Incineration-An Option for Sludge Disposal in Recycled Fiber (RCF) Mills

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ABSTRACT

Handling of waste sludge is a major concern for all pulp and paper mills. It is especially important for recycled fiber mills (RCF) which produces more sludge compared to virgin mills and is even more for deinked mills where it contains ink along with fibre, fillers & coating materials. Currently the waste sludge from these mills are being disposed off as landfill or sold off to board manufactures. The studies conducted at CPPRI has revealed that there is a potential of energy recovery from waste sludge as the heating value is close to that of black liquor, however it requires to be dewatered to a minimum solid concentration of 40%, as high moisture content has a negative influence on combustion temperature. Fluidized, Bed Combustion technology (FBC) is the most viable technology for waste sludge incineration to recover energy using sludge as a mian fuel or after blending with coal. World wide a number of installations have come up on FBC technology utilizing waste sludge for steam generation. In the present Paper, an assessement has been made on fuel characteristics of, waste sludge from RCF mills with respect to its potentialities and limitations for steam generation.

INTRODUCTION

Deinking of waste paper & the use of recycled fibre (RCF) may have numerous environmental and operating benefits like forest resource preservation, decrease in chemical & energy use, decrease in odour emissions etc, but the handling & disposal of waste sludge is still a matter of great concern. Recyclers are known to produce much more sludge as compared to virgin mills, which is partly attributed to the fillers in the paper, and which for the most part, are not recovered. Sludge generation for Deinked (D.I) mills is even more pronounced as the sludge contains ink along with fibre, large amounts of fillers & coating material.

The characteristics & volume of sludge generated however depends on many factors such as size of the mill, waste paper furnish, number of contaminant removal modules in the system and final product development. The amount of waste sludge can be essentially negligible or as much as 40% of the production depending on the raw material, process and product quality consideration. The amount of sludge for different grades of paper usually is in order of Brown grades < Newsprint > Writing/printing < Tissue.

Worldwide several methods are in use to dispose off the waste sludge, however local, ecological,

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economical and regulatory conditions generally dictate which is the most cost effective. The major options are

- Landfilling
- Land spreading
- Incineration
- Land filling ash

Of all these, landfilling is the most commonly used disposal method and landfilling dewatered sludge is often the least expensive disposal method in terms of capital cost although large land areas are required particularly in case of deinked sludge. Another problem with landfilling is the leakage of hazardous components from deinked (DI) sludges particularly heavy metals. It is now becoming a less viable option as environmental problems and restrictive legislation are making landfills a buried liability.

Landspreading technique is rather appealing since it represents a natural reuse & recycling of the material. Landspreading of deinked (DI) sludge may be beneficial to crop or forestland particularly due to its ability to improve soil properties e.g. the water retention of sandy soils. Field study conducted else where (1) have shown that germination and root development rate in sludge amended soils is equal to or greater than the control. However the only concern for landspreading of paper mill sludge is its potential for temporary nitrogen immobilization, which usually begins about one month after plowing of the organic matter when the sludge beings to decompose and therefore a waiting period between sludge application and planting or addition of supplementary nitrogen ferlizer is essential to enhance microbial activitien soil (2).

Sludge incineration is an attractive option of disposal as it allows to recover heat from waste simultaneously reducing the landfill volume. The heat recovered by burning sludge at 40% to 50% solids may reach up to 10,000 KJ/Kg depending on its organic content. The landfill volume required for ash disposal is 70-80 % less than that required for sludge.

Energy recovery covers a wide range of technologies from simple travelling grate process and fluidized bed combustion to more advanced methods such as destructive distillation & wet air oxidation. However the ash must be characterized to determine the leachability of the heavy metals in the ash if it is being disposed to landfills or it can be used in cement, concrete or brick manufacturing.

SLUDGE DISPOSAL PRACTICES IN INDIAN MILLS:

The sludge quantity produced by recycled mills in India ranges from 0.5 t/day to 12 t/ day based on the information collected by CPPRI and largely depends upon the quality of incoming waste paper, process steps involved in processing and type of the end product produced.

Most of these mills are producing packaging variety while others are producing writing/printing grade particularly newsprint. Both indigenous and imported varieties are being used and sometimes ash content is very high in imported varieties. Most of the mills dispose off their sludge by selling it to board manufacturers while few mills have adopted landfilling. However with mounting environmental pressure landfilling is no longer a viable option for country like India where the land is scarce. In view of this studies were conducted at CPPRI to assess the suitability of waste sludge from RCF mills as a fuel for steam generation.

RESULT AND DISCUSSION

Sludge samples collected from different mills producing packaging grades and newsprint were characterized for physico-chemical and thermal properties to evaluate the sludge quality with respect to fuel characteristics. The result of sludge characterization is summarized in Table-I

Characterization of sludge is a prerequisite to evaluate the suitability of waste sludge for combustion and steam generation. In general the sludge samples are characterized by high moisture content, high ash content and modest heating values and can be categorized as "difficult to burn fuels." The studies conducted at CPPRI also revealed the same trend. The results clearly indicate that the quantity of waste sludge produced by deinked mill is more compared to other mills due to more number of unit operations employed by deinking mill. The moisture content ranged from 87.5 to 96.7% as none of the mills was equipped with dewatering equipment.

The ash content is low for clarifier sludge and is in the range of 32-36% compared to deinked sludge with 60% ash content. The reason is attributed to

TABLE - 1
CHARACTERISATON OF WASTE SLUDGE SAMPLES

Particulars	Indian Mills			
	Mill-I	Mill-II	Mill-III	
	Clarifier sludge	Clarifier sludge	Deinked Sludge	Clarifier Sludge
Production, t/d	70	80	54	-
End product	Liner Boards	Duplex Board	Newsprint	-
Type of waste paper	Pre-Consumer	Post Consumer	Post Consumer	-
Sludge production, t/d	3.6	5.0 - 6.0	5.0	-
Ash content, % w/w in incoming raw material	0.35 - 11.4	0.14 - 24.5	1.0 - 17.0	-
Dewatering equipment	Not present	Not present	-	Not present
Moisture, % w/w	89.0	96.7	-	89.2
Volatiles,% w/w	63.1	66.0	50.7	47.0
Ash, % w/w	32.0	31.8	60.0	64.2
Calorific value MJ/Kg (on dry basis)	13.4	11.4	7.5	6.6

the quality of incoming waste paper and the system configuration for contaminant removal, which is different for both the end varieties.

The reason for high ash content in deinked sludge is attributed to the quality of wastepaper being processed; number of cleaning stages and the grade of paper being manufactured. The mill is producing newsprint, a low ash content product, by processing office waste (sorted ledger cutting) which has high initial ash content of 17%. Further, the mill has installed a number of cleaning stages (including deinking) compared to other two mills, to obtain a clean stock with relatively low ash content.

The heating value or calorific value of the sludge depends largely on ash content. Higher the ash content, lower will be its heating value. From the Table it is clear that the clarifier sludge have high calorific values than deinked sludge due to marked difference in their ash contents. The heating values of clarifier sludge is in the range of 11.4 - 13.4 MJ/ KG compared to 6.6-7.5 MJ/kg in deinked sludge.

CONSIDERING SLUDGE AS A FUEL

The key parameters governing the incineration of sludge are the composition, the calorific value and the physical and chemical properties of the sludge.

High moisture and high ash content and usually modest heating values makes the sludges difficult to burn fuels. Large amounts of water makes as-fed heating value of sludge low. It is therefore necessary to mechanically dewater these sludges to a solid content of atleast 40% before considering them as fuel.

Sludges with an ash content higher than 33.5% can not support self sustaining combustion (3). since ash values for clarifier sludge is close to this value, they can be considered as acceptable fuels. However for the D.I. sludges, the high ash value makes it unsuitable for incineration/combustion, as it will require high supplementary fuel and handling of large quantities of ash.

The heating values for the clarifier sludge is although comparable to that of black liquor but lower than the threshold value of 14 MJ/kg required for self sustained combustion (3). The clarifier sludges can be considered as a fuel but will require some auxiliary fuel for sustained combustion if burnt alone or can be burnt with high grade fuels like coal, rice husk bagasse pith etc. The deinked (DI) sludges on the other hand with heating value only half that of threshold value can not be considered as a fuel for steam generation and if burnt along with high-grade fuels will reduce the thermal efficiency. The deinked sludge should be treated separately & should not be mixed with clarifier sludge, if latter is to be used for steam generation.

These observations are further confirmed by the volatile contents, which are known to facilitate the combustibility of the fuel. The clarifier sludge has more volatile content (63-68%) than deinked sludge (47-50%)

SLUDGE DEWATERING

It is an essential step as high moisture content has negative impact on sludge incineration/combustion Wet sludge produces low combustion temperature which further decreases the evaporation rate of moisture and volatiles resulting in reduced boiler efficiency and increased emission. Auto thermal combustion of sludge pre supposes a dry solid content of 35-45%(4).

Today the dewatering equipment's available are capable of attaining as high as 50 to 55 % total solids. Equipment selection is now based on suitability for end use. Individual sludge evaluation is must with respect to disposal method as well as attainable verses economically practical cake dryness. The dryness content is higher with high ash content and low content of biological sludge. Table-2 gives a comparis on of different dewatering equipment available (5).

Maximizing final cake dryness is of prime importance to ensure maximum heat value out of sludge. Recently screw presses is the predominant choice, since they can achieve the high cake dryness usually over 45% with relatively low secondary sludge content. For high ash, low heat value sludges, high pressure belt presses are more practial to yield sludge dryness in the range of 35-40%.

APPROPRIATE COMBUSTION TECHNOLOGIES FOR INCINERATION OF WASTE SLUDGE

Although a number of technologies are available today but based on the fuel characteristics of sludge, the most common type of combustion system for steam generation from waste sludge include the grate furnaces, the bubbling and circulating fluidized bed furnaces. Though the grate furnaces are still in use but it has limitation with co-firing the waste sludge with high grade fuel beyond certain limits of sludge content. The fluidized bed combustion is the most common combustion technology utilized for the incineration of the sludge. The preferred type of

TABLE - 2
VARIOUS DEWATERING EQUIPMENT AVAILABLE FOR SLUDGE DEWATERING

Type of Dewatering Equipment	Inlet Consistency, %	Outlet Consistency, %	Applicability w.r.t Sludge Incineration
Rotary Vacuum	2-4	18-25	Not Applicable
Centrifuge	0.5-2.0	10-30	Not Applicable
V. Belt Press	15-20	22-40	Not Applicable
Belt Filter Press	2-3	30-50	Applicable
Screw press	4-5	33-50	Applicable

fluidized bed combustion is the bubbling bed. Small amount of sludge generation due to smaller scale of operation for recycled fibre based mills, makes the use of circulating fluidized bed combustion uneconomical.

A comparison of both these technologies with respect to sludge Incineration (6) is summarized in Table -3

TRAVELLING GRATE COMBUSTION TECHNOLOGY

It is a common method for burning sludge co-fired with coal using existing power boiler, however blending sludge quanities upto 20% by weight is the limit as beyond this the heating values of solid fuel mix is reduced, drastically. Besides, incineration of sludge with high moisture and ash content increases the amount of boiler clinker & scales and decreases of production of steam significantly (6).

FLUIDIZED BED COMBUSTION TECHNOLOGY

High moisture & ash content do not cause problems in the modern FB boilers & circulating FB boilers. Potential temperature variations, caused by variation in waste fuel or water content are smoothened by the thermal fly wheel effect of the inert bed material. FB boilers are most favorable for the recovery of heat energy for both waste as a main fuel or after blending with coal. However when it is necessary to burn sludge with high quantities of high calorie fuel

TABLE - 3
COMPARISION OF COMBUSTION TECHNOLOGIES W.R.T SLUDGE INCINERATION (6)

Travelling Grate Combustion Technology	Fluidised Bed Combustion Technology
• Sludge can be co-fired with coal/bark using an existing power boiler.	• Sludge can be used as a main fuel as well as co-fired with high HHV fuel.
• Combustion of sludge suitable only for the production of low pressure steam.	• High pressure steam can also be generated.
• Requires high combustion zone Temperature for good combustion and change in fuel moisture negatively influences combustion temperature.	• Allows successful burning at significantly lower combustion temperature. Temperature is between 760 - 900 °C.
• Heat transfer takes place through radiation which is a direct function of combustion temperature and is dropped with decreased combustion temperature.	• Heat transfer is by conduction and the heat transfer remains high as long as the bed temperature is maintained.
• Sludge burning requires more air than coal to release same amount of heat due to low oxygen.	• Generally a dewatered sludge content of atleast 35-40% is required for self combustion of sludge.
• Sludge quantities as much as 20% by weight can be co-fired.	• The boiler can run with 100% sludge with some support fuel eg. coal or oil. Sludge can be burned alone if dewatered to a point where no in bed heat transfer surface is required (Approx. 58-62% MC levels)
• A 10 °C increase in air temperature is required to compensate one moisture point.	• Sand bed offers enormous area for heat exchange with close to ideal mixing. Maintenance is low because of its design and operation.

TABLE - 4
FLUDIZED BED TECHNOLOGY FOR FUEL OF VARIOUS HEATING VALUES

Bed Configuration	Typical Fuel heating Values MJ/Kg
Fluidized	Less than 7.0
Bubbling	7.0 - 10.5
Circulating	More than 10.5

CFB are more suitable.

Typically bubbling beds operate with excess air in bed, however operating bubbling bed as a gasifier in which a portion of the required combustion air to bed is applied to release a portion of the fuels chemical heat, the bed temperature is controlled even with high HHV fuel. The required heating value to sustain combustion without auxiliary fuel is generally lower in bubbling FB combustion than in other combustion methods. Table-4 Summarize the FB technologies in relation to the heating values of the fuel (7).

It is from the Table that the clarifier sludge with heating values between 11-13 MJ/Kg and DI sludge with HHV value of 6-7 MJ/Kg can be effectively burnt in BFB boilers. Also with BFB combustion technology a wide boiler capacity range is achievable. Bubbling FB technology is an efficient, flexible & cost effective method of burning sludge & related low-grade high moisture fuels.

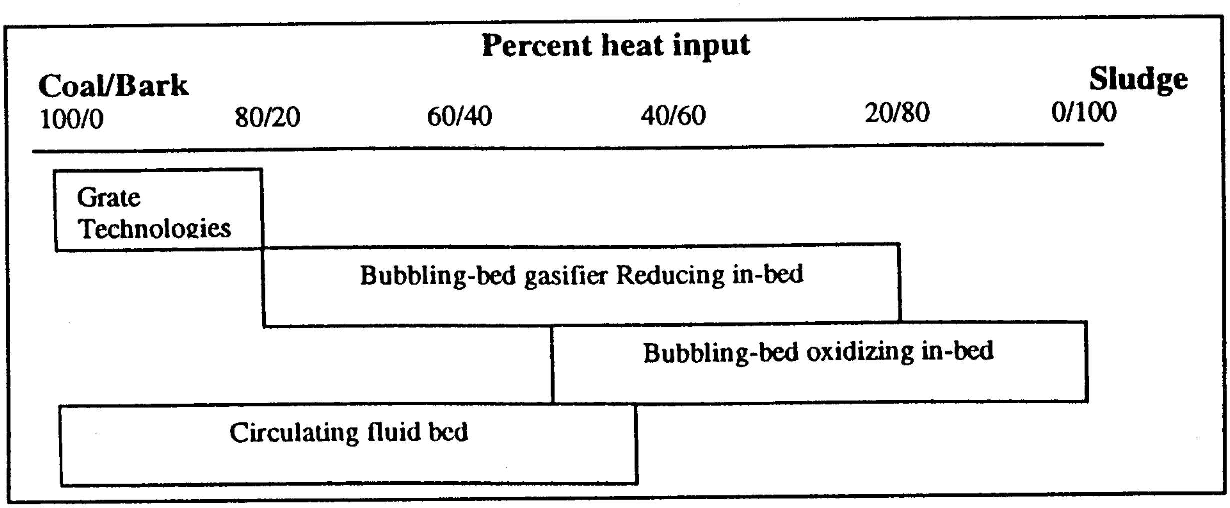
The presence of chlorides in the ash can sometimes be a problem. A value greater than 1% of chloride in the ash can cause lowering of the ash melting temperature & lead to agglomeration & defludization of bed material (8). Though the chloride levels will be low for mills using H_2O_2 bleaching but for mills using calcium hypochlorite, the levels of chloride will be a matter of concern.

Figure-I summarizes different combustion technology choice for varying bark or coal/sludge combination.

COMMERCIAL STATUS

Over 20 installation are now running in Europe

FIGURE - 1
COMBUSTION TECHNOLOGY CHOICES WITH VARYING BARK OR COAL/SLUDGE COMBINATIONS



and United States, several of these are conversion of traditional travelling. or sloping grate successfully converted to FB type.

* In Japan the CFB boiler commissioned at Nippon Paper Industries in 1995 is said to have the biggest capacity in the world with steam generation at 260 t/h at 140 Kg/cm^2 pressure at 550 °C temperature. The distinguished feature of this boiler are:

- Wide adaptability for various kind of coal
- Applicability to incineration of paper sludge
- Low air pollution

The Norske Shog BFB boiler in Golbey, France, commissioned in 1998, utilizes de-inking sludge, bark & natural gas as its main fuel. the boiler provides saturated steam without super heating with a capacity of 144 t/h, 25 bar, 224 °C. The boiler is designed to burn deinking sludge at the rate of 400 tons dry solids per day (42% ash & 45% moisture).

HANDLING OF SLUDGE ASH

If a mill is planning to burn its sludge and dispose of the ash by landfilling, the boiler ash must be characterized to determine its toxicity. The main concern is the leachability of the heavy metals in the ash.

Ash from various sludge samples were characterized at CPPRI for their heavy metal content. Table - V summarizes the values of major components of the ash samples.

FIGURE - 5
ELEMENTAL COMPOSITION OF SLUDGE ASH SAMPLES

Values in, %

Particulars	Mill-I	Mill-II	Mill-III	
	Clarifier Sludge	Clarifier Sludge	Deinked Sludge	Clarifier Sludge
Calcium	0.16	0.14	14.67	15.60
Magnesium	0.33	0.36	0.53	0.68
Chlorides as cl	Not found	2.38	0.18	0.23
Silica as SiO_2	13.75	9.6	12.2	16.3
Mixed Oxides (R_2O_3)	N. D	9.55	11.7	12.0
Chromium	-	-	0.005	0.005
Mangnease	-	-	0.013	0.011
Nickel	-	-	0.004	0.004
Copper	-	-	0.012	0.012
Lead	-	-	0.005	0.004

N.D.-NOT DETERMINED

The ash consists mainly of calcium silica & aluminium and iron oxide i.e. (R_2 O_2) and small amounts of magnesium. These compounds are derived from fillers & coating materials such as clay & calcium carbonate and also from the use of alum for acid sizing.

Chromium, managenese, Nickel copper & lead are the minor components and are of interest due to their potential environmental impact. Since these elements are present in very low concentration, hence will not have any toxic effect on soil. Further lead originating from clay and other heavy metals are likely to be in the form of oxides that are bound within the clay structure and are thus unleachable. Thus, they should not be a concern from an ash disposal point of view. The other option for ash disposal is its utilization in cement, concrete or brick manufacturing.

CONCLUSION

- The waste (both clarifier and DI sludge) are characterized as poor and difficult to burn fuels due to high initial moisture content. Mechanical dewatering to atleast 40% dryness is must, if sludge is to be considered as an acceptable fuel.
- With HHV and ash values close to the threshold value for self sustained combustion i.e. 14MJ/Kg and 33.5%, clarifier sludge is suitable as a fuel.
- Waste sludge from DI mill will require high amount of supporting fuel i.e. coal rice husk oil etc.
- At low percentage of fuel inputs, sludge can be burnt in the existing grate boilers but sludge quantities more than 20% by weight will however result to reduced boiler efficiency.
- The bubbling fluidized bed technology is the most suitable method for burning high mositure, low -grade fuels like sludge owing to its low heating value requirement for sustained auxiliary fuel free combustion & fuel flexibility.
- Recovery of medium and low grade steam not only depends upon the heating value of the sludge but also upon the type of combustion. Fluidized bed type is suitable for generating higher pressure steam compared to the grate process.
- With the average production of sludge in Indian mills in the range of 0.5 -12 tpd, it can be burned together with coal or other secondary fuels in FBC boiler for steam generation.
- In the exiting stoker fired boilers although burning of sludge may not contribute to additional steam generation due to high moisture content, it may help in solid waste management.

REFERENCES

1. Supplement to the application for approval of land application of paper mill sludge for Pop & Talbot, Ayres associates, Eau Claire, wis., March, (1987)
2. Keeney, D.R., Lee, K.W., and Walsh, L.M., Guidelines for the application of waste water sludge to agricultural land in Wisconsin, WDNR Technical Bulletin No.88, (1975)
3. Mc Govern, J.N., Berber, J.G., and Bockheim, J.G., - Tappi Journal 66 (3) : 115 (1983)
4. Nickull. Ole., et.al., Burning mill sludge in a Fluidized -bed Incinerator and waste-heat - recovery system. - Tappi Journal March (1991)
5. Tappi Deinking short course (1995)
6. Kraft, D.L., and Orender. H.C., considerations for using sludge as a fuel. Tappi Journal, 76 (3). (1993)
7. Scott, G.M., Smith. Amy., sludge characteristics and disposal alternatives for recycled fiber plants, Tappi recycling Symposium (1995)
8. CPPRI's unpublished information.