Utilization of Kraft Pulp Mill Waste

Torsten Meyer and Honghi Tran
Pulp & Paper Centre
University of Toronto
Toronto, ON, CANADA

Abstract

Modern kraft pulp mills produce on average about 100 kg of solid waste per ton of pulp produced. The most significant types of mill waste are sludge from wastewater treatment, ash from biomass combustion and dregs, grits and lime mud from the causticizing plant and lime dust from the lime kiln. Presently about half of the mill waste is disposed of on landfills, which highlights the need and the potential for waste recycling and utilization. A significant portion of the sludge generated in pulp and paper mills is utilized either by incineration in hogfuel boilers to generate steam and power, or by various forms of land application including land spreading, composting, or as additive for landfill or mine waste covers. However, the majority of alkaline wastes, mainly hogfuel boiler ash and causticizing plant residues, are currently landfilled. Alkaline wastes can be suitable for land application in agriculture and forestry, for the manufacture of construction material, as well as for road and earth construction.

Introduction

The global annual production of kraft pulp has been steadily increasing to now about 140 million metric tons [1], and is expected to continue growing within the next few years [2,3]. At an average mill waste generation of 100 kg per air dried metric ton (ADMT) pulp, the waste generated at kraft pulp mills amounts to be 14 million metric tons globally. The majority of the waste consists of sludge from wastewater treatment, ash from biomass combustion, green liquor dregs, lime mud, and slaker grits from causticizing.

Diverting waste from landfills and finding strategies for utilization have increasingly become important environmental and social considerations in kraft mill operation. Therefore, many mills are conducting waste utilization programs in order to reduce the amount of waste disposed off on landfills. For example, UPM in Finland is currently implementing a zero-waste program with the goal to avoid any waste disposal on landfills by 2030 [4]. Other pulp and paper producing companies such as Stora Enso and International Paper have also implemented aggressive waste reduction programs aimed at minimizing the landfill disposal [5,6].

Numerous scientific and engineering studies have shown the utilization potential of sludge, ash and causticizing residues in agricultural settings and various environmental engineering applications [7,8]. Full-scale implementation of these applications is often challenging and requires tailoring to the specifics of the waste generated at a mill as well as the market conditions for the waste.

In this paper, we discuss the suitability of various waste utilization methods, while placing emphasis on those that are currently applied by pulp and paper mills, and that have shown to improve the economics and environmental footprint of the mill operation.
Table 1  Average amounts and composition of kraft pulp mill wastes. Amounts of waste are median values, and all others are mean values (except pH of WWTP sludge) (numbers in brackets are ranges).

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Amount [kg/ADMT pulp]</th>
<th>pH</th>
<th>Nitrogen [g/kg]</th>
<th>Phosphorous [g/kg]</th>
<th>Potassium [g/kg]</th>
<th>Calcium [g/kg]</th>
<th>Magnesium [g/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>WWTP sludge</td>
<td>49 (0.5 – 270)¹</td>
<td>6.6 – 8.2²</td>
<td>29 (1.4 – 41)³</td>
<td>3.4 (1.2 – 5.8)³</td>
<td>1.4 (0.4 – 6.0)³</td>
<td>30 (2.7 – 90)³</td>
<td>0.65 (0.11 – 1.0)³</td>
</tr>
<tr>
<td>Wood ash</td>
<td>34 (2.2 – 107)¹</td>
<td>10.4 (9.0–13.5)⁴</td>
<td>1.5 (0.2–7.7)⁴</td>
<td>5.3 (1.0–14)⁴</td>
<td>26 (1.0–130)⁴</td>
<td>150 (25–330)⁴</td>
<td>10 (1.0–25)⁴</td>
</tr>
<tr>
<td>Lime mud</td>
<td>26 (0.2 – 1,200)⁵</td>
<td>11.4 (8.4–13.0)¹</td>
<td>1.8 (2.0–3.0)¹</td>
<td>2.8 (1.1–5.7)¹</td>
<td>0.44 (&lt;0.2–1.2)¹</td>
<td>380 (280–500)¹</td>
<td>6.2 (2.4–10.4)¹</td>
</tr>
<tr>
<td>Dregs</td>
<td>14 (0.02 – 270)⁵</td>
<td>10.8 (9.5–12.1)¹</td>
<td>2.7 (1.6–4.2)¹</td>
<td>0.67 (0.13–1.2)¹</td>
<td>4.6 (0.33–12)¹</td>
<td>190 (35–320)¹</td>
<td>23 (5.8–43)¹</td>
</tr>
<tr>
<td>Grits</td>
<td>6.5 (0.02 – 90)⁵</td>
<td>12.5 (12.2–12.7)¹</td>
<td>2.2 (1.3–5.0)¹</td>
<td>0.81 (0.23–1.7)¹</td>
<td>2.7 (1.3–6.0)¹</td>
<td>360 (340–390)¹</td>
<td>7.2 (3.7–10)¹</td>
</tr>
</tbody>
</table>

¹[9, and refs therein], ²[8, and refs therein], ³[10], ⁴[11, and refs therein], ⁵[12]

**Sludge Utilization**

According to a Canadian pulp and paper mill survey, the average sludge production is about 50 kg/ADMT of pulp or paper [13]. The types of sludges generated at pulp and paper mills are biosludge (waste activated sludge), and primary sludge. Primary sludge is generated during solids settling in primary clarifiers and contains largely fibers, and biosludge is generated as a result of biological wastewater treatment and contains mainly bacterial biomass but also lignocellulosic material. Only about one fifth of the sludge generated in pulp and paper mills worldwide is disposed of on landfills, whereas more than one quarter is beneficially used by means of land application [14,15].

**Land application of sludge**

Biosludge and primary sludge from pulp and paper mills is suitable for land application because of its high organic matter and nutrient contents. Biosludge contains notable concentrations of nitrogen and phosphorous because these nutrients are added to the activated sludge treatment system and partially end up in the sludge. The carbon-nitrogen (C:N) ratio of mill biosludge usually ranges from about 5:1 to 20:1 [16], which is suitable for plant growth. Primary sludge...
can provide other benefits to soils, such as improving the soil structure by means of aggregate formation and an enhancement of the water infiltration rate. Adding primary sludge to clay soils improves aeration and water permeability. Sandy soils benefit from the increased nutrient holding capacity and the higher moisture holding capacity of primary sludge [16]. Primary sludge may also be applied for erosion control and roadside vegetation growth [17].

One of the most significant challenges of land application is a high C:N ratio, particularly in primary sludge, which can lead to nitrogen deficiency in the soil. In this case nitrogen may become immobilized within the tissue of soil microorganisms, and therefore unavailable for plant uptake. Composting of the sludge or the addition of nitrogen can alleviate this deficiency. A pulp mill of Resolute Forest Products, Canada, was adding 2.7 kg of nitrogen per dry ton of sludge prior to land application in order to provide a balanced nutrient supply [18]. Other potential issues of sludge application are related to odor, herbicide ineffectiveness, and the stimulation of weed competition [19]. In most cases, sludge has shown to be non-hazardous in terms of heavy metals and toxicity, according to the Toxicity Chemical Leaching Procedure, [9,20].

Sludge can be land-applied either as dewatered sludge with a solids content of 15 – 40%, or as thickened sludge with a solids content of 3 – 8%. The advantage of the thickened sludge is that it can be sprayed using conventional manure spraying technology. However, due to the higher volume of thickened sludge the associated transportation costs allow land application only within a relatively small radius of 50 – 100 km around the mill.

Composting of mill sludge enhances its fertilizing value by reducing the C:N ratio and increasing the nitrogen availability, as well as increasing the cation exchange and moisture holding capacity. Mill wastes including sludge have been mixed with numerous other types of waste to generate more balanced compost, including food waste, manure, municipal biosolids, yard trimmings, and waste from the pharmaceutical and textile industry [16].

Several pulp mills (kraft and mechanical) in Alberta, Canada deliver their biosludge and primary sludge to surrounding farms. The land application of the sludge saves the farmers substantial costs for nitrogen, and improves soil structure and water holding capacity. The sludge only needs to be applied every several years because the nitrogen in the sludge is mainly present in organic form and is therefore released slowly [21]. Turning mill waste into product can result in numerous benefits. Sludge and bark from Arauco’s mill in Nueva Aldea, Chile are utilized as vegetable substrates, which has led to waste disposal cost savings, decrease in landfilling, and a reduction in ash generation [22]. Some of Domtar’s mills in Ontario, Canada, utilize most of their sludge in agriculture, silviculture, and for soil rehabilitation. The sludge can reduce the application of commercial fertilizer with potential savings of $250/ha for a crop of corn [23].

**Landfill and mine site amendments**

Mill sludge has been incorporated into manufactured soils to be used as landfill capping material and as mine site amendments. As an example, sludge from MeadWestvaco and International Paper kraft mills were tested as covers on mining waste rock stockpiles to provide organic matter and nutrients and help establishing self-sustaining plant growth [24]. One of the advantages of using sludge as cover layer is its higher flexibility than e.g. compacted clay, and lower weight and bearing pressure imposed to the waste material [25]. In another case, paper mill sludge was used as cover for copper uranium tailings [26]. The sludge application provided for vegetation growth, and cut the sludge disposal costs at the mill in half.
Similar to agricultural applications, various types of mill wastes are often mixed to improve the soil properties and engineering requirements. Mixtures consisting of biosludge, wood waste and fly ash were used as barrier layers for the closure of two landfills at Howe Sound Pulp and Paper, Canada. The low hydraulic conductivity layer provided improved erosion stabilization and at the same time provided a growing medium for plants [27].

**Absorbents**

Primary sludge from pulp and paper mills has been harnessed for the production of animal bedding and litter, and as absorbent in various industries. The former requires minimal processing prior to application [28]. Sludge from Rock-Tenn, Finch Paper and SCA, in the Northeastern U.S., is used as animal bedding in numerous nearby farms. Prior to application the sludge is amended with cement kiln dust to increase the drying capacity and inhibit bacteria growth. After usage some farmers re-use the material as soil fertilizer [29]. After sanitation, deodorization, drying and pelletization, mill primary sludge has also been used for the production of kitty litter [30]. In an industrial application mill sludge has been used for the production of industrial absorbents, as demonstrated by Kadant Grantek who produces an oil absorbent from paper mill sludge [28].

**Construction material**

Mixtures of mill sludge and fly ash have been used for the production of light weight aggregate that can be applied in concrete masonry, landscaping, and geotechnical applications [16]. Silica (SiO₂), alumina (Al₂O₃), and iron oxide (Fe₂O₃) are main ingredients of glass aggregate, and sludge can contain notable quantities of silicon, aluminum and iron. A plant in Wisconsin, U.S., uses sludge from several nearby paper mills to produce glass aggregate [31], that can be used for floor tiles, abrasives, roofing shingles, asphalt, and decorative landscaping [16]. Because sludge contains organic matter, the energy recovered during burning is used for the heat fusion process in the glass aggregate production, and for steam production. The steam is then used by one of the nearby mills as process steam [31].

Adding primary sludge to concrete may have several benefits, such as improved durability, increased pumpability of the liquid concrete, reduced shrink and freeze-thaw related cracking, as well as improved salt-scaling resistance [32].

**Other applications**

Sludge has been utilized in various other forms. In a rare application, sludge from the Crown van Gelder paper mill, Netherlands, is used for the production of anti-dust material that is used in coal-based power plants [28]. Drying and pelletization of mill sludge reduces volume and odor, and can improve its storability, as well as facilitate transport and application. Mill sludge has been used as additive to produce pellets that are applied as fuel [32]. In another application mill sludge was used to produce granules that act as carrier material for plant pesticides. Because the product is dust-free and attrition resistant, it may have a benefit over other conventional pesticide carriers [30].
Ash Utilization

Ash from biomass boilers is usually high in concentrations of magnesium, calcium, potassium and phosphorous. In some cases, ash contains elevated concentrations of metals such as arsenic, cadmium, and selenium [32], which may prevent land application. Boiler ash is alkaline with a pH usually ranging between 10 and 11. Bottom ash and fly ash are often treated and utilized separately because of their different properties. Bottom ash has a higher bulk density, and a lower carbon content, as well as lower concentrations of dioxin and furans [33, and refs therein]. The unburned carbon content in ash ranges between <10 and 50% [33] and a high content may be detrimental to some applications such as manufacture of concrete [34]. The mineral composition of ash from biomass boilers depends on the type of the biomass burned, and the location of the mill. Fly ash from coastal mills usually contains notably larger concentrations of dioxins and furans [33] which may prevent certain forms of land application. In North American mills, approximately two thirds of the generated power boiler ash is disposed of on landfills, with the remainder being utilized by means of land application or other beneficial use [19].

Land application of ash

Biomass boiler ash is suitable for land application for several reasons. It contains valuable nutrients that are important for plant growth, and it is alkaline which helps stabilizing the soil pH. Pulp mills that grow own trees for use in pulping often utilize their biomass boiler ash during re-forestation. For example, most kraft pulp mills in Brazil apply their boiler ash on fast-growing eucalyptus trees, which require constant nutrient supply. Due to its high pH, boiler ash can be used as liming agent. However, the particle size of ash is smaller compared to that of liming agents, which may cause a more rapid pH change of the soil [32]. Other challenges of land application are the high reactivity and solubility of the ash, leading to a fast release of nutrients.
However, pelletizing ash with binder can help regulate the release of nutrients [35]. Granulation prior to soil application, as applied on UPM owned forests [36], decreases the costs for spreading and increases the ash’s fertilizing value. Boiler ash has been used as part of manufactured soil for the application at mine waste sites, for landfill covers, and for waste solidification/stabilization [19]. As an example, wood ash from one of Stora Enso mills is used as hardener in filling mine cavities [37]. Mine cavities require large amounts of material, therefore, low-quality ashes that cannot be used as fertilizer are used for this purpose [35]. Fly ash from Catalyst’s Rumford mill is used as stabilizing material at a landfill. Injection of limestone during boiler operation for SO₂ emission control generates ash that is suitable for this purpose [38].

**Ash as composting additive**

Wood ash is particularly suitable as feedstock for composting because it provides nutrients to the compost, it reduces moisture, acts as bulking agent, reduces odor, and darkens the product [16]. The latter is beneficial during spring application on agricultural land while absorbing more heat. Biosludge and ash in compost mixtures complement each other, because ash provides alkalinity and certain nutrients (Ca, Mg, K), whereas biosludge provides other nutrients (N, P) as well as organic matter. Another potential benefit of composting ash-sludge mixtures is that it has shown to notably decrease the concentrations of dioxine and furans during the composting process [39].

**Ash for the manufacture of construction material**

Due to its high mineral content, ash has been applied for the manufacture of construction material, such as concrete, cement and as brick additive. Ash addition to concrete may improve its durability and saltwater erosion resistivity. However, for these types of applications the carbon content of the ash has to be low (<6%) [16]. Because of the differences between bottom ash and fly ash, one pulp mill was using bottom ash as additive for brick production, and fly ash for the production of Portland cement [40]. Utilization of ash is often diversified depending on the demand for certain applications. Ash from pulp mills of Norske Skog, Norway, is used for various applications including the production of concrete and bricks as well as for road construction [41]. Another application of ash is as additive for controlled low-strength material (CLSM) production, which is part of structural fill, foundation support, and pavement bases [32].

**Road work**

Ash from numerous mills has been used for road construction, stabilization and embankments [19], particularly when the ash is high in aluminum, iron and silicon oxide contents. As an example, the ash from sludge incineration at an SCA mill in Lilla Edet, Sweden, is utilized for forest road construction, and as binder in asphalt [42]. Because of its higher density and lower carbon content, bottom ash is commonly used as base material in roads [35]. The stabilizing properties of wood ash has been harnessed by UPM whose ash is partly used for the building of forest roads. Adding wood ash to wet soil has shown to create a hard foundation which can substitute crushed stone in roadwork [43]. Also, ash may act as binder material for clay and silt soil stabilization, while replacing burnt lime [44].

**Activated carbon**

Fly ash containing a relatively large fraction of unburned carbon (~30%) has been proven suitable for the production of activated carbon. The product can be used as absorbent of colors and odors [16].
Figure 2. Typical applications of bottom ash and fly ash.

Green Liquor Dregs

Dregs are removed from the green liquor by settling or filtering, and consist mostly of carbonaceous material, calcium, sodium, magnesium, and sulfur [16]. Dregs are highly alkaline with a pH of 9.5 – 12.1 [9]. On average, about 10 - 15 kg dregs are generated per ton of product.

Land application of dregs

Dregs can be beneficial as a soil supplement due to its alkalinity and high calcium and magnesium contents. Dregs can have a similar liming effect as commercial limestone [45]. However, one of the main challenges of soil application is the high sodium content of dregs. The sodium adsorption ratio (SAR) is often used to assess the suitability of dregs for land application. The SAR considers the concentration of sodium on the one hand, and the concentrations of calcium and magnesium on the other hand, whereas high concentrations of the latter two elements are beneficial to the soil. In order to diminish the negative effects of sodium, mills have been applied mixtures consisting of dregs and other mill waste as liming agent. Mixtures consisting of dregs and grits are typically applied at about 6 tons/ha land for liming purposes [12]. In the U.S., farmers usually receive the residuals and the application without charge, whereas the mill benefits from the extended landfill lifetime [12]. Another potential utilization method involves drying and pelletization of dregs/lime mud mixtures which then may be applied on agricultural land. The pellets limit the leachability of sodium due to a smaller specific surface area [46].
**Dregs as mine site amendments**

Long term effects of mining operations include the formation of acid mine drainage in sulfide-laden mine waste sites [47]. Dregs have been applied as part of manufactured soils for the capping of mine sites. In a large demonstration scale project, dregs from Swedish pulp and paper mills are mixed with till and applied on a mine site to prevent acid rock drainage. The mixture acts as a sealing layer while preventing oxidation of the mine waste, infiltration of water, and leaching of heavy metals [48]. Challenges of dregs application may be its stickiness and low shear strength, preventing them from engineering applications that require supporting the weight of a protective layer or application in a sloped sealing layer without the risk of sliding [49].

**Construction material**

After washing off most of the sulfur and sodium, causticizing residues were reportedly used as additives for cement production, and as fine aggregate in hot-mixed asphalt [32]. The calcium, silicon, aluminum and iron contents in dregs makes it suitable for these types of applications. Dregs/fly ash mixtures have been utilized as earthwork construction material for a landfill used for mill deposits [50]. UPM’s mill in Kymi incinerates their dregs together with sludge and hog fuel, and the resulting ash is utilized for soil construction projects [51]. Dregs and ash from several mills from International Paper were used to produce “AshCrete”, a product applied in various earthwork projects [52]. In another attempt to utilize dregs, grits and lime mud, a European consortium, including The Navigator Company and Domsjö Aditya Birla, aims at implementing valorization routes for causticizing residues. The demonstration projects include applications of lime mud as concrete filler, dregs and grits as aggregates for asphalt pavements, as well as dregs as sealing layer for mine waste deposits [53].

**Dregs as neutralizing agent**

The alkalinity of dregs has been harnessed by Stora Enso’s Veitsiluoto mill, Finland, for neutralization of acidic mill wastewater [37]. Also, in a pilot project UPM is testing dregs utilization for neutralization of acidic gases and to remove sulfur dioxide [51] by the calcium carbonate contained in the dregs.

**Lime Mud Utilization**

A small portion of lime mud, typically in the form of lime dust from lime kilns, is purged from the lime cycle in order to control accumulation of non-process elements. Lime mud is alkaline and consists mainly of calcium carbonate (CaCO₃).

The most common application of lime mud is its usage as soil amendment on agricultural lands, as it is practised by several SAPPI mills. The high pH of lime mud helps adjust the pH of crop soil, allowing for better absorption of nutrients, and a better yield of the forage crop alfalfa used in dairy farming [54]. Liming capacity of lime mud is higher than that of dregs/grits mixture, and lime mud is typically applied at 2.5 tons/ha land [12]. The calcium carbonate equivalence (CCE) of lime mud and grits is often higher than that of commercial limestone, whereas the CCE of dregs is usually lower [12]. Lime mud and/or grits and dregs from several mills have been used as additive for the production of topsoil or potting mix [12]. Because of the low concentrations of magnesium in lime mud and dregs, long-term application as liming agent may cause magnesium deficiencies in the soils [9].
Another usage of lime mud is application in forestry. Lime mud and ash from Portucel Soporcel in Portugal is used as fertilizer in oak, pine and eucalyptus forestlands [42]. One of the challenges is how to condition the lime mud prior to utilization, e.g. dredging it from mill holding ponds and drying/pulverizing it so that it can be distributed with conventional dry lime spreaders.

Lime mud has also been used as additive for road construction, and soil stabilization [32]. Lime mud from several U.S. mills was used for the production of manufactured soil for applications that improve the bearing capacity of soils, such as roads and parking lots [12]. In another application the lime mud and the grits from a mill was used as additive for the production of cement [12].

Similar to dregs, lime mud has also been shown suitable for pH control of mill wastewater. Mahmood and Paice [55] report on several Canadian kraft mills that add lime mud to their aerated stabilization basins for this purpose.

---

**Slaker Grits Utilization**

Grits constitute the settleable material in the slaker, and consists mostly of CaCO$_3$ with some Ca(OH)$_2$, sodium, magnesium, and aluminum compounds. On average about 6 kg of grits are generated per ton of pulp.

Grits are alkaline, and therefore have been utilized for liming purposes on agricultural and forest land. As an example, grits, dregs and sludge from Cenibra, Brazil, are used for soil fertilization and pH control in forestry [56]. Grits are also suitable for use as additive to soil that is used for daily landfill covers. In this application grits have been shown to help control blowing litter,
animals, and insects [32]. Lime mud, grits and dregs from at least one mill in the U.S. were marketed for various uses including strip mine reclamation [12]. Mixtures consisting of sand and grits from a kraft mill were used for the construction of roads affected by heavy-truck traffic. In this case, less maintenance is required than for unpaved roads using native soils. Also, grits have better liquid-holding capacity which makes some dust suppression techniques more effective [30]. Examples of full-scale applications include SAPPI’s use of grits for road bed underlayment [54], and the application of sand/grits mixtures as road stabilizer at Arauco Constitucion pulp mill in Chile [22].

**Challenges of Mill Waste Utilization**

There are several challenges related to the utilization of mill waste. One of the main challenges is the large day-to-day variations of the physical and chemical properties of the waste. Particularly, applications of mill waste for the manufacture of construction material require a consistent quality in terms of mineral and organic matter content. Markets have to be available for the mill waste that are reliable on a longer-term basis in terms of the required quantity and the price. Also, the geographical vicinity to the companies that utilizes the waste is important in order to keep transport costs at a minimum.

The implementation of mill waste utilization programs has to comply with environmental health and safety regulations at the mill, with regulatory requirements, and with economic requirements. If the utilization method is more costly than the conventional method of disposal, implementation will likely not take place.

Contamination of wood waste such as heavy metals or organic contaminants in sludge can also prevent utilization.

**Summary**

Currently, about half of all waste generated in kraft pulp mills are landfilled. Mill waste is most suitable for land application, road and earth work and construction. However, every utilization strategy has to be tailored to the specific conditions at the mill including waste type and amount, and the quality and variations in waste composition. Further, long-term waste utilization programs require reliable market conditions in terms of supply and demand.

A substantial portion of the sludge generated in pulp and paper mills is put to some use either by incineration, or various forms of land application including land spreading, composting, or adding to landfill or mine waste covers. However, the majority of the alkaline wastes (ash and causticizing residues) are currently landfilled. Wood ash is suitable for land application in agriculture and forestry, because it is rich in nutrients such as potassium, calcium and phosphorus, and it provides alkalinity for pH stabilization. Ash can also be used for the manufacture of building material such as concrete, cement and bricks, as well as for road and earth construction. The alkalinity of causticizing residues has been harnessed for the purpose of neutralizing acidic effluents or acid leachate. The combination of alkalinity and nutrients has led numerous mills to apply their lime mud and dregs in agricultural settings. Grits have been shown to be useful as additive for construction and road building material, and for landfill covers.
Some of the challenges to utilize mill waste are large day-to-day variations in the amount and composition. Also, the transport and the geographical vicinity to the waste recipients are important aspects of feasibility. Potential utilization as soil amendment requires long-term toxicology and leachability assessments. Other challenges may be related to the chemical composition of the waste, such as low nitrogen / high heavy metal content in sludge, or high sodium content in dregs.

References


43. UPM (2016b) Ash is a major waste fraction with many possibilities for utilization. Article, Sep 07, 2016, Author: Saara Töyssy, upm.com [accessed Aug 30, 2019].


Utilization of Kraft Pulp Mill Waste

Torsten Meyer and Honghi Tran
University of Toronto
Toronto, ON, Canada
Types of mill waste

• Wastewater treatment sludges: primary sludge, biosludge
• Causticizing residues: green liquor dregs, slaker grits, lime mud
• Ashes: wood fly ash, bottom ash
Average amount of waste per ton pulp produced

- Primary Sludge: 35 kg
- Ash: 34 kg
- Lime Mud: 26 kg
- Biosludge (Waste Activated Sludge): 16 kg
- Dregs: 14 kg
- Grits: 6.5 kg

Sources:
University of Toronto, Pulp & Paper Mill survey.
Sludges from wastewater treatment

- Primary sludge: mainly lignocellulosic fiber; easily dewaterable
- Biosludge (WAS): microorganisms, lignin
- Biosludge much more challenging
- Costs for sludge handling/dewatering usually >1$M per year
Conventional sludge disposal methods

• Incineration
  • Co-firing with wood waste
  • Often negative energy balance due to high moisture content

• Landfilling
  • Transport costs, tipping fees
Land application

• Globally, ~25% of the mill sludge land applied (Fisher Int., 2016)

• Land spreading
  • Soil conditioner in agriculture, silviculture; soil rehabilitation
  • Thickened (sprayable), or dewatered

• Composting
  • Mixed with other types of waste (e.g. wood ash, food waste, manure)
  • Reduces C:N ratio, increases cation exchange / moisture holding capacity
Landfill and mine waste covers

• Part of manufactured soil
• Capping of landfills
• Acid mine tailings
• Mine waste rock stockpiles

[Images: Sludge covering copper deposits, Mine reclamation, Landfill barrier layers & intermediate cover]
Other mill sludge applications

- Absorbent in various industries (primary sludge)
- Animal bedding
- Glass aggregate production
- Primary sludge as concrete additive
- Pelletization & usage as fuel supplement
- Anti-dust material
Sludge utilization challenges

• Low nitrogen (especially when mixed with primary sludge), heavy metals
• Public acceptance
• Regulatory issues
• High variability in composition
Wood ash

• Mainly biomass boiler fly ash, bottom ash
• High in magnesium, calcium, potassium; alkaline
• Unburned carbon: <10 – 50%
• About two thirds of the wood ash is landfilled
• Bottom ash: higher bulk density & lower carbon content than fly ash
Wood ash: land application

• Agriculture
  • Liming agent; nutrients

• Manufactured soil
  • Mine waste sites, landfill covers

• Forestry
  • Pulp wood plantations
Wood ash: additive for composting

- Provides nutrients
- Moisture reduction
- Bulking agent
- Product darkening
- Odor reduction
- Mixtures ash/biosludge complementary
Wood ash: road & earth work, construction, others

- Road construction, embankments (bottom ash)
- Binder in asphalt or for soil stabilization
- Concrete, cement and brick manufacture (requires specific mineral content; carbon <6%)
- Hardener for mine cavity fillings
- Activated carbon (high in unburned C): odor or color absorbent
Lime mud

- Purged from lime cycle for NPE control
- Consists mainly of calcium carbonate
- Highly alkaline
- High concentrations of phosphorous, calcium, magnesium
Lime mud utilization

• Liming agent in agriculture
• Liming capacity often higher than commercial limestone
• Forestry (lime mud/ash mixtures)
• Additive for topsoil/potting mix
• Road construction, soil stabilization
• Cement production
• pH control of mill wastewater
Green liquor dregs

- Settleable material in green liquor
- Consists mostly of carbonaceous material, calcium, sodium, magnesium
- Highly alkaline
- Vast majority is landfilled
Dregs: land application

• Soil supplement (alkalinity, nutrients)
• High sodium content challenging
• Sodium adsorption ratio used to assess suitability for land application
• Often dregs/grits mixtures applied
• Additive for composting of mill biosludge
Dregs: mine waste covers & earth work

- Prevention of acid rock drainage:
  - Sealing layer: e.g. dregs mixed with coarse till, and/or ash
  - Preventing oxidation of mine waste
  - Hydraulic barrier
  - Neutralization of acid leachate
- Dregs/fly ash mixtures utilized as material for earth work
- Stickiness and low shear strength may be challenging

Dregs/till mix covering a mine waste site

www.paperadvance.com, Sep 21, 2015
Dregs: other uses

• Cement production (after washing off most of the sulfur and sodium)
• Aggregate in asphalt paving
• Neutralizing of acidic wastewaters
• Tests to neutralize acidic gases and remove SO$_2$
Slaker Grits

• Slaker settleable material
• Consists mostly of calcium carbonate with some Ca(OH)$_2$, Na, Mg, and Al compounds
• Alkaline
• Relatively high in potassium, calcium, magnesium
• Majority is landfilled
Grits beneficial use

- pH stabilization and nutrients in agriculture/horticulture
- Daily landfill cover
- Road bed underlayment
- Compacted grits/sand mixtures for heavy-truck traffic
- Additive for production of cement

www.metsafibre.com
Challenges in utilizing causticizing residues & ash

- Physical & chemical properties:
  - Heavy metals (cadmium, copper, zinc)
  - Large day-to-day variations
- Engineering (e.g. lacking shear strength of dregs)
- Reliable markets for the product
- Geographical vicinity to waste accepter
- Too much/too little material
- Economics of the utilization method
Summary

• Currently about half of all mill waste landfilled (>70% of ash & recaust residuals)

• Mill waste most suitable for land application, road/earth work, and as landfill cover

• Utilization strategy tailored to the specifics of the mill waste and the market conditions (supply-demand, transport, etc.)
Acknowledgements