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Evaluation of biodegradation feasibility through rotary drum composting recalcitrant primary paper mill sludge

Jayeeta Hazarika [a,*], Meena Khwairakpam [b]

[a] Department of Civil Engineering (Environmental Division), NIT Meghalaya, India
[b] Centre for Rural Technology, IIT Guwahati, India

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ABSTRACT

Primary paper mill sludge (PPMS) is the major waste expelled from the pulp and paper industries contributing soil and water pollution through the recalcitrant organic and inorganic constituents. These pollutants can, however, be transformed into a high-value soil ameliorating material with nominal investment and time. Current study therefore evaluated the potential of rotary drum composting PPMS for 20 days to delineate an environmentally sustainable option. Five trials with proportions of PPMS, cow dung and saw dust: Trial 1 (10:0:0), Trial 2 (8:1:1), Trial 3 (7:2:1), Trial 4 (6:3:1) and Trial 5 (5:4:1) were performed for evaluation of degrading and nutritive ability along with the fate of pollutants for total mass of 150 kg. Trial 4 exhibited highest metabolic activity contributing higher temperature evolution and longer thermophilic phase (10 days) owing to optimum addition of innoculum and nitrogen through the cattle manure. Moreover, degradation of 16.8% organic matter was also best achieved in Trial 4 following up first-order kinetics. Furthermore, BOD, COD and C/N ratio also explains degradation to be maximum in trial 4 (6:3:1) with reduction of 59.3%, 60.1% and C/N ratio from 55.1 to 18 respectively, proving to be the essential determining factors. Phosphorus availability increased by around 67% in trial 4. PPMS can be thus transformed into a potential valued added product and safe for subsequent land application.

1. Introduction

Primary paper mill sludge (PPMS) eliminated from virgin pulp and paper and recycled paper industries consist of recalcitrant organic pollutants such as fugitive cellulosic fibres, hemicellulose, lignin, resins, phenolics, chlorinated inorganic residues and considerable amount of heavy metals hazardous to the environment. Removal of the cellulosic fibers and other form of suspended solids from the wastewater by sedimentation during effluent treatment, results into the primary sludge majorly organic (40–60%) in nature (Gallardo et al., 2012) with no microbial intervention rendering biodegradation extremely difficult. Sludge generated is around 40–50 kg (dry) tons per ton product/day (Joyce et al., 1979; Bajpai, 2014). Therefore against annual global demand of 402 million tons of paper (Kulkarni, 2013) nearly 18.25 million dry tons of sludge are generated to be disposed annually at the global scale and 492.75 thousand tons of sludge apparently in India. Consequently the alarmingly increasing, inevitable production of sludge presents a critical question. In the current scenario, PPMS is not put to any explicit use rather minimization of waste volume to be disposed is the major concern. The current study is based on Nagaon paper mill (NPM), a unit of Hindustan Paper Corporation limited situated in Jagiroad, Assam, India. The mill has adopted kraft process for pulp making (mostly bamboo) wherein; the woodchips are cooked in a solution of sodium hydroxide (NaOH) and sodium sulfide (NaS_2) at an elevated temperature and pressure to break chips into cellulosic fibrous mass. The manufacture of paper thus generates significant quantities of wastewater, as high as 60 m^3/tonne of paper produced (Thompson et al., 2001). Suspended matters present in the wastewater consist of primarily bark particles, fiber, fiber debris, filler and coating materials. Physicochemical treatment before discharge of the effluent includes screening and primary clarification process which generates huge amount of primary sludge (Fig. 1(b)). Aerated lagoons consist of the secondary treatment. The primary sludge hence with no gainful utilization, infact incurring huge expenses are disposed in the nearby low lying areas causing great environmental threat. Disposal strategies of pulp and paper mill residues hence should be reconsidered.

PPMS are mostly landfilled including landspreading in low lying areas (Pervaiz and Sain, 2015). Incineration is also a popular strategy for volume reduction and energy generation (Faubert et al., 2016).

* Corresponding author.
E-mail address: jayeeta.hazarika@gmail.com (J. Hazarika).

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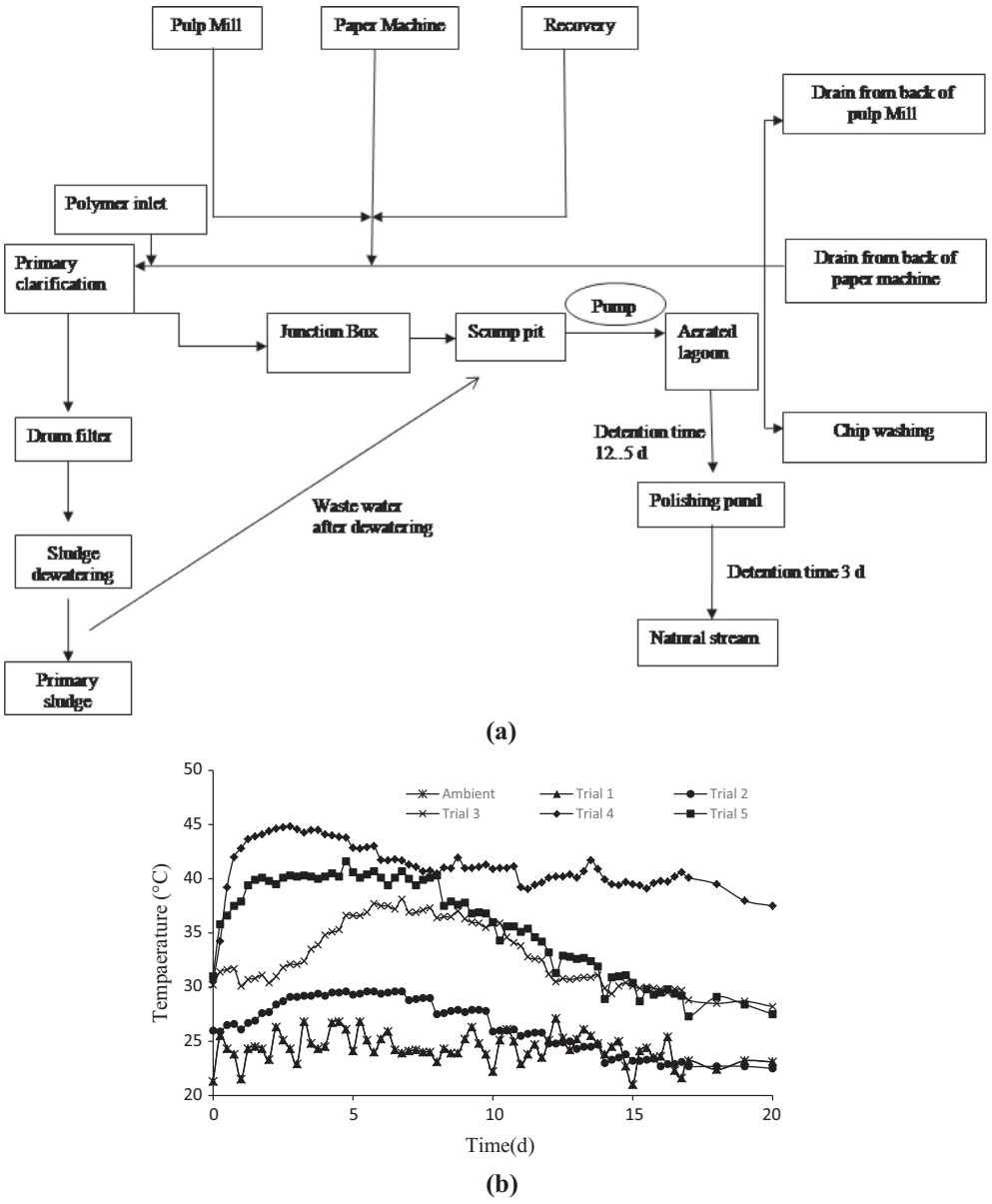

Fig. 1. (a) Wastewater treatment process in Nagaon Paper Mill (Assam, India) and (b) Temperature profile of different trials with combination of PPMS, Cow dung and Saw Dust.

Certain other infrequent methodologies include anaerobic digestion (Meyer and Edwards, 2014), pyrolysis (Reckamp et al., 2014), composite materials (Faubert et al., 2016), bioethanol and hydrogen production (Moreau et al., 2015). However most of these methods fail to cater the need of tackling the huge quantity of PPMS, in its original form and needs transformation of the waste by application of additional investments. The inadequacy is posed by the un-economic and hazardous circumstances such as the cost and energy intensive mechanical dewatering, low net calorific value (2–6 MJ/kg), transport, growing shortage of space, emission of noxious gases (SO_2 and NO_x), contamination (nutrient leaching) and constant change in properties of the sludge among generating industries (Feldkirchner et al., 2003; Stoica et al., 2009). Therefore expensive methodologies with rising restrictions and changing policies of environmental protection agencies have encouraged onsite sustainable utilization of the sludge without suffering high expenses.

In this context, biological treatment of the sludge is beneficial as apart from volume reduction it can aid in the generation of a product of resalable value, thus adding benefit to the waste management program of the industry. Owing to the simplicity and effectiveness in recycling organic wastes as reported by Varma and Kalamdhad (2013), composting is the best feasible method as it does not involve any preprocessing or pretreatment of material thus not sustaining additional costs. Earlier studies though have reported composting of PPMS to be one of the best options, but it fails to be comprehensive and therefore to locate the lacunae more elaborate study is required (Aycan et al., 2014). Further lesser are the studies specifically focused on primary sludge (rich in carbon) which otherwise is far more challenging to degrade due to nitrogen deficit and comparatively massive in production. Previous studies were limited to composting the combined primary and secondary sludge forms which were comparatively easier to degrade because of nitrogenous content (Atkinson et al., 1997; Das et al., 2001; Marche et al., 2003; Dinel et al., 2004). However very few studies which evaluated composting of primary sludge as a sole substrate, were supplemented with chemical fertilizers

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