

DENITRIFICATION EFFICIENCY IN A COMPOST BED WITH VARIOUS CARBON AND NITROGEN CONTENTS

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Abstract: This research investigated nitrate removal in a compost bed with various contents of carbon and nitrogen. The process was carried out in continuous flow by which nitrate loading was administered from 0.19 to 1.11 g N h⁻¹L⁻¹. Increasing nitrate loading brought about increasing denitrification efficiency and decreasing the final C:N ratio in a compost with the initial C:N ratio of 20:1. Compost with the initial C:N ratio of 10:1 performed decreasing denitrification efficiency and increasing the final C:N ratio. Based on the denitrification efficiency performance, a compost maturity index was proposed at the limit C:N ratio of 15:1.

Keywords: C:N ratio, maturity index, nitrate removal, volumetric loading

INTRODUCTION

Central and local governments of Indonesia encourage the community to convert solid waste into compost. Small scale compost producers could be found in many urban cities, and they put the compost into market [1]. Compost producers are used to add microbial starter to enhance the compost production rate. This is intended to minimize the operation cost rather than balancing in the market need, it is therefore no product quality was assured [2]. As a result, compost varies widely in carbon and nitrogen contents depending on composting processes as well as differences in carbon and nitrogen of its original materials. Based on carbon and nitrogen content, compost was classified as mature and immature compost [3]. International composting industries generally adopted the limit C:N ratio of less than 20 for mature compost [1]. Mature compost has generally low ammonium because it is rapidly converted to nitrate under normal conditions. Bezdicsek and Fauci [4] described a rough relationship between the C:N ratio of compost and the release rate of organic nitrogen to inorganic nitrogen. Generally, compost with the C:N ratio of more than 25:1 releases slight inorganic nitrogen instantaneously, because the high amount of carbon tied up inorganic nitrogen inside the compost. Compost in the range of 15 to 25:1 releases

nitrogen at an intermediate rate. On the other hand, compost with the C:N ratio of less than 15:1 would release nitrogen more rapid and would be able to reach up to the range of 10 to 50% greater than the release rate of most composts. The end use of compost is for agricultural application in rural area, or greenspace and soil amendment in urban housing where on-site system is applied.

The on-site system was used as a means of domestic wastes disposal from septic tank to soil absorption bed. Wastewater and human wastes, in particular, contain valuable nutrients, including nitrogen, phosphorus, and potassium. Many studies had been conducted on methods to remove nitrogen from residential wastewater, involving various engineered systems for denitrification [5–7]. The engineered system might create difficulties in the implementation and financing the treatment technology for on-site sanitation system. As the nitrogen-rich organic wastewater is biodegradable, there is a potential to develop a heterotrophic denitrification process in the soil absorption bed. The limiting process parameters for heterotrophic denitrification in sand bed had been investigated [8]. Therefore, the current study investigated the denitrification in compost bed by which enables to alter the nitrogen cycle of wastewater and compost.

It was well known that nitrogen was found in the organic form and bounded with carbon, or inorganic form, consisting of ammonium, nitrite, nitrate, and nitrogen gas. Ammonia was not subject to leach in the compost matrix, but could be lost through volatilization in form of ammoniacal gas. Whereas, nitrate was subject to leach in the compost matrix. Little was known to the extent of nitrate leaching in various carbon and nitrogen content of the compost and therefore, the investigation was addressed to assess the denitrification efficiency in various C:N ratios of mature compost. Mature compost was used in order to support the end use of compost for on-site sanitation system, hence, solving the environmental problem of both.

MATERIALS AND METHODS

Compost characteristics

Three commercial composts were collected from local compost producers in Surabaya. These producers used municipal solid waste as a feedstock for compost production. There was no label regarding the C:N ratio and therefore carbon and nitrogen contents of the compost were determined in the laboratory. The test method of Llewelyn [9] was applied for determining total organic carbon. Carbon dioxide emitted by the compost was collected during 4 days following equilibration period of 3 days at 30 °C incubation. Carbon dioxide entrapment solution was sodium hydroxide; the collected sodium carbonate is precipitated as barium carbonate by the addition of excess barium chloride. The concentration of carbon dioxide evolved by the compost is measured by titration of the residual sodium hydroxide with standard acid using phenolphthalein indicator. The total nitrogen consisting organic and inorganic forms was measured in water extractable substances. Hot distillate water was used in order to extract sugars, amino acids, starch and pectins, which all are biodegradable organic matter-containing compost [10]. Following shaking for 24 hours, an aliquot was examined for the total kjeldahl nitrogen, consisting of organic nitrogen and ammonium, also nitrate (NO₃⁻) and nitrite (NO₂⁻). The original compost contained C:N ratio of 8 to 10 which was classified as mature compost.

Compost bed treatments

Compost bed was constructed by mixing compost with sand in which the test wastewater passes through. Glucose (*p.a*) was added to the original compost for C:N ratio adjustment. Three

initial maturity levels of compost were set, consisting C:N ratio of 10, 15 and 20. Each compost maturity level was mixed with clean sand for water conductance purposes. The compost bed of each maturity level consisted of 75% compost and 25% clean sand by weight. Carbon to nitrogen ratio was measured for each compost bed using the same method for original compost determination.

Test solutions

A test solution was prepared for 100 mg NO₃⁻ L⁻¹ by dissolving 163 mg KNO₃ (*p.a*) into 1 L of aquadest. Addition of phosphorus was required for nutrient adjustment and to suppress nitrite accumulation [8]. The amount of 3 mg PO₄³⁻-P/L was prepared by dissolving 13.2 mg KH₂PO₄ (*p.a*) into 1 L of aquadest. The dose of phosphate was sufficient for 100 mg NO₃⁻ L⁻¹. The same procedure was applied for test solutions which contained 200 and 300 mg NO₃⁻ L⁻¹.

Inoculant of denitrifiers

An inoculant was prepared by means of dissolving 10 g healthy garden soil into 200 mL physiological solution made of 8.5 g NaCl L⁻¹. The soil solution was introduced in a nitrate and glucose containing solution in a closed Erlenmeyer. The sealed cap of Erlenmeyer was equipped with a pipe to allow gas to flow into an up turned cylinder glass which contained destilate water. The reaction system was incubated at 28 °C for 1 week. Gas bubbles were produced in the up turned cylinder as a result of the heterotrophic denitrification process, and the solution in a closed Erlenmeyer was used as inoculant.

Process operation

The process operation was carried out in a saturated compost bed to represent anoxic condition. A compost bed was placed in a PVC column of Ø 50 mm up to the height of 250 mm, and this accounted for the active volume of the compost bed (V) of 0.5 L. Denitrification was carried out in flow process in which the test solution was introduced from the top of the PVC column and passing through the compost bed. The bottom of the PVC column was equipped with a pipe to allow the test solution to flow to the effluent container. Nitrate containing effluent was measured and the compost was examined for carbon and nitrogen contents at the end of each detention time.

The process operations were repeated three times. Laboratory works for all analytical measurements were in accordance with Standard Methods [11], including additional parameters such as temperature, pH, dry weight, and volatile solids.

RESULTS AND DISCUSSION

Process parameters

The solution pH increased up to 7.9±0.2 at the onset of experiment but stabilized at a pH of 7.3±0.1. Monitoring of the temperatures of influent and effluent were between 28 – 30 °C. Both process parameters were suitable for heterotrophic denitrification process [8] as well as the compost which had a capacity to maintain a suitable pH for denitrification. Therefore pH and temperatures were not the limiting factors for the increase in nitrogen volumetric loadings for various carbon and nitrogen contents. In addition, C and N contents for sand were measured, and each was less than 5 % of the compost. Nitrite level in effluent was not detected, suggesting no nitrification was occurred.

Denitrification efficiency and the C:N ratio

In the compost bed with the initial C:N ratio of 20:1, increasing nitrogen volumetric loading resulted in an increase in denitrification efficiency as shown in Fig. 1 (A). The results confirmed to the work of Schipper *et al.* [12] and Lo Tsui *et al.* [13] who demonstrated denitrification process in a mixed carbon source such as sawdust, soils and compost for a nitrate input of 50 mg N L⁻¹. They concluded that denitrification rates increased when nitrate was added, indicating that denitrification remained limited by nitrate. This limitation was partially attributed to nitrate that predominantly moves through zones of the greater hydraulic conductivity or through the mobile fraction of the water, and slow diffusion to the immobile fraction where denitrifiers were active.

In addition, the final C:N ratio was 2 to 3 levels higher than the initial one, and increasing nitrogen volumetric loading resulted in decreasing the final C:N ratio as shown in Fig. 1 (B). This result might be explained as found by Cárdenas-González *et al.* [14] and Lo Tsui *et al.* [13]. They concluded that no significant amount of organic nitrogen content depleted from the media of immature yard-waste compost because of its relatively large organic carbon content, high microbial activity, and buffering capacity. Composts with a C:N ratio of more than 25:1 released little inorganic nitrogen immediately [4], and hence, the decreasing of the final C:N ratio for the current research was probably due to the initial nitrogen that was tied up by carbon while excessive nitrate input resulted in decreasing C:N ratio.

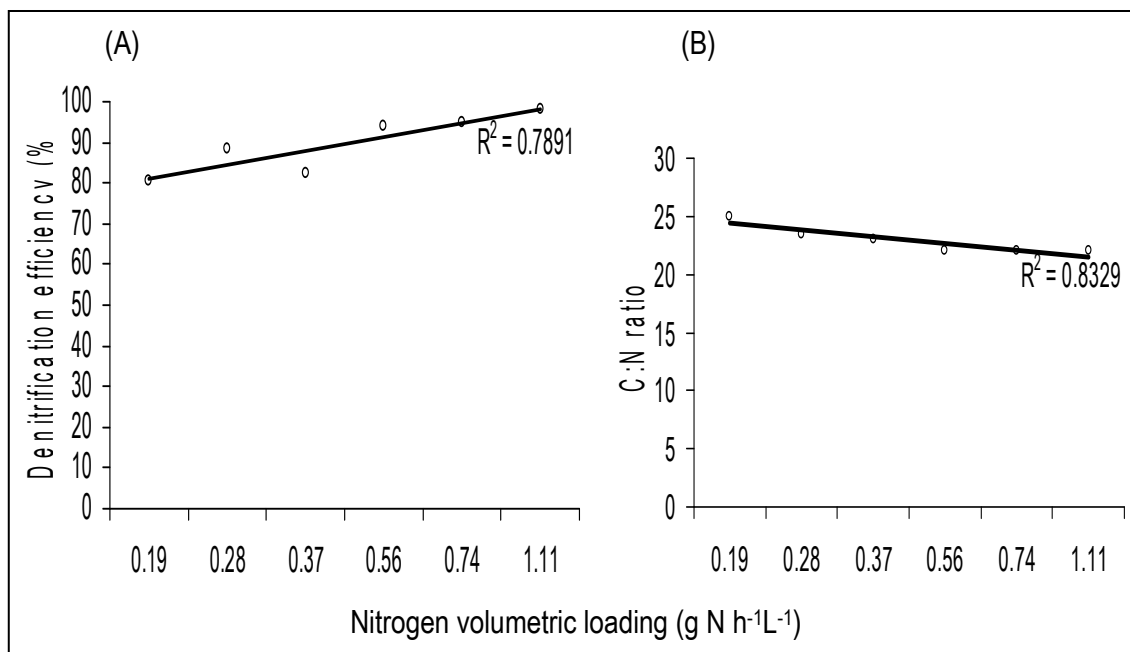


Fig. 1: Denitrification efficiency and final C:N ratio for the initial C:N ratio of 20:1

A mature compost with the initial C:N ratio of 10:1 brought about decreasing denitrification efficiency as nitrogen volumetric loading increased (Fig. 2, A). The results revealed that mature compost was probably insufficient to provide organic carbon for denitrifier growth in order to enhance denitrification efficiency. Therefore, addition of nitrate loading into the mature compost resulted in increasing the final C:N ratio as shown in Fig. 2 (B). The final C:N ratio was 2 to 5 levels higher than the initial one.

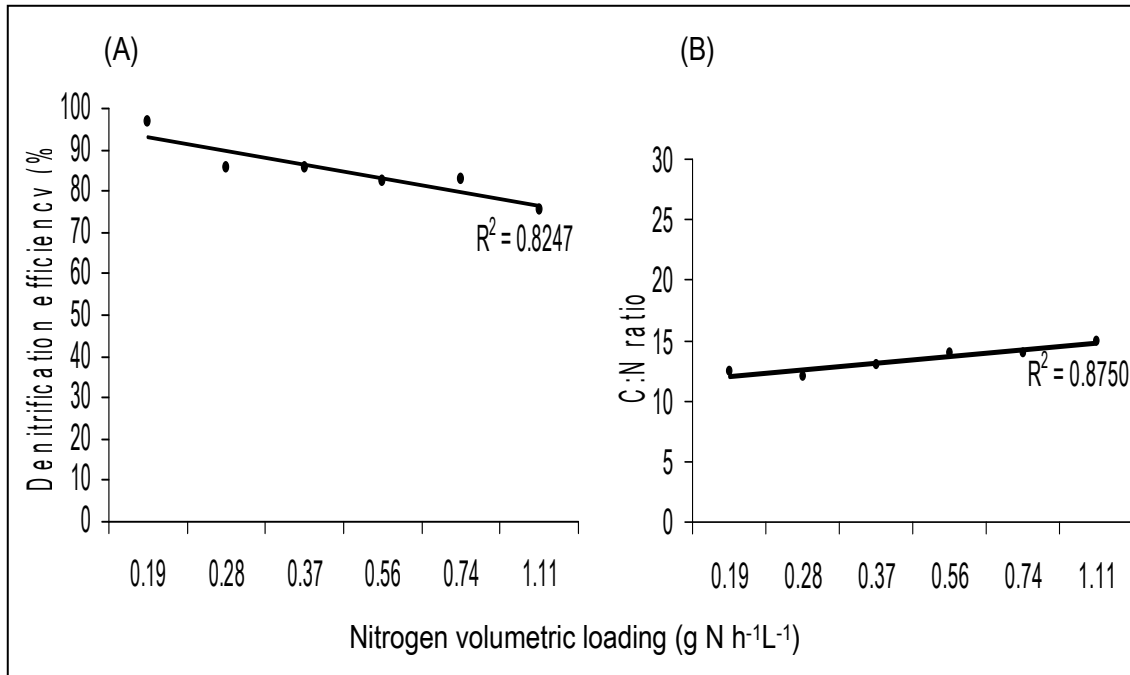


Fig. 2: Denitrification efficiency and final C:N ratio for mature compost

It was important to address the limit of maturity index based on the denitrification process performance. The current research found no significant correlation between volumetric nitrogen loading and denitrification efficiency as well as the final C:N ratio for the initial C:N ratio of 15:1 (Fig. 3). This revealed nitrogen transformation was at intermediate rate *i.e.* the C:N ratio of more than 15:1 would release little inorganic nitrogen, and the nitrogen released quickly for the C:N ratio of less than 15:1 [4]. Therefore, the limit of compost maturity index was proposed to be C:N ratio of 15:1, supporting maturity index in relation to stability index [15].

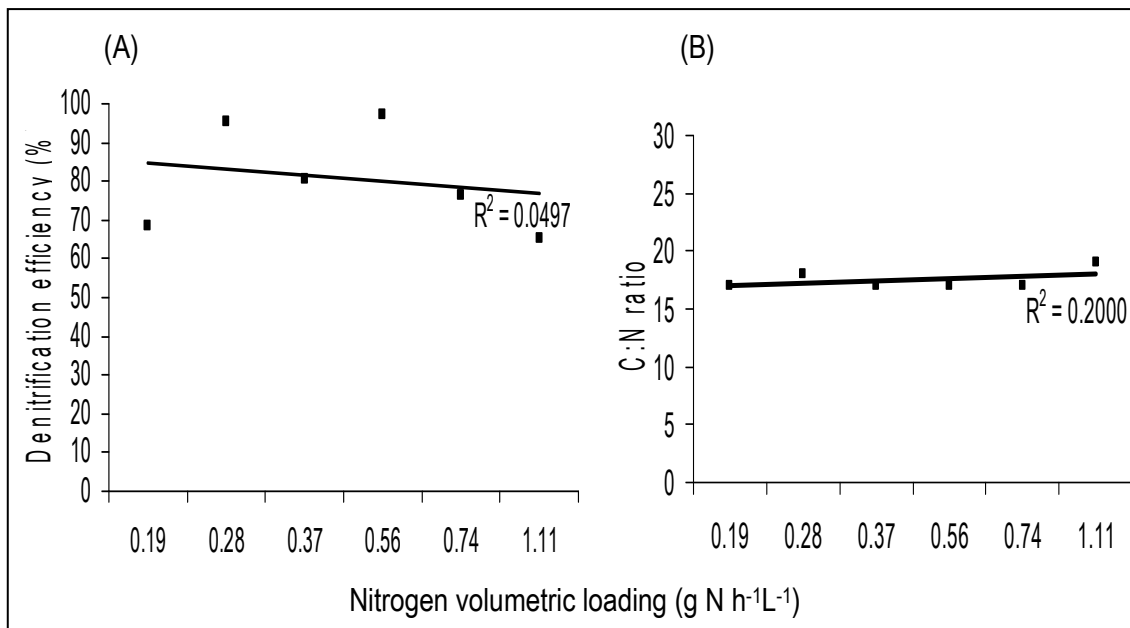


Fig. 3: Denitrification efficiency and final C:N ratio for the initial C:N ratio of 15:1

CONCLUSIONS

The important finding of the current research was that compost with an initial C:N ratio of more and less than 15:1 affected significantly denitrification efficiency. It is therefore a compost maturity index was proposed at the limit C:N ratio of 15:1

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