semarang City, Indonesia, until ammonium concentration in leachate was 2000 mg/l NH_4-N. Three plants species were used in the experiment namely *Eleusine indica* (L.) Gaertn, *Alocasia macrorrhiza* Schott, *Fimbristylis globulosa* (Retz) Kunth.

Every set reactor was made in two sizes, where the large reactor as a main reactor and small reactor as a toxicity indicator reactor or as an early warning system reactor, depend on their placement in the system. Upflow anaerobic reactor was made by plastic tube with 19 L volume for large reactor and 2.5 for small reactor. The "bioball" was using as bacterial media in reactors, at the upper reactor there was a hole and connected with plastic hose to measure glass that inserted into the water.

The liquid volume in each reactor are 15 and 1.5 L respectively. Main evapotranspiration reactor consists of two containers namely 80 gallons and 70 gallons. Smaller container was used for plants media which ± 1 cm^2 hole at the bottom and then it was put into large container. Small evapotranspiration reactor consisted of polybag for planting plants media and placed into container. The liquid volume in this system is 1.5 L. After evapotranspiration reactors were ready, the gravel added into container bottom layer media. Then, soil added with 20 cm

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 1936-6612/2017/23/2586/003 doi:10.1166/asl.2017.8720

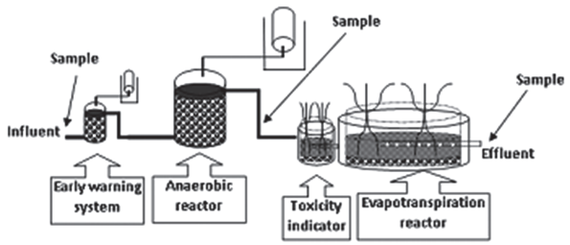

Fig. 1. Anaerobic-evapotranspiration system (AES).

high layer as plants cultivation media. In each container was cultivated with 2 individual plants namely *Eleusine indica* (L.) Gaertn (ER-1) and *Alocasia macrorrhiza* Schott (ER-2), and two colonies (5 individual per colony) of *Fimbristylis globulosa* (Retz) Kunth (code: ER-3). Then, all plants were maintained for 30 days, where each set reactor was made in triplicate (Fig. 1).

Experiment was conducted in two steps. First step is anaerobic-evapotranspiration system (AES) and second step is evapotranspiration-anaerobic system (EAS). The system coded with R-1 when ER using *Eleusine indica* (L.) Gaertn, R-2 when ER using *Alocasia macrorrhiza* Schott, and R-3 when ER using *Fimbristylis globulosa* (Retz) Kunth, respectively. The reactors was operated in 30 days, and leachate sample was taken in every 3 days from sampling point. Ammonium concentrations was determine with spectrophotometric method at λ_{max} 425 nm and BOD was measured according to the procedure described in Indonesian National Standard (SNI).[7]

3. RESULTS AND DISCUSSION

3.1. Anaerobic-Evapotranspiration System (AES)

The result shown Ammonium removal efficiency from anaerobic reactor (AR) in AES system was increase gradually in 30 days. At the end operation, the average efficiency was reached 75.51% with 1939,79 mg/l NH_4-N ammonium load. Removal rate variation in anaerobic reactor less than 0,5 mg NH_4-N/l.day, due to bacterial adaptation under high ammonium concentration. The degradation indicate nitrification process was occured in the bottom layer anaerobic reactor as an initial leachate influent and still contain dissolved oxygen even with low concentration (3.3–4.4 mg/l). This process result ammmonium oxidation by oxidizing bacteria (*Nitrosomonas sp.*) produce nitrite, and then by nitrite oxidizing bacteria (*Nitrobacter sp*) will produce Nitrate. This Products will flow to upper layer when anoxic condition taken place. It will undergo a denitrification process by facultative heterotrophic organisms, that utilize nitrate compounds as a metabolism source and will produce nitrogen.[8–10] Moreover, it can also produce nitrogen oxides as a by product.[11] Even in the best conditions, the reproductive rate of nitrifying bacteria is minimal. Due to the relatively large quantity of ammonium ions and nitrite ions, that needed to assimilate carbon dioxide, nitrifying bacteria have a very low reproductive rate. Therefore, AR efficiency is relatively low (<80%).

Ammonium removal efficiency from ER was increase as a result of bacterial and plant performance. The average of daily ammonium removal rate in ER-1, ER-2 and ER-3 was 49,83 mg NH_4-N/l.day, 42,88 mg NH_4-N/l.day, 45,66 mg NH_4-N/l.day, respectively. Basically, ammonium degradation occurs in two parts, namely the rhizosphere and plant.[12] Nitrification processes occur in two step namely ammonia oxidizing bacteria that produce nitrite and then nitrite oxidizing bacteria that produce nitrate.[13] The oxidation process of ammonium to nitrite in normal conditions have limited rate.[14, 15] The nitrite oxidation run faster in the nitrate form to nitrite, and then accumulation in the reactor was rare.[16] The second ammonium degradation process was occurs in plants where nitrate compounds was as primary nitrogen source and as most important mineral for growth in aerobic soil.[17] While, ammonium it self was a major source of inorganic nitrogen for root, and an attractive nitrogen form for plant roots.[18] In the plants, ammonium was a central connection during the process of nitrate reduction, photorespiration, phenyl propanoid metabolism, transport degradation amide and protein catabolism.[19–21] Ammonium will absorb and assimilated in the roots, and can undergo translocation in plant tissue but under low concentrations with helped by transporters. However, ammonium removal efficiency from RE shown fluctuative, but tends to increase and relatively high removal rate. Though, at days 24th shown removal efficiency was reach to stable condition. That conditions indicate bacterial growth inhibition and competition occurred in the rhizosphere and plant root. This processes affected by decreasing ammonium, nitrate and nitrite influent from AR. Although, two step processes using AR and ER ammonium efficiency was increase gradually and at the end reactor operation efficiency from R-1, R-2 and R-3 was achieve 87.91%, 85.24%, 89.69%, respectively (Fig. 2). Where, at the end ammonium effluent from R-1, R-2, and R-3 was 234,5 mg/l NH_4-N, 286,23 mg/l NH_4-N and 200,01 mg/l NH_4-N, respectively.

3.2. Evapotranspiration-Anaerobic System (EAS)

Higher ammonium concentration load (2314,66 mg/l NH_4-N) to ER in EAS affect ammonium removal efficiency was increase gradually and approach to bacterial growth pattern. At the end operational time, the average removal efficiency from ER-1, ER-2, and ER-3 was reach to 53,24%, 50,62%, and 52,66% respectively.[22] When ER as the first reactor position, the plants and aerobic bacteria will use ammonium as nitrogen resource via nitrification-denitrification and translocation as described above. Plants also can use ammonium as the sole nitrogen source.

Eleusine indica, Alocasia macrorrhiza, Fimbristylis globulosa shown it's species perform well when ammonium is the only or predominant, source of Nitrogen.[23] Where, Localized nitrogen supply stimulates root growth, root branching and lateral root elongation, but most of the positive effects on root proliferation have been attributed to nitrate, rather than ammonium. Nevertheless, in long-term reactor operation ammonium inhibition can

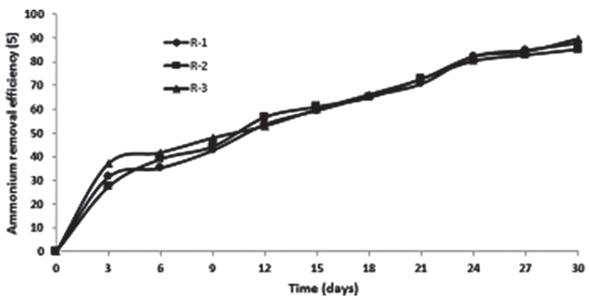

Fig. 2. Ammonium efficiency from AES using *Eleusine indica* (R1), using *Alocasia macrorrhiza* (R2), using *Fimbristylis globulosa* (R3).

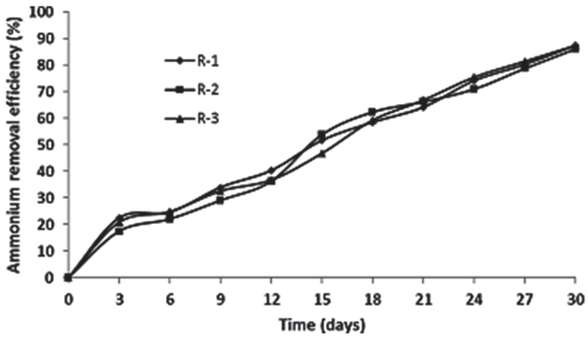

Fig. 3. Ammonium efficiency from AES using *Eleusine indica* (R1), using *Alocasia macrorrhiza* (R2), using *Fimbristylis globulosa* (R3).

occur.[24] It's evidence at 18th days, ammonium removal rate efficiency was slower than before and can be as toxicity symptom of plants and/or aerobic bacterial. Ammonium essentiality in the range of 20–200 μM in agricultural soils, but will toxic when in excess. The ammonium concentration to AR was decreased during reactor operation. The efficiency of AR was increase lineary with reactor operational time. The average removal efficiency at the end operation from AR-1, AR-2, and AR-3 was 72,84%, 71,94%, and 73,46% respectively with daily removal rate in AR-1, AR-2 and AR-3 was 64,72 mg NH_4-N/l.day, 63,43 mg NH_4-N/l.day and 65,03 mg NH_4-N/l.day, respectively.

Reverse with ER, removal rate efficiency after 18th days was higher than days before. It's condition can be described that bacteria in AR degrade ammonium, nitrite and nitrate were not treated by aerobic bacteria and plants in evapotranspiration reactor. At the beginning of the current process, bacterial in AR did not get enough nitrogen for growth because most of ammonium has been degraded in the evapotranspiration reactor. When efficiency in evapotranspiration reactor was slower, more ammonium, nitrit and nitrate will entry to AR and bacterial will growth faster. It causes bacteria will grow following an exponential pattern and may cause by increasing of leachate biodegradability after processed in ER. Ammonium removal efficiency from EAS shown gradually increase following linier pattern, where in the end reactor operation efficiency level in R-1, R-2 and R-3 was achieve 87,30%, 86,15%, 87,44%, respectively (Fig. 3).

4. CONCLUSION

Evapotranspiration Anaerobic System (EAS) has better ability as a system to treat of high strength ammonium in leachate than AES. The ammonium removal efficiency increases gradually better with EAS than AES. The influence of different type of plants to ammonium removal efficiency is not significance. The ammonium removal efficiency percentage in R-1, R-2, and R-3 were 87.91, 85.24, and 89.69 for AES system, and 87.30, 86.15, and 87.44 for EAS system, respectively.

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Received: 12 October 2016. Accepted: 2 November 2016.