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Resource Recovery from Paper Mill Sludge through Vermicomposting

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Abstract

Huge amounts of paper mill sludge are generated from the paper manufacturing industries and these can pose environmental contamination problems if not properly managed. Vermicomposting was therefore investigated as a paper mill waste management initiative to produce vermicompost. A total of 3kg of paper mill sludge was fed into a vermireactor and allowed to vermicompost over a period of 60 days using *Eisenia Fetida* as the vermicomposting media. The paper mill sludge had a moisture content of 65% and the vermicomposting processed occurred under standard conditions aerobically. After the 60 days, the vermicompost was analysed for the total nitrogen (TKN), phosphorous (TP) and potassium (TK) composition using standard methods. The vermicompost had an average of 4.3%, 0.45% and 1.89% for TKN, TP and TK respectively. Vermiwash was also generated during the process and contained 1.63%, 0.14% and 0.59% respectively for TKN, TP and TK. The paper mill vermicompost can be used as a source of bio fertilizers.

Keywords: Earthworms; paper mill sludge; resource recovery; TK; TKN; TP; vermicompost

1. Introduction

The paper manufacturing industry generates huge amounts of paper mill sludge as a waste product during the processes (Kaviraj and Sharma., 2009). This paper mill sludge if not properly managed can lead to environmental pollution and degradation, pollution as well as climate change effect (Basheer and Agrawal., 2013). However, this paper mill sludge is also a highly biodegradable material and has potential to be valorised into useful products such as vermicompost, a form of bio fertilizer. During the vermicomposting process, earthworms such as *Eisenia Fetida, E. Andrei, Eudrilus Eugeniae* (Yadav and Madan., 2013) feed on the organic material with the earthworm gut acting as the bio reactor. The earthworm's excreta during the process are then termed vermicompost and are nutrient rich in

nitrogen, phosphorous and potassium content (Kaushik and Garg., 2004; Mohapatra et al., 2017). As the vermicomposting process progresses, a leachate which can also be applied as a bio fertilizer is produced. Vermicomposting period ranging from 30-120 days has studied before for various organic materials (Mohapatra et al., 2018). This study focused on the bio conversion paper mill sludge to vermicompost as both a waste management initiative for the paper mill industry as well as the valorisation of the paper mill sludge.

2. Materials and methods

Paper mill sludge was obtained from a paper milling industry. *Eisenia Fetida* earthworms were obtained from the local fishermen and were used as the vermicomposting inoculant. Vermireactors were obtained from Full Cycle, South Africa. Three sets of vermireactors were used for the vermicomposting process and were operated set at standard conditions. Each vermireactor was loaded with 3kg of waste and 20 Eisenia Fetida worms were used as the inoculant. Vermicomposting was allowed to take place over a period of 60 days. The paper mill sludge moisture content, total solids, ash content, organic carbon (OC), total nitrogen (TKN), total phosphate (TP), total potassium (TK), fibre and pH were determined. The effect of the vermicomposting process on the TKN, TP, TK and OC was also assessed and the changes in the parameters were measured over a 10 day period.

The pH was measured using a Hanna HI pH probe, the TKN content was determined using the KJeldhal methodology, the moisture content was determined by calculation of the loss in weight after a 5g sample was oven dried at 105 ◦C whereas the OC was determined by calculating the loss due to ignition at 450 ◦C for 4 hours. The TP and TK were determined through wet digestion using an H_2SO_4-H_2O_2 mixture. The total solids in the paper mill sludge were measured by heating 5g of the sample in an oven at 103 ◦C and 105 ◦C, the difference in the weight indicated the amount of solids. The ash content of the paper mill sludge was obtained as a percentage by heating the sample at 815 ◦C in a muffle furnace.

3. Results and discussion

3.1 Characteristics of the paper mill sludge

The paper mill sludge had an ash content of 78%. The characteristics of the paper mill sludge are given in Table 1. The moisture content of the paper mill sludge was 43% and the pH was 9.2. The moisture content and the pH are critical parameters in the vermicomposting process.

Table 1. Paper mill sludge characteristics

Parameter	Value
Moisture content	43.2
Total solids	21.9±0.95
Ash content	78.6±4.4
Organic carbon	22.3±0.36
Total nitrogen	1.55±0.13
Total phosphate	0.21±0.03
Total potassium	0.53±0.05
Fibre	76.4±3.4
pH	9.2±0.1

3.2 Effect of vermicomposting on total nitrogen content

The vermicomposting of paper mill sludge resulted in increased TKN content in the media (Figure 1). The TKN composition increased by 178% during the vermicomposting period. During vermicomposting, nitrogenous components are excreted from the earthworm gut resulting in increased nitrogen composition. The vermicomposting process results in net loss of the dry matter during the oxidation process as well as due to the addition of mucus which is rich in nitrogen hence the increase in the TKN (Kaviraj and Sharma, 2009).

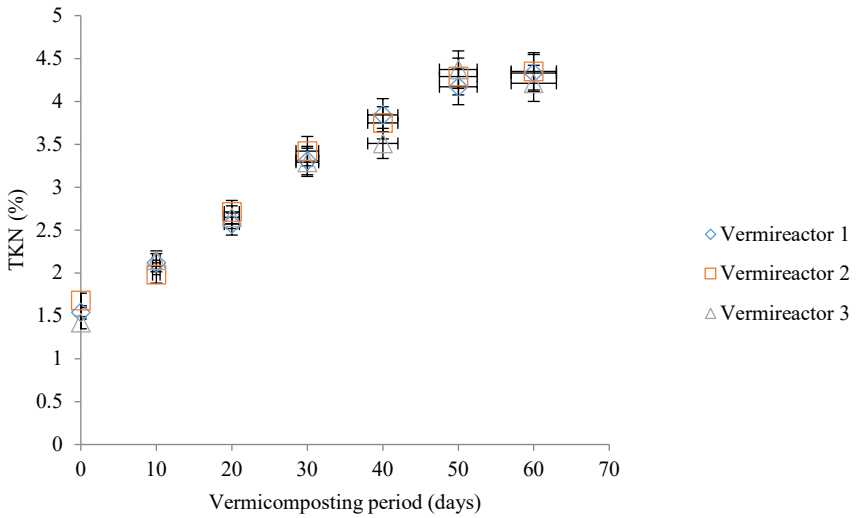

Figure 1. TKN changes during paper mill sludge vermicomposting

3.3 Effect of paper mill sludge vermicomposting on total phosphate

The vermicomposting of paper mill sludge resulted in increased TP content (Figure 2). As the vermicomposting period increased, the TP content increased by 116% over the 60 days. The increase in the TP is attributed to the mineralization of the paper mill sludge during the bio conversion in the earthworms' gut. The earthworms also release phosphates which then results in the increase of TP in the vermicompost (Yadav and Madan., 2013).

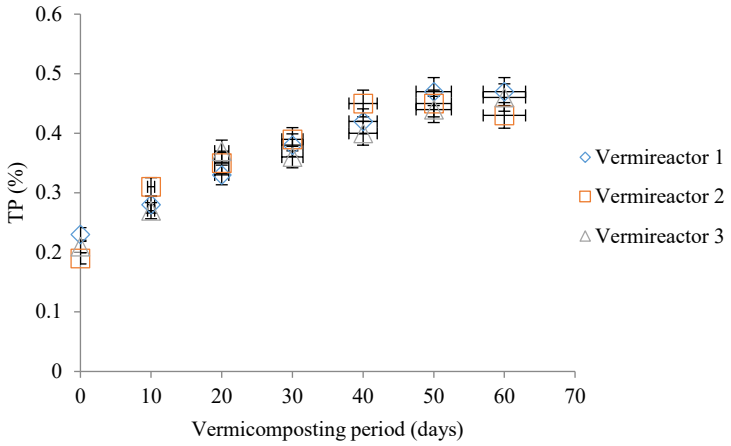

Figure 2. TP changes during paper mill sludge vermicomposting

3.4 Effect of paper mill sludge vermicomposting on TK

As the paper mill sludge vermicomposting process occurred, the TK content in the media also increased (Figure 3). The TK content increased by 257% during the 60 day vermicomposting period. Passage of the paper mill sludge through the earthworm gut makes the potassium nutrients more available hence the increase in TK (Yadav and Madan., 2013).

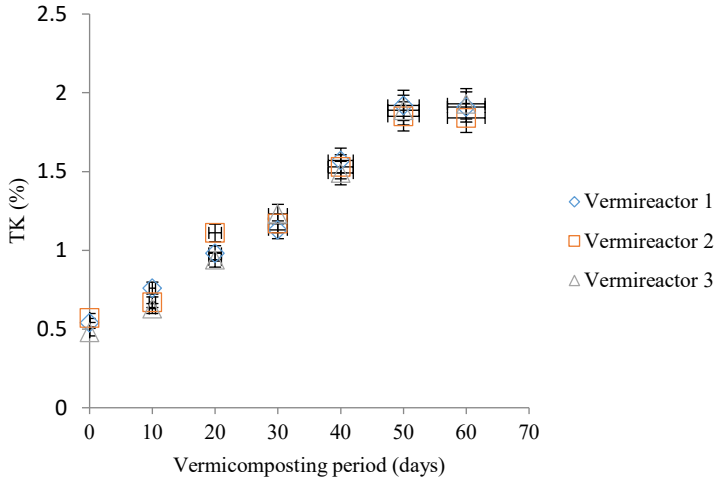

Figure 3. TP changes during paper mill sludge vermicomposting

3.5 Effect of paper mill sludge vermicomposting on organic carbon loading

The organic carbon loading in the paper mill slugged decreased with increase in the vermicompost period (Figure 4). A 39% decrease was observed in the OC and this can be attributed to the conversion on the paper mill sludge to vermicompost by the earthworms. The same trend in OC was observed by Yadav and Madan (2013) during the vermicomposting of paper mill sludge mixed with various other organic wastes with a 28.5% decrease in OC being reported.

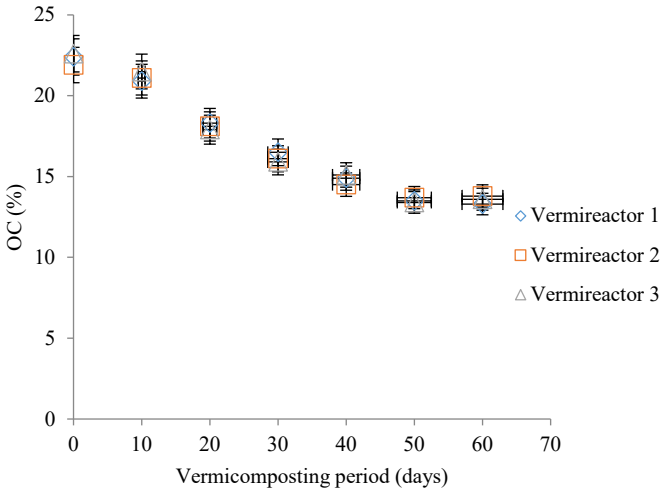

Figure 4. OC changes during paper mill sludge vermicomposting

3.6 Vermiwash characteristics

Vermiwash, a liquid leachate was obtained as a by-product of the vermicomposting process. This leachate can be applied as liquid fertiliser or foliar spray in agriculture. The vermiwash had a composition of 1.63%, 0.14% and 0.59% in terms of TKN, TP and TK respectively.

3.7 Paper mill sludge vermicomposting process

A summary of the paper mill sludge vermicomposting process is illustrated in Figure 5 whereby the inputs are the paper mill sludge and the earthworms. The vermicompost and vermiwash are recovered as the products. A conversion of 60% of paper mill sludge to vermicompost was observed.

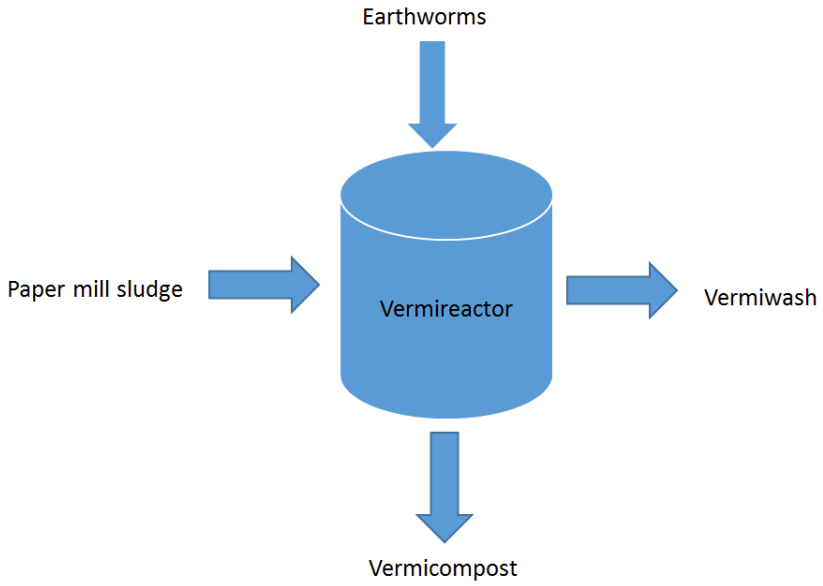

Figure 5. Paper mill sludge vermicomposting process

4. Conclusion

Paper mill sludge can be valorised to vermicompost through the application of the vermicompost technology. Vermicompost with TKN, TP and TK with composition of 4.30%, 0.45% and 1.89% respectively were produced. Significant increases in these parameters was noted and ascertained by the 39% decrease in organic loading. Vermiwash with TKN, TP and TK compositions of 1.63%, 0.14% and 0.59% respectively was also produced.

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Biographies

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