Application of Paper Sludge in different Fields

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Abstract - *In the Pulp and Paper Industry several types of solid wastes and sludge are generated. Solid waste is mainly produced from pulping, deinking processes and wastewater treatment. The waste generation is strongly affected by the production process and wastewater treatment technologies. About 40–50 kg of sludge (dry) is generated in the production of 1 tonne of paper at a paper mill and of that approximately 70 % is primary sludge and 30 % secondary sludge. The amount of sludge on a dry mass basis may vary from 20 % in a newsprint mill to 40 % in a tissue mill. Different types of solid wastes and sludge are generated in the Pulp and Paper Industry at different production processes.*

The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in plants at the paper mill, producing paper sludge ash or disposal to landfill. The scope for landfill spreading is limited. Usage of paper increased to a great extent now days, results in large production of waste paper sludge (WPS). A large percentage of WPS produced are used for land filling and it run out of the storage space. There is therefore a growing need to find alternative uses of Waste Paper Sludge. In present applications, sludge has some proven benefits, and significant research and development is currently underway to discover other commercially viable uses.

Key Words: *Paper Sludge, Hydraulic Barrier, Hydrophobic concrete, soil fertility*

1. INTRODUCTION

The management of wastes, in particular of industrial waste, in an economically and environmentally acceptable manner is one of the most critical issues facing modern industry, mainly due to the increased difficulties in properly locating disposal works and complying with even more stringent environmental quality requirements imposed by legislation. Industrial wastes are generated through different industrial processes or energy production utilities as additional materials. Industrial symbiosis theory defines non-deliberately produced material as by-products or valuable raw materials which can be exploited in other industrial avenues.

Paper industry is a strategic industry in many countries but in the same time, the production of paper consumes high quantities of energy, chemicals and wood pulp. Pulp and paper mills typically generate significant quantities of non-hazardous solid waste which require management as a waste material or as a by-product. Most of these solids are removed after primary mechanical treatment, resulting in a sludge that contains large quantities of fibers, papermaking fillers, or both. Consequently, the paper production industry produces high environmental emission levels mainly as CO2 due to energy consumption, or solid waste streams which include wastewater treatment sludge, lime mud, lime slacker grits, green liquor dregs, boiler and furnace ash, scrubber sludge and wood processing residuals. In terms of volume, most solids or liquids are those from the treatment of effluents, although waste from wood is also produced in large quantities.

As per Indian paper mill association (IPMA), industries providing employment to 5 lakh people over 750 paper mills every year in India. Pulp and paper mills typically generate significant quantities of non-hazardous solid waste. Limited number of time only recycled paper can use for making good quality of paper, which produces large amount of solid waste. The recycling of paper is the process by which waste paper is turned into new paper products. It has a number of important benefits besides saving trees from being cut down. It is less energy and water intensive than paper made from wood pulp.

1.1 Application of paper sludge

Paper sludge in agricultural fields

Paper waste arising at paper mills results from two principal routes of effluent treatment – the primary and secondary treatment processes. While primary treatment is basically physical, secondary treatment may be chemical/physical or biological. Primary treatment involves initial screening of the mill effluent to increase the fiber content of the paper waste by, for example, settlement. Secondary chemical/physical treatment reduces the biological/chemical oxygen demand and clarifies the effluent using a range of methods, such as adding chemical coagulants or polymer flocculants, or dissolved air flotation. It also increases the dry solids content of the paper waste. Secondary biological treatment is also used to reduce the biological/chemical oxygen demand of the effluent and to increase the dry solids content of the paper waste, but uses methods such as the surplus activated sludge process. Tertiary treatment is used to reduce the solids and ammonia content of effluent being discharged from mills. (V.K Philip et al, 1997).

Agricultural benefits of paper sludge are;

- Soil conditioning due to organic matter
- Soil pH increases due to liming value
- Addition of major plant nutrients

Hydraulic barrier

Another use of paper sludge as a hydraulic barrier material in landfills is a technology that has gained some attention since the early 1990s and is an innovative way to recycle paper mill residuals. The geotechnical properties of paper sludge are similar to those of compacted clays. Paper sludge produced in Slovenia can be divided into three types/groups in terms of their origin. The paper sludge originating from cellulose production (virgin fibers), those that are produced during two-stage manufacture of paper from waste paper. Laboratory testing was undertaken to determine the de-inking paper sludge and the composite with wood ash having the lowest hydraulic conductivity ratio. (JOZE KORTNIK, 2008)

Hydrophobic concrete using paper sludge

Paper sludge ash (PSA) is a waste generated by the paper recycling industry. It is produced when dewatered waste paper sludge, a byproduct of the de-inking and re-pulping of paper, is combusted to reduce waste volume and to produce energy. The feasibility of using super hydrophobic PSA powder as a partial cement replacement to improve the resistance of concrete to water ingress. Recent research has demonstrated that PSA can be transformed into a super hydrophobic powder using simple, low-cost processing. Initial studies have also examined applying the super-hydrophobic PSA as a surface treatment ton produce a water-repellent and self-cleaning coating. The influence of the super-hydrophobic PSA on a range of properties including absorption, diffusion, permeation and electrical conduction (Hong S. Wong, 2015).

2. LITERARURE REVIEW

Use of paper sludge in agricultural fields

A three year experimental study was conducted to improve the soil conditions and increase the crop yield using paper mill sludge in Pira International Research Centre, UK. Factors influencing the application of paper sludge in agricultural land were studied.6 m x6m plot were selected allowing spreading to be carried out by full sized agricultural machinery. Factors investigated are crop type, soil type, and sludge type. Method of application is surface spreading of dewatered sludge, surface spreading of undewatered sludge and surface injection of undewatered sludge. Rate of application: 5 – 10 t DM/ ha in first year, 10 – 20 t DM/ ha in second and third year. Assessment of soil condition includes both chemical and physical analysis. Chemical analysis includes Particle size analyses, pH and Percent of organic carbon. Physical analysis includes Bulk density, Air capacity (vol %), Total pore space (vol %). Surface spreading of dewatered sludge method is one of the most homogeneous distributions in the top soil (V.K Philip et al, 1997).

Paper Sludge Layer as Low Permeability Barrier on Waste Landfills

The laboratory test ere conducted to evaluate the suitability of paper mill sludge collected from various Slovene paper mills for use as hydraulic barrier in landfill covers. The landfill cover typically contains five basic components: the cover or vegetative soil layer, drainage layer, impermeable barrier layer, filter layer and the gas vent layer. Water content, Uniaxial compressive and shear strength, Hydraulic conductivity, Electric conductivity are the parameters were studied in samples of various paper sludge and composite mixtures. Wood ash (WA), fly ash and cement (C) were used as additives in composite mixtures. Various types of Slovene paper sludge were used in our preliminary studies. From each paper sludge or paper sludge composite sample, six cylindrical samples made (with a diameter of 70 mm and a height of 100 mm), along with up to six prismatic samples (with a square cross-section having 35 mm sides and a length of 60 mm). The samples were aged for up to 28 days, and then a pressure leaching test was performed to determine the permeability coefficient *k*, as well as a test to determine their elastic properties. Hydraulic conductivity testing was done in odometer apparatus and triaxial pressure leaching cell was done in direct shear strength apparatus. This study evaluated the suitability of paper mill sludge collected from various Slovene paper mills for use as hydraulic barrier in landfill covers (JOZE KORTNIK, 2008).

Hydrophobic concrete using waste paper sludge ash

A study was conducted in Department of Civil and Environmental Engineering, Imperial College London, UK to find out transforming a waste product into a high value super-hydrophobic powder with very little processing and applying the hydrophobic powder to improve the performance of concrete. The pastes were prepared by dry mixing cement and hydrophobic PSA in a bowl mixer. Batch water was then added and mixed for 3 min. Disc samples were cast in steel moulds (100Ø × 50mm) and compacted in two layers using a vibrating table until no significant air bubbles escaped the surface. There was a noticeable decrease in workability caused by the hydrophobic PSA powder, particularly at 8% addition and higher. Thus, the amount of vibration was adjusted to account for this.

Compacted samples were covered with polyethylene sheet and wet hessian for the first 24 h,then de-moulded and cured in a fog room at 20 °C.Series II consists of paste samples that were surface coated with hydrophobic PSA. Series III consists of concrete samples containing 0, 4, 8 and 12 wt.% replacement of cement with hydrophobic PSA. Total aggregate fraction for all mixes was maintained at 65 vol.% and sand-to-total aggregate mass ratio was 0.35. Batch water was adjusted to account for aggregate absorption so that the target free w/c ratio was achieved. An entrapped air content of 1 vol. % was assumed in the mix design based on our previous measurements of similar concrete mixes. The mix design was carried out by absolute volume. Batching was done in a 30-litre capacity pan mixer by first dry mixing cement and aggregates for 60 s, followed by the hydrophobic PSA powder for 45 s. Finally, water was added and mixed for a further 3 minute. Cubes (100mm) and discs (100Ø × 50mm) were cast in steel moulds and vibrated in three layers until no significant release of air bubbles was observed. Samples were then placed on a polythene sheet, covered with damp hessian and a further polythene sheet for the first 24 h. Samples were then de-moulded, weighed, wrapped in cling film and sealed in polythene bags and cured at 20ºC for 3 and 28 days(Hong S. Wong,2015).

Feasibility of recycling pulp and paper mill sludge in the paper and board industries

The feasibility of recycling sludge in the paper and board industrial sectors in applications where the sludge does not modify the quality of the final product. In an effort to explore these possibilities, the fiber content, fiber quality, and key physical and chemical properties (humidity, ash content, abrasiveness, drainability, and O2 uptake) of 20 different primary sludge sampled in European mills are studied in Segovia, Spain. In this study Percent moisture (w/w) was estimated as described in the ISO 638-1978 test method. A time of 4 h was enough to obtain a constant mass value. Ash content (w/w) was determined on ignition at 900ºC, according to the ISO 2144:1997 method. Drainability was calculated according to the Schopper-Riegler method (ISO 5267-1:1999).The pH was determined from aqueous extracts according to the ISO 6588-1981 method. Sludge fractionation was carried out to quantify the fiber content. Sludge (1kg) was disintegrated and the resulting material passed through a vibrating flat screen (0.4mmslits).Sludge and recycled old corrugated cartons (OCC) were soaked, disintegrated, and made into small circular sheets of paper in a laboratory sheet former (ISO 5269-2:1998). Sludge (60 g at a consistency of 1.5%, w/w) were disintegrated at 3000rpm for 20 min in the standard disintegrator described in ISO 5263:1995. OCC samples were soaked for 30min before disintegration. Basis weight of sheets was determined following the ISO 536:1995 standard method. Thickness (also called caliper) was measured using a micrometer of precisely specified pressure-foot area and load (ISO 534:1988). Physical properties of laboratory sheets (burst strength, breaking length, tear strength) were determined using the ISO 5270:1998 standard methods. Stiffness was measured as described in the ISO 5629:1983 standard. Paper roughness (porosity) was determined according to Bentsen's method (ISO 5636/3:1992). Whiteness and opacity were measured in a photovoltaic apparatus following the ISO 2469:1994 and ISO 2471:1998 standard methods, respectively. Ring crush test (RCT) was measured as described in the UNE-57 170 standard (which is similar to ISO 12192:2002) evaluating sludge application in board.(Jesus' A.G.et al, 2008).

Paper sludge (PS) to bioethanol: Evaluation of virgin and recycle mill sludge

Bioethanol production from paper sludge presents a feasible contribution to sustainable clean energy generation is an another use of paper sudge.The potential for biofuels to contribute to energy security and environmental benefits, together with the concerns with starch based first generation biofuel technologies have shifted the focus to biofuels produced from lignocelluloses using second generation technologies. Bioethanol production from PS presents a feasible contribution to sustainable clean energy generation, while also avoiding disposal of these wastes by landfill. Thirty-seven PS samples from 11 paper and pulp mills exhibited large variation in chemical composition and resulting ethanol production in South Africa in 2016.

The PS samples used for hydrolysis and fermentation screening were dried at 75 º C, after removing the impurities such as plastic, pieces of paper and twigs. Larger quantities of PS required for fed-batch SSF experiments in 5 L bioreactors was dried in a high tunnel (hoop greenhouse) at 40º–45 º C. Dried samples were stored in sealed plastic bags at room temperature and the chemical composition was determined according to the National Renewable Energy Laboratory (NREL) standard procedure. The calculation of means and standard deviations for statistical analysis were done in Microsoft Excel, version 2013. Statistical, version 10 was used to design the Central Composite Design (CCD) that used Response Surface Methodology (RSM).It is used to predict the interaction between the two independent variables, solids loading and enzyme dosage, and the dependant variables, final ethanol concentration, ethanol yield, and ethanol productivity. Desirability surface plots were used to interpret the effect of the independent variables on the overall response desirability which is a combination of all the dependant variables. The desirability function requires each dependant variable to have a desirability value assigned to it, with 0 being very undesirable to 1 being very desirable (Sonja Bosh off, et al, 2016).

Use of paper sludge in brick manufacturing

For making eco-friendly lightweight bricks through binary mix of paper mill sludge (PMS) is another way of using the paper mill sludge. The pre-manufacture activities include mineralogical, chemical, thermal and index properties characterization of two kinds of soils (laterite and alluvial) and PMS.Dewatered PMS was collected from the effluent treatment plant (ETP) of Nagaon Paper Mill, Kagajnagar, Assam, and India. Nagaon Paper Mill belongs to the Hindustan Paper Corporation and produces more than 100,000 tone/year paper using bamboo as the raw material. As suggested by Indian standards and other studies laterite and alluvial soils are suitable for brick making. Both soils and PMS were dried and grinded to particle size finer than 1 mm for brick making process.Laterite soil was collected from IIT Guwahati campus and alluvial soil was obtained from a nearby brick kiln. Oven dried PMS was added in different amounts (5, 10,15 and 20%) in both type of soils and thorough dry mixing was done for homogenisation. Industrial level production can be achieved without drying the soil and PMS. Higher amount of moisture (70–75%) in PMS will save the amount of water required for brick moulding. The control bricks (0% PMS) were also prepared for benchmarking the results. The brick specimens were air-dried at room temperature for 24 h and then oven dried at 105 C for additional 24 h to ensure complete removal of the moisture. These over dried bricks will henceforth be termed as Green bricks in rest of the paper. The brick samples were designated as M for the bricks made with laterite soil and X for bricks made with alluvial soil. The mixes were named as M: brick body std; M 5: 95 wt.% soil + 5 wt.% PMS; M 10: 90 wt.% soil + 10 wt.% PMS; M 15: 85 wt.% soil + 15 wt.% PMS; M 20: 80 wt.% soil + 20 wt.% PMS for laterite soil. PMS Mix with alluvial soil was also named in the similar manner. To avoid any uncertainty in the experimental results, six trials were performed and average of the six samples is being reported. Green bricks were fired in electrically operated muffle furnace at two temperatures (850º C and 900 ºC).

The target temperature was achieved in about 7–8 h and bricks were kept in the furnace at this temperature for 1 h. The fired brick samples were cooled down to room temperature in the furnace by natural convection. These temperatures were selected based on kiln conditions. In order to determine mineralogical, chemical, thermal and index properties, constituent materials of the brick (i.e. soils and PMS) were thoroughly characterized. Chemical analysis by X-ray fluorescence and Elemental Analysis to detect the presence of chemical elements such as C, H, N and S was performed by combustion of powdered samples in oxygen rich atmosphere. Changes in linear shrinkage values were measured using a digital vernier caliper after drying and firing with a precision of 0.01 mm. (Gaurav Goel et al, 2017).

3. CONCLUSION

From the review, the paper sludge need to be carbonized under the optimized conditions then it is adding with soil proper amount will give the higher yield in agricultural field, there is no additional minerals are needed. Adding paper sludge used on soil as a soil amendment not only cause soil pollution but also improved the soil qualities, and then increased the plant growth when the amount of sludge applied on soil was proper. Disposal of paper sludge has been a major concern of the paper making industry for years. Using paper sludge (i.e. waste) as recycled materials prevents environmental pollution and reduces raw materials consumption in consideration of sustainable development.

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BIOGRAPHIES

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