

BIOSOLIDS FOR RECLAIMING MINELANDS



Minnesota Department of Natural Resources
Division of Lands and Minerals
1525 E. 3rd Ave
Hibbing, MN 55746

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218-262-6767

Cover photo: WLSSD anaerobically-digested biosolids storage pile at United Taconite just prior to application on the tailings basin.

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Acknowledgements

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If a reader has any questions about information contained in this report, they could contact Steve Dewar or Anne Jagunich at MN DNR Lands and Minerals 218-262-6767.

1. Overview

Open pit iron ore mining has occurred in Minnesota for over 100 years. Low-grade iron ore, or taconite, has been actively mined for the last 50 years. During the process of mining taconite, waste materials such as tailings, surface overburden, and waste rock are stockpiled or deposited on the land. Minnesota reclamation laws require mining companies to stabilize tailings, waste rock, and surface overburden stockpiles with vegetation. Typically, the properties of mined soils are not favorable for plant growth. Coarse-textured tailings are particularly difficult to vegetate because of low nutrients and poor water-holding capacity.

Biosolids are the nutrient-rich organic wastewater solids derived from sewage treatment that has been treated to destroy pathogens (disease-causing bacteria, viruses, and other microorganisms). In past years most of the biosolids were land-filled or incinerated. Environmental and economic factors have led to an increase in the practice of land spreading of biosolids as an acceptable method of management. In addition to supplying nutrients, land applied biosolids improve soil properties such as texture and water holding capacity, creating conditions more favorable for plant growth. Because the Minnesota Pollution Control Agency (MPCA) administers the state's rules for wastewater treatment and disposal, they also regulate land spreading of biosolids through Minnesota Rules, Chapter 7041. Concerns about the land spreading of biosolids have been reported in some areas of the state. Rigorous MPCA requirements of reporting and recordkeeping help prevent the mismanagement of biosolids use and disposal.

Nearly all of the towns on the Mesabi Range land apply biosolids from their treatment plants on former mining lands such as abandoned natural ore stockpiles or tailings basins. These sites are considered disposal sites, and are permitted by the MPCA. Disposal sites eventually reach their maximum capacity for receiving biosolids, and the users must find alternate sites. Some of these same communities are producing biosolids in relatively close proximity to active taconite mining areas in need of reclamation.

Over the years a variety of organic materials used as soil treatments have been investigated for tailings revegetation, including biosolids, peat, municipal solid waste (garbage) compost, yard waste, paper mill waste, and dredge material. Of all the organic amendments tested, biosolids seem to be the most practical and economical way to increase fertility on reclamation sites.

2. Purpose

The purpose of this report is to inform mining companies and municipalities about the potential for using biosolids for reclamation and to review recent reclamation projects utilizing biosolids on the Mesabi Range.

3. Mineland Reclamation in Minnesota

As directed by the Mineland Reclamation Act, Minnesota's "Rules Relating to Mineland Reclamation" were established to promote the orderly development of mining, reduce the environmental impacts of mining, and ensure reclamation during and following completion of mining.

The vegetation requirements in the reclamation rules can be summarized by the following:

- Vegetation must be established on all areas disturbed by mining after 1980.
- A 90% ground cover is required in three growing seasons on north and east slopes.
- A 90% ground cover is required in five growing seasons on south or west facing slopes.
- Within 10 growing seasons, the site should exhibit a vegetative community that controls erosion through self-sustaining and regenerating species that provide wildlife habitat or other uses such as pasture or timberland.

Taconite tailings basins are situated on 28,000 acres of land and represent about 30% of the land area disturbed by mining. Without vegetation, tailings basins are prone to wind and water erosion. Most of the revegetation work completed by mining companies has been in tailings basins, which are the most difficult mineland feature to revegetate.

Taconite tailings produced by the different mining companies on the Mesabi Range share many similarities. They have an alkaline pH (7.5-8.2) and are very low or deplete of nitrogen, phosphorus, and organic matter. Except for the tailings from Northshore Mining's Silver Bay plant, they contain adequate levels of potassium. The lack of organic matter and clay particles also makes them low in cation exchange capacity (the ability to hold nutrients).

Variation among taconite companies in the way tailings are separated from the ore affects the distribution of particle sizes and, thus, their disposal. Hibbing Taconite and Keewatin Tac (formerly National Steel Mining Company) produce a mixed tailings slurry containing

all of the coarse and fine particles. This slurry is piped to a tailings basin where the material settles out of the mixture according to particle size, the coarse material near the spigot point, and the fines downstream into the pond. At Keewatin Tac, the tailings dikes are constructed by using the coarse tailings material near the perimeter spigot points. At Hibbing Tac, dikes are constructed utilizing surface materials taken from nearby borrow areas.



Figure 1. Tailings slurry being spigotted at Keewatin Tac (formerly National Steel).

United Tac (formerly EVTAC), Minntac, Northshore Mining, and Ispat Inland separate the coarse fraction of the tailings from the fines, or slimes, as they are sometimes called. The coarse material is then truck-or-rail hauled to its destination, often to be used in the construction of tailings dikes or dams. The fines are piped into the tailings basin interior.

The reclamation rules require that tailings dikes be vegetated. Vegetation is also required on fine tailings flats for dust control and reclamation. The standard mineland reclamation (SMR) practice employed by taconite mining companies for tailings revegetation is to incorporate diammonium phosphate fertilizer (18-46-0) at a rate of 400 pounds per acre (for temporary vegetation) to 550 pounds per acre (for permanent vegetation). The tailings

are then seeded with a grass and legume mixture that typically contains alfalfa, sweet clover, smooth brome, red fescue, redtop, and ryegrass, depending on the tailings texture and moisture. Hay mulch is then applied at a rate of two tons per acre. Coarse tailings, because of their low water and nutrient holding capacity, are more difficult to vegetate than fine tailings and rarely meet reclamation standards without an organic matter amendment.



Figure 2. Coarse tailings dike being sloped at United Tac prior to reclamation.

4. Land Application of Biosolids

As an alternative to standard reclamation practices, recycling biosolids through land application provides needed nutrients while serving several other purposes. It improves soil texture and water holding capacity and supplies a variety of macro and micronutrients in a slow release manner. Organic forms of nutrients are not as soluble as chemical fertilizers and are, therefore, less likely to leach into groundwater or runoff into surface waters (EPA, Biosolids 832-F-00-064). The MPCA regulates wastewater treatment and the landspreading of biosolids.



Figure 3. Biosolids being loaded onto spreader at United Tac.

4.1. Types of Biosolids

Before biosolids can be land-applied they must go through a process of “stabilization” to help minimize odor, destroy pathogens, and reduce their potential to attract insects, birds, and rodents that act as transportation agents. There are several methods to stabilize wastewater solids, including lime stabilization, digestion, composting, or heat drying. Depending on the degree of treatment the solids have received for pathogen reduction, they are categorized as either Class A (highly treated) or Class B (less treated) biosolids. Both types are safe for land application, but some additional restrictions apply to Class B materials. The additional requirements may include incorporation into the soil, restricting public access to the application site, limiting livestock grazing, and controlling crop harvesting schedules.

Biosolids also range in solids content. Liquid biosolids are only 3-7 percent solids (over 90% water). To reduce the volume, some treatment systems use a dewatering process such as draining, pressing or centrifuging, which can increase the solids content up to 30%.

Odor from biosolids can be a nuisance, especially during delivery to the site, temporary stockpiling, spreading, and before incorporation into the soil. Studies show that health risks to humans from biosolids that have been properly applied are exceedingly low. (Attachment A1.2)

4.2. Agronomic Value of Biosolids

Biosolids contain considerable quantities of organic matter and can usually supply the nitrogen and phosphorus needs of plant species used in reclamation. Incorporation of the biosolids into the soil through disking reduces loss of nitrogen through volatilization. The organically bound nitrogen will be slowly released over a period of several years. Biosolids can be land-applied to supply appropriate amounts of plant available nitrogen (PAN) and usually contain adequate levels of plant available phosphorus (PAP) to maintain a grass/legume cover, but they may not contain a sufficient supply of potassium (Thom, W.O. 1984; Sullivan, D. 1998). As mentioned above, most taconite tailings already have enough potassium for plant growth. Biosolids from the Western Lake Superior Sanitary District in Duluth, MN (WLSSD) were low in PAP when they were lime-stabilized prior to 2001. Biosolids are now anaerobically digested at the WLSSD, and PAP levels are much higher. Analysis for biosolids and the mine soil needs to be performed prior to landspreading to determine if the biosolids contain sufficient levels of nutrients to sustain vegetation.

The value of biosolids to the reclamation site manager stems directly from the cost savings of a full rate of commercial fertilizer that is not needed when biosolids are applied. Longer term benefits are seen from the added organic matter, which increases the nutrient and water holding capacity of tailings. Better vegetation cover and production have been documented following biosolids application in comparison to standard practices.

4.3. Application Methods

Land application of biosolids is usually the method of choice for disposing of wastes from small wastewater treatment facilities. It is an excellent way to recycle wastewater solids as long as the material meets quality control standards. The treatment facility typically provides the necessary hauling and land application equipment. Applications may be limited to certain times of the year due to road restrictions or weather conditions. The availability of biosolids from WLSSD for land application on mined lands may sometimes be limited during the growing season when there can be a high demand from close-haul agricultural users.

There are several ways to apply biosolids. Liquid biosolids can be injected into the soil with specialized equipment used for this purpose or applied to the land surface with modified tanker trucks. Most communities in the Mesabi Range area produce liquid biosolids. If applied to the surface, biosolids are usually incorporated into the soil with conventional farm equipment. Dewatered biosolids, like those produced at WLSSD, can be land-applied with conventional manure spreading equipment or with specialized spreaders designed for biosolids applications.



Figure 4. Western Lake Superior Sanitary District (WLSSD) biosolids being surfaced-applied to existing vegetation on a slope at the United Taconite tailings basin.

4.4. Land Spreading Regulations

An MPCA permit for land application is necessary and typically obtained by the treatment plant operator or a biosolids manager/hauler under contract to the treatment plant operator. Regardless of what method of disposal is used, all treatment plants must meet state regulatory requirements for biosolids stabilization. In order to obtain a permit for land spreading, the suitability of the site must also be determined. The waste facility manager must have one or more soil (tailings) samples collected and analyzed for nutrient and metal content, as well as texture and permeability. Other information required for a permit includes such things as slope, depth to groundwater (from soil maps), and proximity to water bodies and dwellings. The results are examined by the MPCA.

Land spreading regulations have maximum limits of nutrient concentrations that cannot be exceeded at a biosolids application site without a permit modification from the MPCA. Just prior to landspreading, a biosolids sample is submitted by the treatment plant operator to a laboratory for analysis of percent solids, nutrients, and metals. These analyses are used to determine application rates for that site. Nitrogen, rather than metals, is usually the limiting factor for rates allowed in land application of biosolids from small treatment plants. Slopes can also be a limiting factor, although the MPCA rules may allow a modification of land application of biosolids on steeper slopes for reclamation (7041.0800 subpart 5). Topdressing of WLSSD biosolids in winter is being permitted on tailings basins, provided the site is level.

Generally, higher one-time application rates may be allowed for reclamation sites than would be permitted on agricultural land where repeated applications can be made over a season or period of years (provision 7041.1200 subpart 4 item A). Appendix 2 lists contacts for more information about the MPCA land spreading regulations, land application program contacts, and modification of management practices.

5. Case Studies of Land Spreading Biosolids on the Mesabi Range

Four taconite companies, United Taconite, US Steel Minntac, KeewatinTaconite, and Cliffs Erie, participated in using biosolids for vegetating tailings in recent years. This section summarizes those activities by company. Appendix Figure A3.1 shows the locations of biosolids producers and taconite mines.

5.1. United Taconite (formerly EVTAC) Mining Company, Forbes, MN.

United Taconite has used biosolids and other organic amendments in the reclamation of their tailings basin since 1997. The following sections provide a chronological summary of applications at United Tac.

5.1.1. Year 1997

To evaluate the effect of biosolids and paper mill waste on water quality and vegetation, a small-scale plot study was initiated and combined with a field scale demonstration project. Materials used in the study were Quad-City (Virginia, Mountain Iron, Gilbert, Eveleth) biosolids, Blandin paper mill waste from Grand Rapids, and Consolidated (Stora Enso) paper mill waste from Duluth.

In the fall of 1997 fourteen bins were constructed with liners and water collection equipment and then filled about three feet deep with tailings. Six different soil amendments and a control of bare tailings were installed in duplicate plots. All plots were seeded with 44 lbs per acre of a standard reclamation seed mix and mulched with 2 tons per acre of straw. The effect of these amendments on the quality of both surface runoff and infiltration water was examined.

The same six amendment combinations were applied to 5-acre portions of United Tac's coarse tailings dam. Prior to application, the coarse tailings dike was graded to a 3:1 slope with three 50-foot lifts and two 20-foot wide benches. The various treatments were applied, disked to a depth of 6 inches, seeded and mulched. Vegetation on these plots was monitored from 1998 to 2002.

The six treatments (plus control) were:

Amendment	Amendment Application rate (dry tons/acre)	Fertilizer (18-46-0) Application Rate (lbs/acre)	Mulch Application Rate (tons/acre)	Seed Application Rate (lbs/acre)
Control	0	0	0	0
Standard mineland reclamation (SMR)	0	500 (90 lb N) ¹	2	44
Paper - Blandin	20 (116 lb N)	889 (160 lb N)	2	44
Paper - Consolidated	20 (51 lb N)	889 (160 lb N)	2	44
Municipal solid waste compost (MSW)	20 (509 lb N)	500 (90 lb N)	2	44
Biosolids (Quad-City)	5.88 (162 lb N)	0	2	44
Blandin/Biosolids	20 + 9.82 (386 lb N)	0	2	44

¹ lbs N per acre. A discussion of Carbon:Nitrogen ratios of the various amendments and calculations of available N is provided in Attachment A3.1.

Results from the small bin, water quality study showed that despite applying the amendment in the fall after the growing season, there was no substantial impact on the quality of either the surface runoff or the water that infiltrated the tailings (Table A3.5.). The total volume of surface runoff from all plots was extremely small, and the highest average runoff was from the untreated control plot (Eger et al., 2000).

Vegetation was evaluated by measuring percent cover and biomass. Percent cover includes live vegetation and litter from previous years' vegetation (but not mulch). After two years, percent cover on all of the amended small plots was at least 50% higher than the cover produced by the standard mineland reclamation practice (seed, fertilizer, and mulch).



Figure 5.
Biosolids bin plots at United Tac. White barrels are to collect water samples for water quality testing.

Although none of the plots met the three-year cover standard of 90%, two plots exceeded 80%. Biomass was highest in the standard mineland reclamation plot after one growing season. After the second growing season, biomass increased substantially in all treated plots except the SMR plots where biomass decreased by more than 80%.

Percent cover was also measured on the 5-acre plots. In general, vegetative percent cover increased with time for all treatments. Standard mineland reclamation treatment (SMR) had significantly less cover than any of the other treatments. Vegetation cover was better when Blandin paper waste was mixed with biosolids than either treatment applied alone. Municipal solid waste (MSW) compost had the highest percent cover after 4 years (Figure 6).

In the fall of 2000, a surface application of WLSSD lime-stabilized biosolids (LSB) was applied to each of the 5-acre study plots, leaving a small portion of each plot untreated. Measurements conducted in 2001 and 2002 showed that, in most cases, the treated areas exhibited a noticeable improvement in vegetative cover compared to the untreated portion (Figure 6). More detail is shown in Appendix Table A3.4.

Figure 6. 1997 United Tac Amended Demonstration Plots

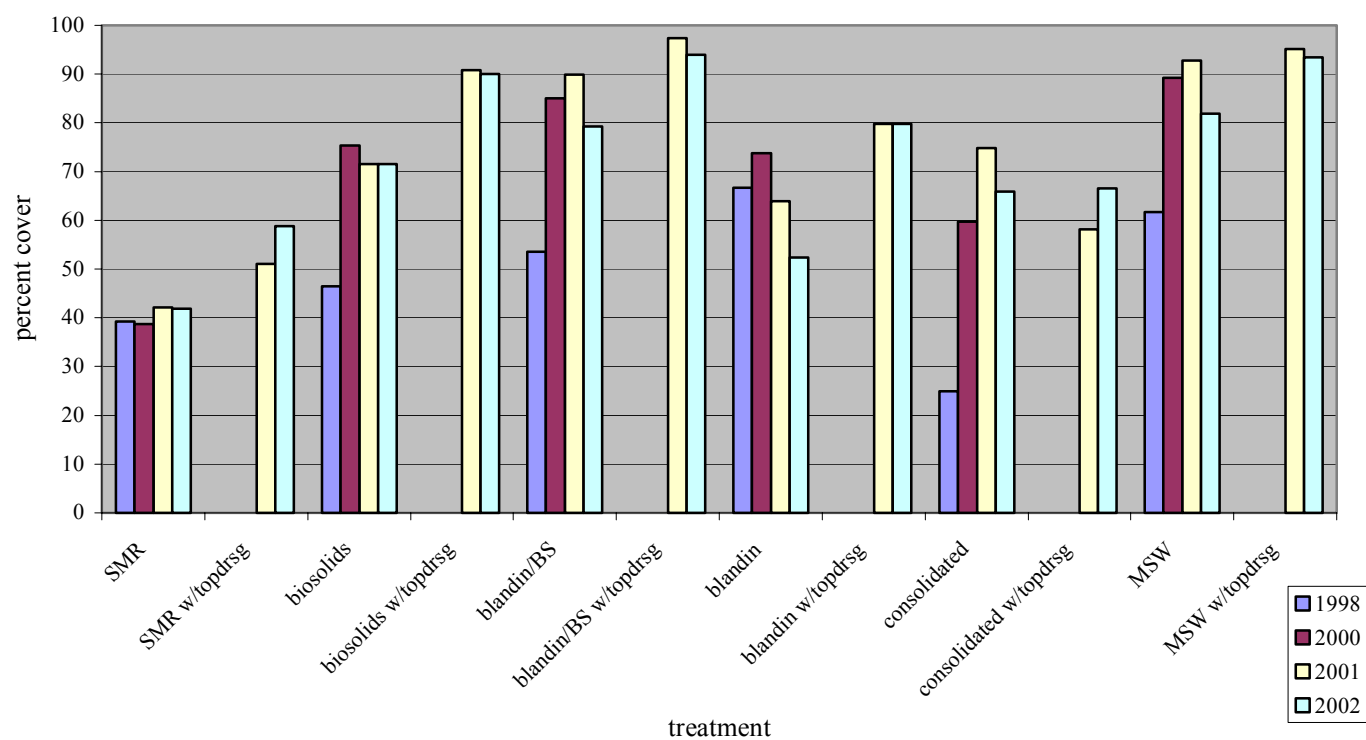


Figure 7. Biosolids demonstration plot at United Tac being monitored for vegetative growth.



5.1.2. Year 2000 biosolids application at United Tac

Spigotting of tailings into United Tac's basin #1 was discontinued in November 2000 when basin #2 came on line. Final reclamation of basin #1 was now fully underway in accordance with closure plans for the basin. These plans included the use of biosolids for reclamation of the tailings.

The spreading of WLSSD lime-stabilized biosolids (LSB) on about 200 acres of the tops and slopes of tailings basin #1 was initiated in late summer 2000 (see map figure A3.3). Some of the application areas were already vegetated and only received a top-dressing of biosolids (100 lbs nitrogen/acre). The LSB were about 22% solids and contained about 30 pounds of plant available nitrogen (PAN) per dry ton.

Forty-three acres of coarse tailings roadway on the top of the basin were used to test various application rates of biosolids (0, 100, 200, and 400 lbs N/acre) and became known as the 'circle of sludge'. An analysis of the biosolids indicated a low level of plant available phosphorus (PAP) due to the lime-stabilizing process, so some plots received an addition of inorganic phosphorus (P) fertilizer. Following application to the coarse bare areas, the tailings were disked, seeded, and mulched.

Vegetation monitoring conducted by the DNR on the circle of sludge in 2001 indicated that biosolids applications improved the vegetative cover over standard treatment; however, the higher rates of biosolids appeared to enhance the growth of Russian thistle, *Salsola kali*, an invasive, nitrogen loving, annual weed. Our observations were that seeded legumes such as alfalfa and sweet clover seemed to be diminished by the higher applications of biosolids, while Russian thistle flourished during the first two growing seasons. Legumes may not respond noticeably to applied nitrogen since they have the ability to produce their own nitrogen. By the end of the third growing season (2003), Russian thistle appeared to be diminishing and smooth brome grass was increasing.

A very high population of grasshoppers in the vegetated areas of United Tac's tailings basin also undoubtedly had a negative impact on the vegetation success during the 2001 and 2002 growing season. A quantitative analysis of the vegetation on the circle of sludge plots was done in 2003 (Figures 8 & 9). In general, the plots receiving both LSB and P fertilizer had more vegetation than their counterparts without P. The high rate of biosolids (400 lb N) without P was comparable to the 200 lb N rate with P. The response to P fertilizer was not unexpected since the PAP level in the lime-stabilized biosolids was low. None of the trial plots met the three-year reclamation standard. Russian thistle weed, grasshoppers, and periodic droughty conditions were all factors in the limited growth of seeded species. Tailings samples were taken for nutrient analyses during 2003 to help determine what additional treatment(s) will promote an acceptable species composition and level of vegetation cover on this site.

Figure 8. 2003 percent cover on United Tac coarse tailing plots installed in 2000 ('Circle of Sludge').

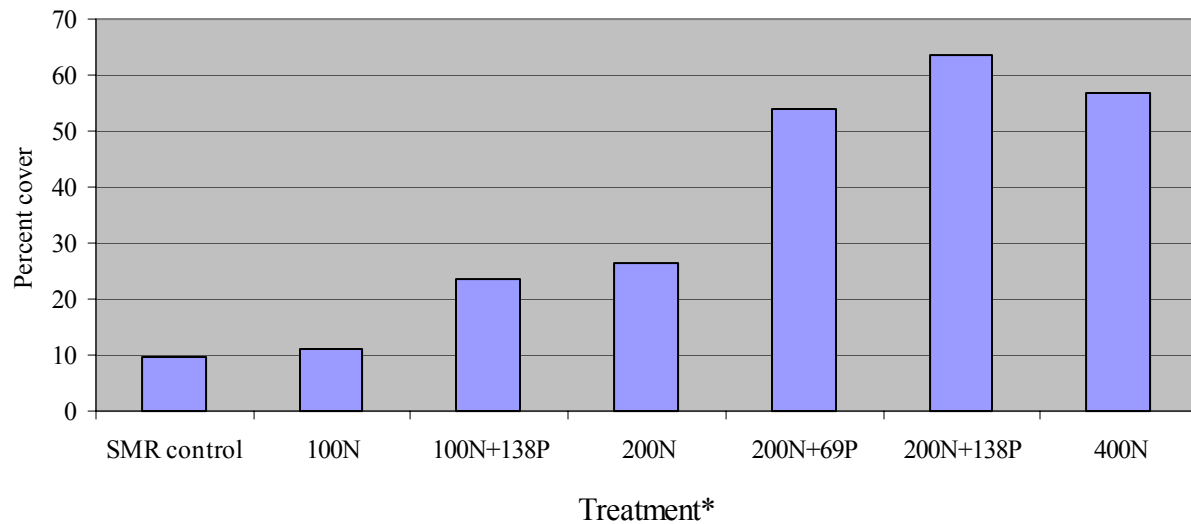
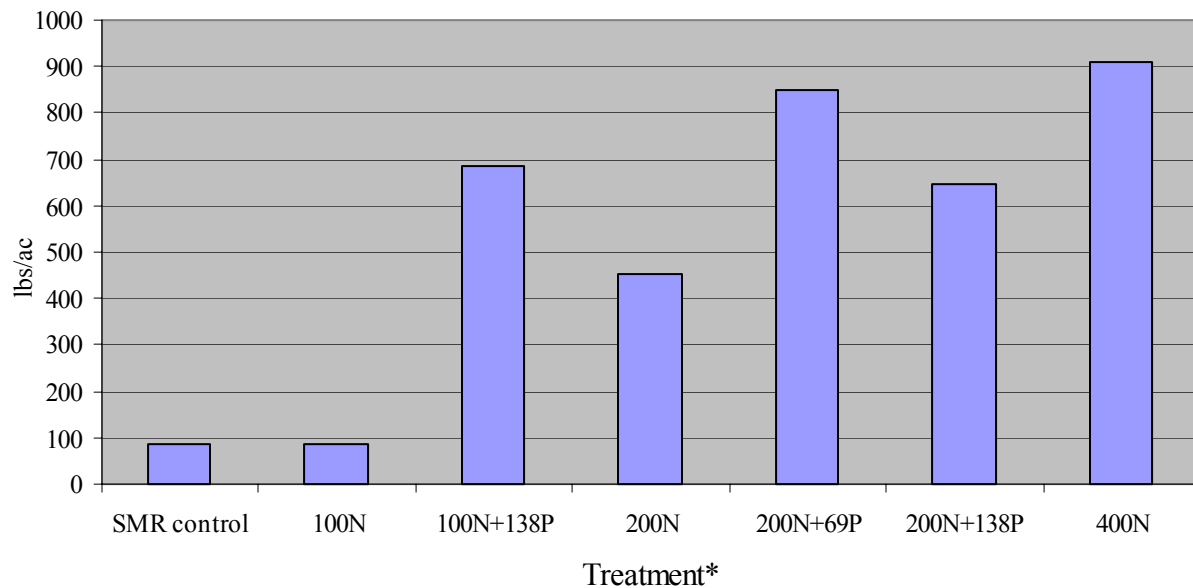


Figure 9. 2003 biomass measurements on coarse tailings plots installed in 2000 ('Circle of Sludge')



*Treatment rates are in pounds per acre nitrogen and elemental phosphorus.

5.1.3. Year 2002 biosolids applications at United Tac

During 2001, WLSSD changed their waste treatment process from lime-stabilization to one that anaerobically digests the solids. The anaerobically digested biosolids (ADB) were about 28% solids and delivered about 29 pounds of plant available nitrogen (PAN) per dry ton when surface applied and about 37 pounds of PAN when incorporated. The ADB yield a much greater level of ammonia-N (NH_3), which is readily available for plant growth; however, approximately half of the ammonia volatilizes when biosolids are surface-applied. The digestion process also produces approximately twice the amount of plant available phosphorus (PAP) than does lime-stabilization.

A third study was initiated in 2002 on the northwest corner of the tailings basin dike using this new material. The study examined the impact of WLSSD ADB and ADB plus paper mill residue (PMR) on water quality and vegetative response when applied to coarse tailings. Since there was more PAP in these biosolids, no additional P fertilizer was deemed necessary. Again, both a small-scale bin study and large field plots were installed. Six variations in ADB and paper residue amendments were applied to 2-acre plots on coarse tailings dike slopes. The same treatments were used in the small bins. Bare tailings with no fertilizer or amendment and standard mineland reclamation practice were used for control and comparison. Small plot treatments were installed in duplicate. The effect of these amendments on vegetation and the quantity and quality of both surface runoff and infiltration water was monitored.

The bin treatments were:

- Bare tailings (no fertilizer or amendment)
- Standard mineland reclamation
- Biosolids to provide 100 lb. Available Nitrogen ~ 3.1 dry tons/acre
- Biosolids to provide 200 lb. Available Nitrogen ~ 6.2 dry tons/acre
- Biosolids to provide 400 lb. Available Nitrogen ~ 12.4 dry tons/acre
- Biosolids to provide 200 lb. Available Nitrogen ~ 6.2 dry tons/acre + paper mill residue from Stora Enso in Duluth ~ 28 dry tons/acre
- Biosolids to provide 400 lb. available Nitrogen ~12.4 dry tons/acre + paper mill residue from Stora Enso in Duluth ~ 56 dry tons/acre

All plots were seeded with 55 lbs/acre of a standard reclamation seed mix and mulched with 2 tons/acre of straw. Although there appeared to be excellent initial germination in the bins, all the vegetation except a few isolated sweet clover plants disappeared in July. A late planting combined with a healthy grasshopper population is believed to be responsible for the disappearing vegetation. The plots were reseeded in August 2002.

Percent cover and biomass were measured in summer 2003 (Figures 10 and 11). Generally speaking, cover and biomass increased with increasing rates of biosolids. The

400 lb N rate with PMR had the greatest biomass but the 400 rate without paper mill residue had the most percent cover. These are data from essentially one growing season because the plots were denuded by grasshoppers and then reseeded in August 2002.

Figure 10. 2003 percent cover measurements on WLSSD small bin study installed in 2002 at United Tac.*

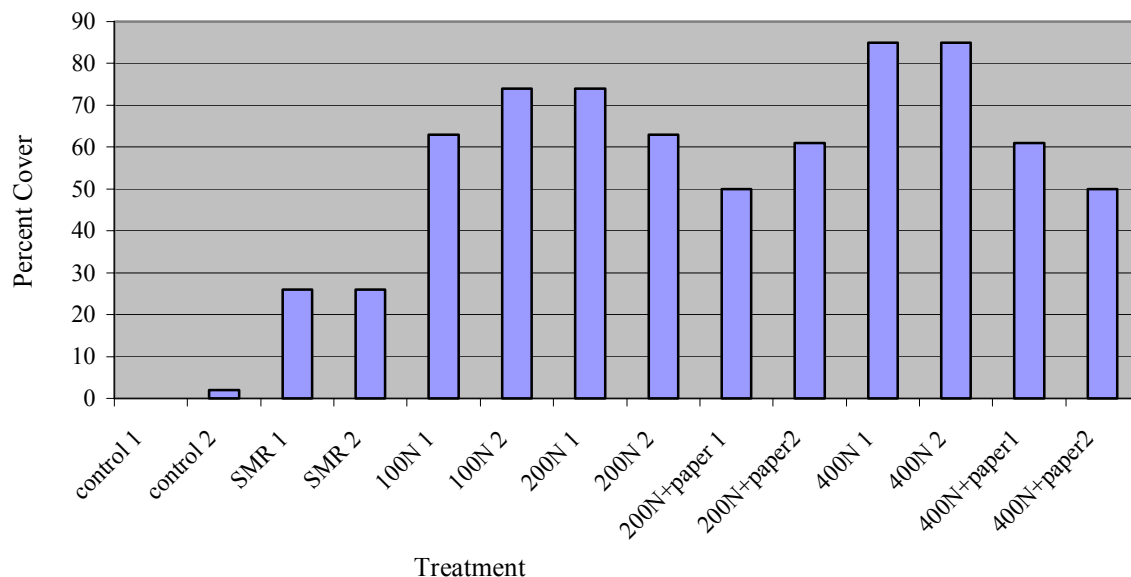
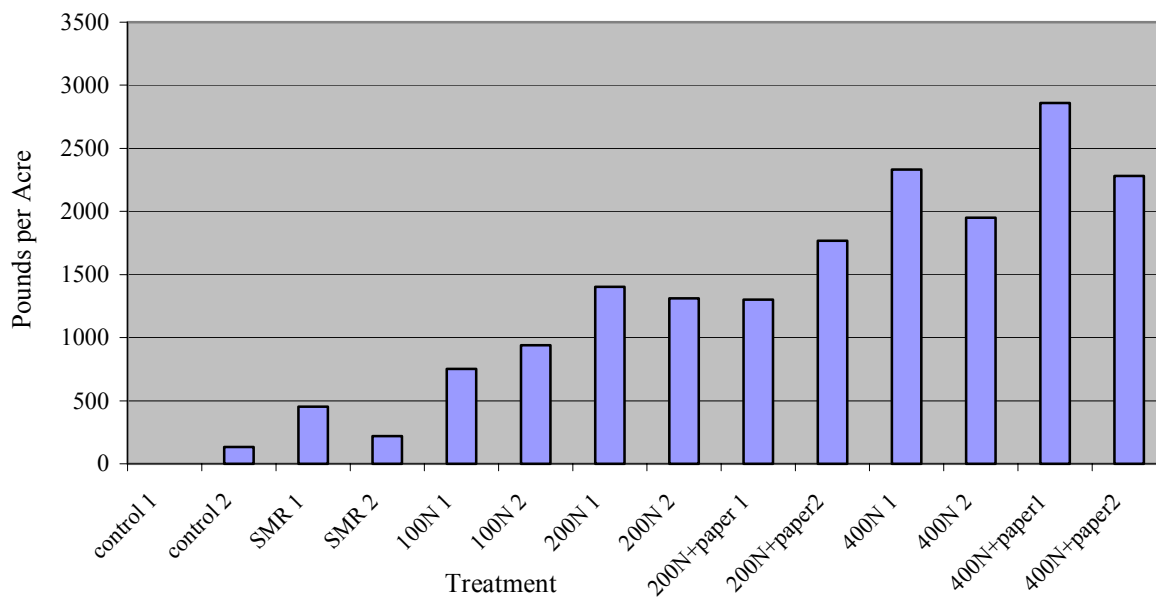


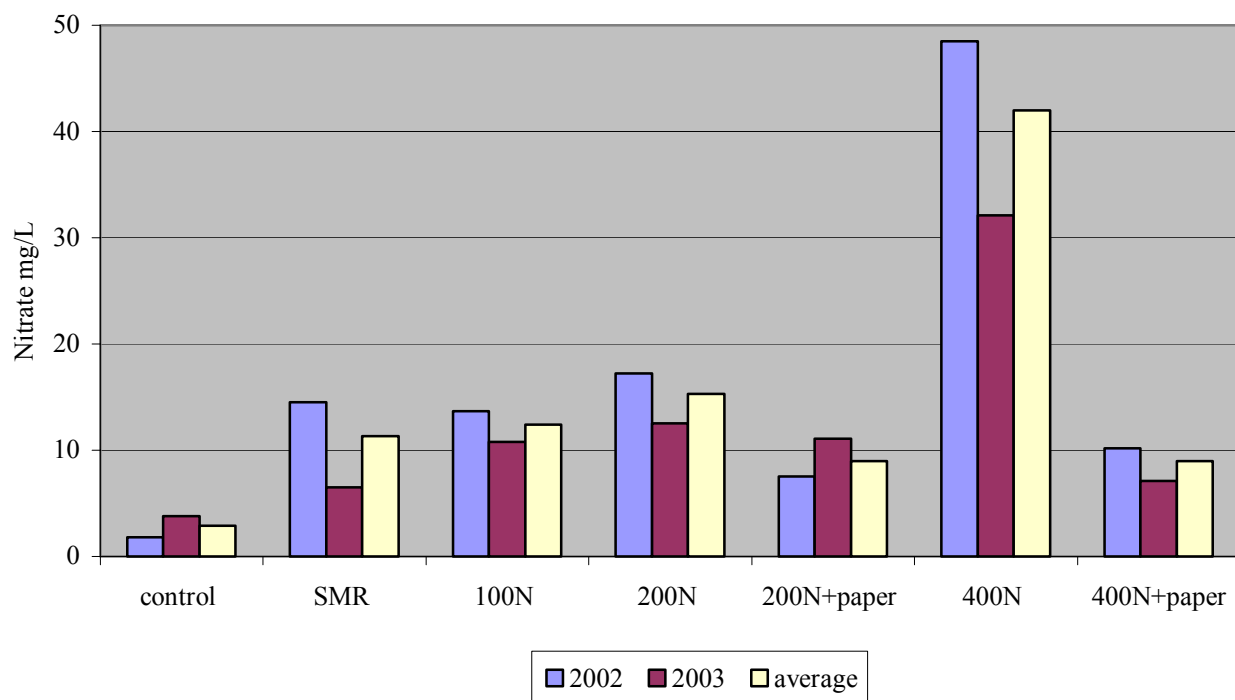
Figure 11. 2003 biomass measurements on WLSSD small bin study installed in 2002 at United Tac.*



*Charts show data from each duplicate plot.

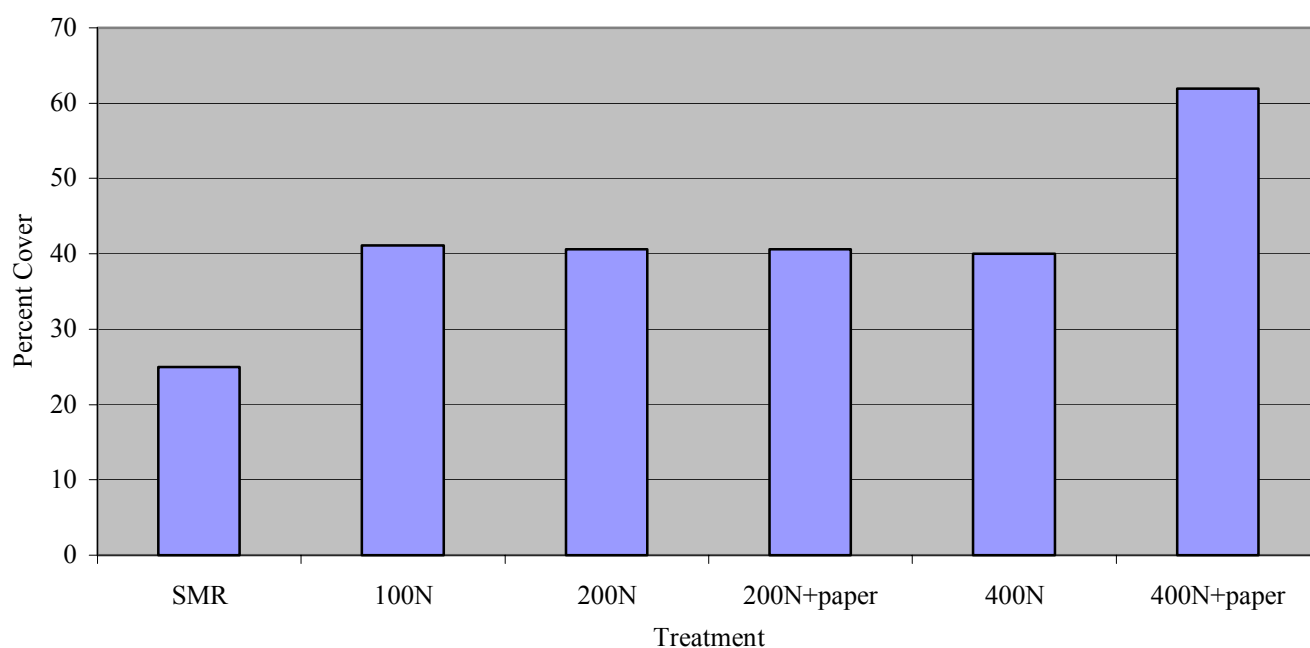
The bins were monitored for quality of infiltrated and surface runoff water. With the exception of nitrate, there were no water quality concerns (Appendix Table 2.1.). With essentially no vegetation in any of the plots during the first summer, the average nitrate values in water drainage from most of the treated plots, including standard mineland reclamation, were elevated. That year the average nitrate values from all plots except the control and the 200N biosolids plus paper mill residue plots exceeded the drinking water quality standard of 10 mg/L to some degree. Nitrate concentrations were significantly lower in the bins treated with paper mill residue compared to the counterpart biosolids rate without PMR. Infiltration water was also collected from the plots during 2003, and nitrates were lower in all the plots with the exception of the control and 200N plus paper. (Figure 12).

Figure 12. Concentration of nitrate in infiltration water from WLSSD biosolids study bins



The demonstration plots on the tailings dike slopes were planted several weeks after the bins, and the mulching was not completed until the middle of July. Despite this late planting, vegetation did grow on the dike slopes, mainly the lower slope. The contrast in vegetation between upper and lower slopes could be due to either poor seed coverage on the upper slopes during seeding or more moisture availability from dike seepage to the lower slope or both. Percent cover on the dike demonstration plots was measured in August 2003 (Figure 13). All of the plots that received anaerobically digested biosolids had more cover than the control, but it may take a few growing seasons to see if there will be any difference among ADB plots.

Figure 13. 2003 percent cover on United Tac tailings dike demonstration plots planted in 2002.



Biosolids were also applied as a top dressing to about 255 acres of existing vegetation on the top of the basin at the rate of 90 lbs N/acre during 2002. A severe grasshopper infestation affected much of the new and existing vegetation on the top of the basin.



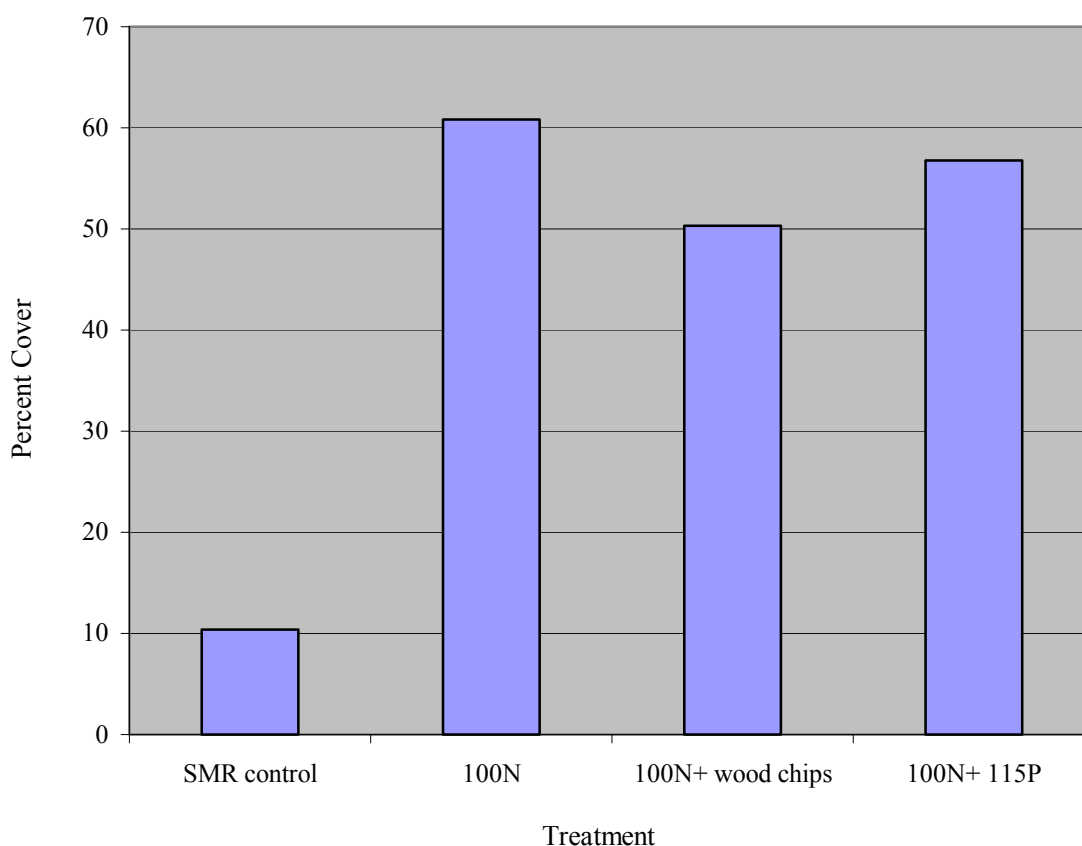
Figures 14 and 15. Before and after seeding of the 2002 demonstration plots at United Tac tailings dike utilizing WLSSD anaerobically digested biosolids mixed with Stora Enso paper waste. The small bin plots can be seen in the picture below.



5.2. US Steel Minntac: Mountain Iron, MN

A portion of the USS Minntac coarse tailings basin dike was sloped to about a 3:1 grade and anaerobically digested biosolids (ADB) from WLSSD were applied to 70 acres in September 2001. Disking, seeding, and mulching followed. Experimental treatments included the use of a control plot (standard mineland reclamation), ADB (100 lbs N/acre), ADB with phosphorus fertilizer supplement, and ADB mixed with wood chips. Vegetation monitoring of this site was conducted in the summer of 2003 after two growing seasons (Figure 16). In general, all of the amended plots had significantly more vegetation cover than the standard treatment. Early observations suggest that wood chips mixed with ADB seems to enhance the growth of legumes and diminish the growth of weeds, probably by limiting readily available nitrogen (see C:N ratio discussion in Appendix 3). So far, any benefit from added phosphorus was indiscernible on these plots. It is possible that phosphorus has a more long-term effect on vegetation. Monitoring of the site over time should reveal any such differences.

Figure 16. 2003 percent cover on USS tailings dike (planted in September 2001)





Figures 17 and 18. USS Minntac's tailing basin reclamation site showing before and after application of biosolids and seeding.



In 2002, USS used WLSSD ADB in revegetating 65 acres of fine tailings. WLSSD applied biosolids at a rate of 100 lb N/acre. An adjacent plot of standard reclamation treatment on fine tailings will offer a comparison to this biosolids application.

In March 2003, WLSSD delivered and spread six truckloads of biosolids over an 8.3-acre USS rock dump lift that was covered with a mixture of surface overburden and coarse tailings for a truck driving surface.

Also in March, 100 truck loads of WLSSD biosolids were spread at the 100 lb N/acre rate over 150 acres of tailings previously vegetated. The hope is to boost and increase the spotty vegetation resulting from the initial seeding for stabilization of this cell. About 80 acres of the cell will be left unamended for comparison. These sites will be monitored after two or more growing seasons

5.3. Other Sites

Two other sites that were identified for biosolids applications included the Keewatin Taconite tailings basin, utilizing the City of Hibbing's liquid biosolids, and a Cliffs-Erie (formerly LTV Steel Mining Company) overburden dump, utilizing liquid biosolids from Aurora and Hoyt Lakes. At the Keewatin Tac basin, aerobically digested, Class B biosolids from Hibbing were spread at the rate of 80 pounds of plant available nitrogen per acre and immediately incorporated into the tailings after spreading. The site was seeded within two weeks with a grass/legume seed mix. The Cliffs-Erie reclamation site was split into two areas, one area for Aurora and the other for Hoyt Lakes. During summer and fall of 2003, the split site received a surface application of anaerobically digested, Class B biosolids at the rate of 23 to 31 pounds PAN per acre. The biosolids were spread over what was mostly an existing cover of vegetation (see Figure 20). The site is permitted for an allowable 100 lbs N/ac, so will receive additional applications of biosolids. Areas that may require more vegetative cover will be seeded in the spring. Monitoring will be conducted on both the Keewatin and Cliffs-Erie sites during 2004.



Figure 19. City of Hibbing liquid biosolids application site at National's tailing basin a few days after seeding was completed.



Figure 20. Aurora liquid biosolids landspreading site at Cliffs Erie surface stockpile one hour after application. This was a bare, one-acre test site where seed was added to the biosolids before spreading.

6. Win/Win Situation May Exist

In the past few years, the WLSSD and other biosolids producers have delivered, spread and incorporated their biosolids to reclamation sites at their cost. This is a benefit to the mine operator since reclamation costs are lowered with the reduction or elimination of fertilizer costs. Continued monitoring of the application sites will determine whether there is a need for additional biosolids or inorganic fertilizer. In addition, biosolids applications have shown to be more successful than fertilizer in establishing vegetation on coarse tailings reclamation sites

Although the cost of commercial fertilizer fluctuates, the cost has been high in recent years. In contrast, biosolids have been provided free-of-charge. Treatment plants also supply the equipment needed to haul, spread and incorporate biosolids, so reclamation managers have not been charged for these services to date. Soil sampling, laboratory analysis, and the preparation of permit applications submitted to the MPCA are part of the site selection and approval process completed by the biosolids producer prior to land applications.

The WLSSD has a demand for their biosolids from nearby agricultural customers, many of which are located less than 30 miles away from the treatment facility. Haulage cost for WLSSD is a major economic consideration in delivering biosolids to a landspreading site. Dewatering their biosolids lowers haulage costs. The haul distance from WLSSD in Duluth to mine reclamation sites on the Mesabi Range ranges from 60-80 miles.

The WLSSD is interested in maintaining a relationship with the mining companies for landspreading their biosolids on mineland reclamation sites. They find it important to have these sites available during spring road restrictions when the nearby agricultural sites may not be accessible. Mining companies usually have potential sites located along roadways that are not restricted. Fall and sometimes winter seasons, when agricultural demand can be low, may also be available for the mining companies. Thus, the longer haul to minelands is offset by their accessibility during times when road restrictions and lower seasonal demands deter delivery to nearby agricultural customers.

Small biosolids producers on the Iron Range may find, like the cities of Hibbing, Aurora and Hoyt Lakes did, nearby reclamation sites that could benefit from an application of biosolids. Hauling costs for these liquid biosolids may not be a critical limiting factor if the mine reclamation landspreading site is nearby.

7. Summary

1. Applying biosolids on reclamation sites can be an economical way of adding organic matter and nutrients to enhance vegetation and success of reclamation.
2. Results to date indicate that biosolids applied at 100-200 lbs N/acre significantly increases vegetative cover and production. Biosolids applied at rates greater than 200 lbs N/acre does not significantly increase planted grasses and legumes but may increase the growth of invasive weeds.
3. Incorporating other organic materials such as paper waste or wood chips with biosolids at the appropriate rate (C:N ratio of about 25) is encouraged. Other organic materials may help limit the amount of nitrates available for weed growth and leaching into groundwater.
4. Most types of biosolids may be surface-applied to areas that have previously received treatments of biosolids and are vegetated, provided soil tests or plant analyses indicate a need for additional nutrients to enhance existing vegetation.
5. It is recommended that the more difficult to vegetate coarse tailing reclamation sites receive priority for biosolids application over fine tailing flats and other waste stockpile sites.
6. Not all biosolids have an adequate amount of plant available phosphorus. Nutrient analysis of the biosolids before application will help to determine if more phosphorus is necessary or desirable.
7. There are anecdotal reports attributing adverse health effects to exposure from biosolids. No human health risks are associated with the proper management of biosolids; however, the odor from stockpiled or freshly applied biosolids can be offensive, and land application proposals may encounter some public opposition.
8. Studies completed on WLSSD biosolids indicate that drainage water quality was not affected by lime-stabilized biosolids. Drainage water quality from the unvegetated coarse tailings amended with anaerobically digested WLSSD biosolids showed elevated nitrate concentrations from most of the plots (compared to drinking water standards), initially. The nitrate levels dropped over a one year period.

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List of Appendices

- A1. Frequently asked questions about biosolids and other related fact sheets
- A2 Regulations: MPCA and MN DNR web sites
- A3. Additional detail and results of reclamation trials with biosolids

Appendix 1

General Information about Biosolids

Attachment A1.1. Frequently asked questions about biosolids.

Attachment A1.2. Q and A about health hazards from biosolids.

Attachment A1.3 List of websites that provide information about biosolids.

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Biosolids

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Frequently Asked Questions

1) What are Biosolids?

They are nutrient-rich organic materials resulting from the treatment of domestic sewage in a treatment facility. When treated and processed, these residuals can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth.

2) What is the difference between biosolids and sludge?

Biosolids are treated sewage sludge. Biosolids are carefully treated and monitored and must be used in accordance with regulatory requirements.

3) Why do we have biosolids?

We have biosolids as a result of the wastewater treatment process. Water treatment technology has made our water safer for recreation and seafood harvesting. Thirty years ago, thousands of American cities dumped their raw sewage directly into the nation's rivers, lakes, and bays. Through regulation of this dumping, local governments now required to treat wastewater and to make the decision whether to recycle biosolids as fertilizer, incinerate it, or bury it in a landfill.

4) How are biosolids generated and processed?

Biosolids are created through the treatment of domestic wastewater generated from sewage treatment facilities. The treatment of biosolids can actually begin before the wastewater reaches the sewage treatment plant. In many larger wastewater treatment systems, pre-treatment regulations require that industrial facilities pre-treat their wastewater to remove many hazardous contaminants before it is sent to a wastewater treatment plant. Wastewater treatment facilities monitor incoming wastewater streams to ensure their recyclability and compatibility with the treatment plant process.

Once the wastewater reaches the plant, the sewage goes through physical, chemical and biological processes which clean the wastewater and remove the solids. If necessary, the solids are then treated with lime to raise the pH level to eliminate objectionable odors. The wastewater treatment processes sanitize wastewater solids to control pathogens (disease-causing organisms, such as certain bacteria, viruses and parasites) and other organisms capable of transporting disease.

5) How are biosolids used?

After treatment and processing, biosolids can be recycled and applied as fertilizer to improve and maintain productive soils and stimulate plant growth. The controlled land application of biosolids completes a natural cycle in the environment. By treating sewage sludge, it becomes biosolids which can be used as valuable fertilizer, instead of taking up space in a landfill or other disposal facility.

6) Where are biosolids used?

Farmers and gardeners have been recycling biosolids for ages. Biosolids recycling is the process of beneficially using treated residuals from wastewater treatment to promote the growth of agricultural crops, fertilize gardens and parks and reclaim mining sites. Land application of biosolids takes place in all 50 states.

7) Why are biosolids used on farms?

The application of biosolids reduces the need for chemical fertilizers. As more wastewater plants become capable of producing high quality biosolids, there is an even greater opportunity to make use of this valuable resource.

8) What percentage of biosolids are recycled and how many farms use biosolids?

About 50% of all biosolids are ~~not~~ being recycled to land. These biosolids are used on less than one percent of the nation's agricultural land.

9) Are biosolids safe?

The National Academy of Sciences has reviewed current practices, public health concerns and regulator standards, and has concluded that "the use of these materials in the production of crops for human consumption when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the consumer, to crop production and to the environment."

10) Do biosolids smell?

Biosolids may have their own distinctive odor depending on the type of treatment it has been through. Some biosolids may have only a slight musty, ammonia odor. Others have a stronger odor that may be offensive to some people. Much of the odor is caused by compounds containing sulfur and ammonia, both of which are plant nutrients.

11) Are there regulations for the land application of biosolids?

The federal biosolids rule is contained in 40 CFR Part 503. Biosolids that are to be land applied must meet these strict regulations and quality standards. The Part 503 rule governing the use and disposal of biosolids contain numerical limits, for metals in biosolids, pathogen reduction standards, site restriction, crop harvesting restrictions and monitoring, record keeping and reporting requirements for land applied biosolids as well as similar requirements for biosolids that are surface disposed or incinerated. Most recently, standards have been proposed to include requirements in the Part 503 Rule that limit the concentration of dioxin and dioxin like compounds in biosolids to ensure safe land application.

12) Where can I find out more about the regulations?

The biosolids rule is described in the EPA publication, [A Plain English Guide to the EPA Part 503 Biosolids Rule](#). This guide states and interprets the Part 503 rule for the general reader. This guide is also available in hard copy. In addition to the Plain English Guide, EPA has prepared [A Guide to the Biosolids Risk Assessments for the EPA Part 503 Rule](#) which shows the many steps followed to develop the scientifically defensible, safe set of rules (also available from EPA in hard copy.)

13) How are biosolids used for agriculture?

Biosolids are used to fertilize fields for raising crops. Agricultural use of biosolids, that meet strict quality criteria and application rates, have been shown to produce significant improvements in crop growth and yield. Nutrients found in biosolids, such as nitrogen, phosphorus and potassium and trace elements such as calcium, copper, iron, magnesium, manganese, sulfur and zinc, are necessary for crop production and growth. The use of biosolids reduces the farmer's production costs and replenishes the organic matter that has been depleted over time. The organic matter improves soil structure by increasing the soil's ability to absorb and store moisture.

The organic nitrogen and phosphorous found in biosolids are used very efficiently by crops because these plant nutrients are released slowly throughout the growing season. This enables the crop to absorb these nutrients as the crop grows. This efficiency lessens the likelihood of groundwater pollution of nitrogen and phosphorous.

14) Can biosolids be used for mine reclamation?

Biosolids have been used successfully at mine sites to establish sustainable vegetation. Not only does the organic matter, inorganic matrix and nutrients present in the biosolids reduce the bioavailability of toxic substances often found in highly disturbed mine soils, but also regenerate the soil layer. This regeneration is very important for reclaiming abandoned mine sites with little or no topsoil. The biosolids application rate for mine reclamation is generally higher than the agronomic rate which cannot be exceeded for use of agricultural soils.

15) How are biosolids used for forestry?

Biosolids have been found to promote rapid timber growth, allowing quicker and more efficient harvest of an important natural resource.

16) Can biosolids be used for composting?

Yes, biosolids may be composted and sold or distributed for use on lawns and home gardens. Most biosolids composts, are highly desirable products that are easy to store, transport and use.

17) Are there rules about where biosolids can be applied?

To determine whether biosolids can be applied to a particular farm site, an evaluation of the site's suitability is generally performed by the land applier. The evaluation examines water supplies, soil characteristics, slopes, vegetation, crop needs and the distances to surface and groundwater.

There are different rules for different classes of biosolids. Class A biosolids contain no detectible levels of pathogens. Class A biosolids that meet strict vector attraction reduction requirements and low levels metals contents, only have to apply for permits to ensure that these very tough standards have been met. Class B biosolids are treated but still contain detectible levels of pathogens. There are buffer requirements, public access, and crop harvesting restrictions for virtually all forms of Class B biosolids.

Nutrient management planning ensures that the appropriate quantity and quality of biosolids are land applied to the farmland. The biosolids application is specifically calculated to match the nutrient uptake requirements of the particular crop. Nutrient management technicians work with the farm community to assure proper land application and nutrient control.

18) Are there buffer requirements or restrictions on public access to sites with biosolids?

In general, exceptional quality (Class A) biosolids used in small quantities by general public have no buffer requirements, crop type, crop harvesting or site access restrictions. Exceptional Quality biosolids is the name given to treated residuals that contain low levels of metals and do not attract vectors. When used in bulk, Class A biosolids are subject to buffer requirements, but not to crop harvesting restrictions. In general, there are buffer requirements, public access, and crop harvesting restrictions for virtually all forms of Class B biosolids (treated but still containing detectable levels of pathogens).

19) Can anyone apply biosolids to land?

Anyone who wants to use biosolids for land application must comply with all relevant federal and state regulations. In some cases a permit may be required.

20) What will it mean for a wastewater treatment plant, biosolids manager or land applier to agree to follow an Environmental Management System (EMS) for Biosolids?

A voluntary EMS is now being developed for biosolids by the National Biosolids Partnership (NBP). The NBP consists of members from the Association of Metropolitan Sewerage Agency, the Water Environment Federation, the U.S. Environmental Protection Agency (EPA) and other stakeholders including the general public. Those facilities who pledge to follow the EMS are agreeing to follow community-friendly practices in addition to being in compliance with applicable state and Federal regulations. Community friendly practices refer to the control of odor, traffic, noise, and dust as well as the management of nutrients. Those who pledge to follow the EMS will be subjected to audit by impartial independent third parties.

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Last updated on Friday, June 28th, 2002
URL: <http://www.epa.gov/owmitnet/mtb/biosolids/genqa.htm>

Attachment A1.2. Q & A about health hazards from biosolids

April 9, 2003

Greg Kester
Wisconsin State Residuals Coordinator
Wisconsin Department of Natural Resources

Dear Greg,

Here are our responses to the questions within your email of April 4, 2003.

1. Can you summarize the work you have done to investigate the occurrence of *Staphylococcus aureus* in Class A and Class B biosolids and what, if any, conclusions you have drawn from that work?

The W-Q-C study in 2002 looked at all major types of Class A & B biosolids for the presence of *Staphylococcus aureus*. Results are as follows:

- *S. aureus* found in 60% of all raw sewage samples.
- *S. aureus* never found in biosolids (Class A or B)
- *S. aureus* never found in bioaerosol samples taken close (2m to 20m) to fields with land applied biosolids.

Based on these data we conclude that

- This study provides evidence for the absence of *S. aureus* in biosolids
- Class B biosolids are not a source of human exposure to *S. aureus*

The latest “theory” that irritant chemicals from biosolids promote *S. aureus* infections (from ubiquitous sources) is pure speculation. There is no precedent for this type of interaction with this microbe or chemical.

2. Can you summarize the work you have done in evaluating the potential for bioaerosol transport from land application of biosolids? Additionally, can you summarize any conclusions that may be drawn regarding the potential for adverse health effects from bioaerosol transport?

To date we have taken approximately 500 aerosol samples in the Western USA in a) Tucson, Arizona; b) Mojave, Arizona; c) Solano County, California; d) Seattle, Washington; e) Yakima, Washington. The number of samples and the diversity of microbes monitored are greater than in any previous study.

The results can be summarized as follows:

- No human pathogens (bacteria or virus) detected as bioaerosols
- Indicator organisms occasionally found
- Recent studies with seeded water to which viruses had been added indicate that majority of viruses are sorbed to solid phase biosolids and not available to be aerosolized
- Overall risk of infection from aerosols emanating from land applied biosolids is exceedingly low

3. Can you provide an interpretation of the Dowd et al. paper published in the Journal of Environmental Quality in 2000 (29:343–348), and why its findings may differ from your own?

The Dowd paper was published in 2000 (J. Environ. Qual 29:343–348). This paper was a preliminary evaluation of the potential for bioaerosol transport from land applied biosolids. We consider it preliminary for the following reasons:

- This was a virtual study—no analyses were made. All data and contents used in this study were derived from a variety of sources and with a variety of assumptions, some dating back several decades.
- Using the Sierra Blanca study from 1996, indicator organisms aerosol concentrations were used to model human pathogens with respect to transport.
- No attempt was ever made to analyse for human viruses.
- The only human bacteria analysed for was *Salmonella*. This organism can only infect chickens as an aerosol—not humans.
- Die-off factors for the modeling were based on laboratory studies not field studies.
- The highest risks calculated in this study were based on wind speeds of over 25 mph. Under these conditions land application of biosolids is not allowed in Solano County.
- Overall, the models used in this study deliberately overestimated risks i.e., ultra conservative.

Based on these shortcomings, our present study has evaluated the presence of actual pathogens under field conditions. Risks based on the current study are dramatically lower than those predicted by the Dowd paper. Although the Dowd paper illustrates the application of theoretical transport modeling it has no relevance to the potential for bioaerosols from land application in Solano County.

4. Have you examined the potential for secondary health effects that may arise from dust transport and consequential irritation in compromised individuals?

We have not done work in this area.

Sincerely,



Ian L. Pepper, Director
UA NSF Water Quality Center

Attachment A1.3. List of websites that provide information about biosolids.

1. www.epa.gov/own/mtb/biosolids - fact sheets
Biosolids Technology Fact Sheet: Land Application of Biosolids
2. www.wef.org/Whowear/WWIndustry/biosolidsinfo.jhtml - Biosolids
3. www.wef.org/publicinfo/factsheets/biosolidsrecycling.html - Biosolids
Recycling: Beneficial Technology for a Better Environment
4. www.wlssd.duluth.mn.us - Western Lake Superior Sanitary District
website

Appendix 2 Regulations

Minnesota Pollution Control Agency. MN Rules Chapter 7041.1100: Sewage Sludge Management. www.revisor.leg.state.mn.us/arule/7041

Land Application of Biosolids contact:

Jorja DuFresne, Soil Scientist, MPCA. jorja.dufresne@pca.state.mn.us.
office: (651)296-9292

Minnesota Dept. of Natural Resources. Mineland Reclamation Rules Chapter 6130:
www.revisor.leg.state.mn.us/arule/6130

MN DNR Lands and Minerals contact:

Steve Dewar, Field Reclamation supervisor MN DNR Lands and Minerals Division. steve.dewar@dnr.state.mn.us, office: (218)262-7324

Appendix 3

Additional detail and results of reclamation trials with biosolids

Figure A3.1. Map showing location of tailings basins and biosolids producers.

Figure A3.2. Map showing reclamation by year on United Tac tailings Basin 1.

Table A3.1. 1997 United Tac biosolids study. Soil fertility analysis of tailings and organic amendments.

Table A3.2. Standard mineland reclamation seed mix used at United Tac, 1997.

Table A3.3. 2002 United Tac biosolids study. Soil fertility analysis of tailings and organic amendments.

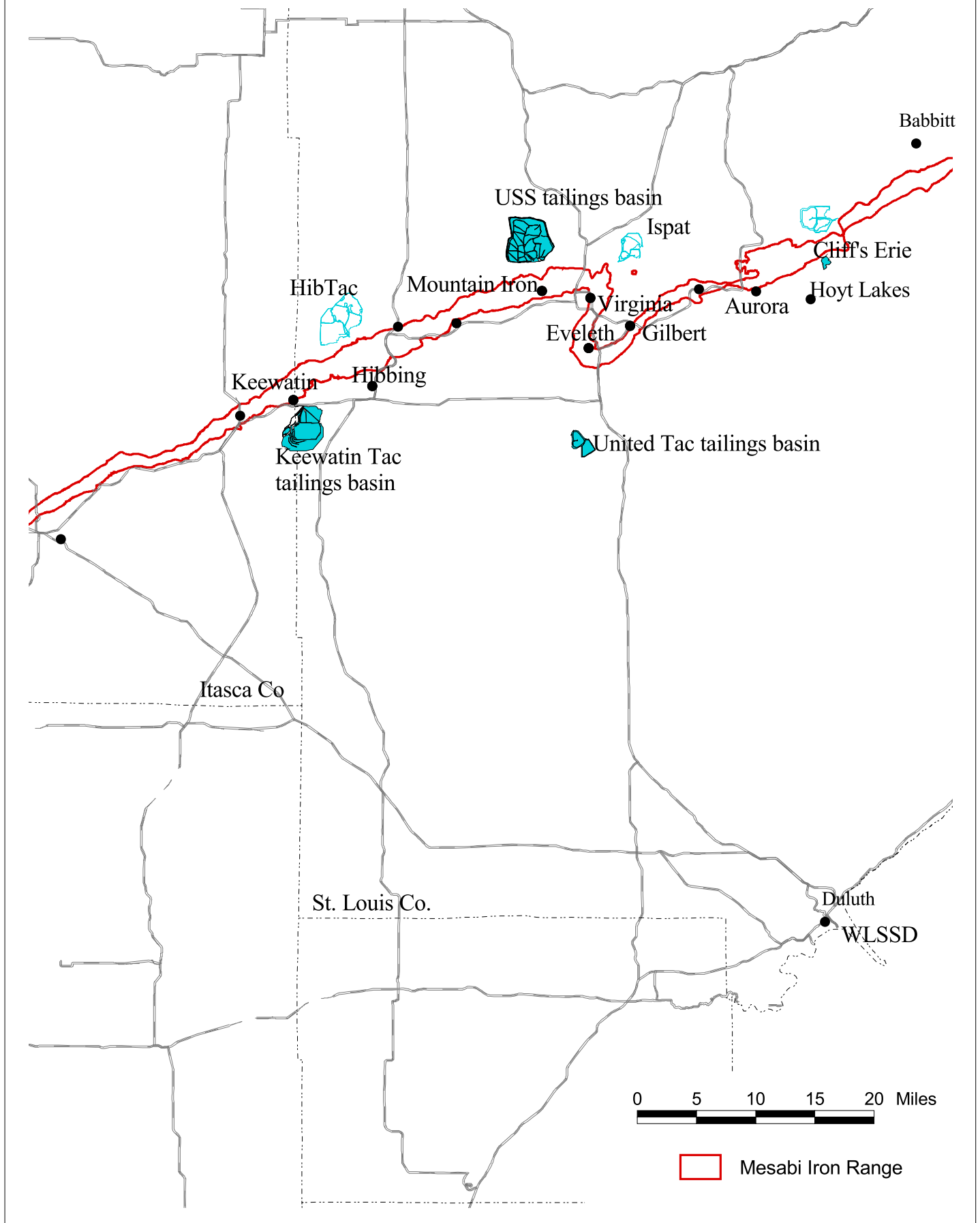
Attachment A3.1. Discussion of carbon to nitrogen ratio and plant nutrient availability.

Table A3.4. Four years of vegetation measurements on 1997 slopes.

Table A3.5. Water quality (average concentration per treatment) of infiltration. Initial bin study, 1997 to 1999 results.

Table A3.6. Water quality (average concentration per treatment) of infiltration. 2002 WLSSD water quality bin study, 2002-2003 results.

Figure A3.1. Location of tailings basins and biosolids producers



Attachment A3.1. Discussion of carbon to nitrogen ratio and plant nutrient availability.

While the use of organic amendments has been proven to increase vegetative success in reclamation studies, it is important to know the composition of the material.

The C:N ratio (organic carbon: total nitrogen) is important in determining application and fertilizer rates. A high C:N ratio (such as that in the paper wastes used in these trials) indicate that there is a low nitrogen content relative to its carbon content. This would result in a nitrogen deficiency for the plants unless additional fertilizer was applied. As reported in reference literature, ideally the ratio of 20 to 25:1 provides enough nitrogen for both the microorganisms and the plants. In mixtures with ratios below 20:1, there is a chance that nitrogen could be lost as ammonia-N. When this ratio ranges from 25:1 to 30:1, there is enough nitrogen to supply microorganisms, but not for the release of nitrogen to plants. Ratios exceeding 30:1 may limit plant growth due to the competition between microorganisms and plants for nitrogen. High ratios are common in residues such as the paper mill residues that contain wood fibers, thus, a nitrogen supplement in the form of fertilizer or a nitrogen- rich material such as biosolids, is needed to ensure plant growth.

Figure A3.2. WLSSD biosolids applications at United Tac 2000-2002 (lb N/acre)

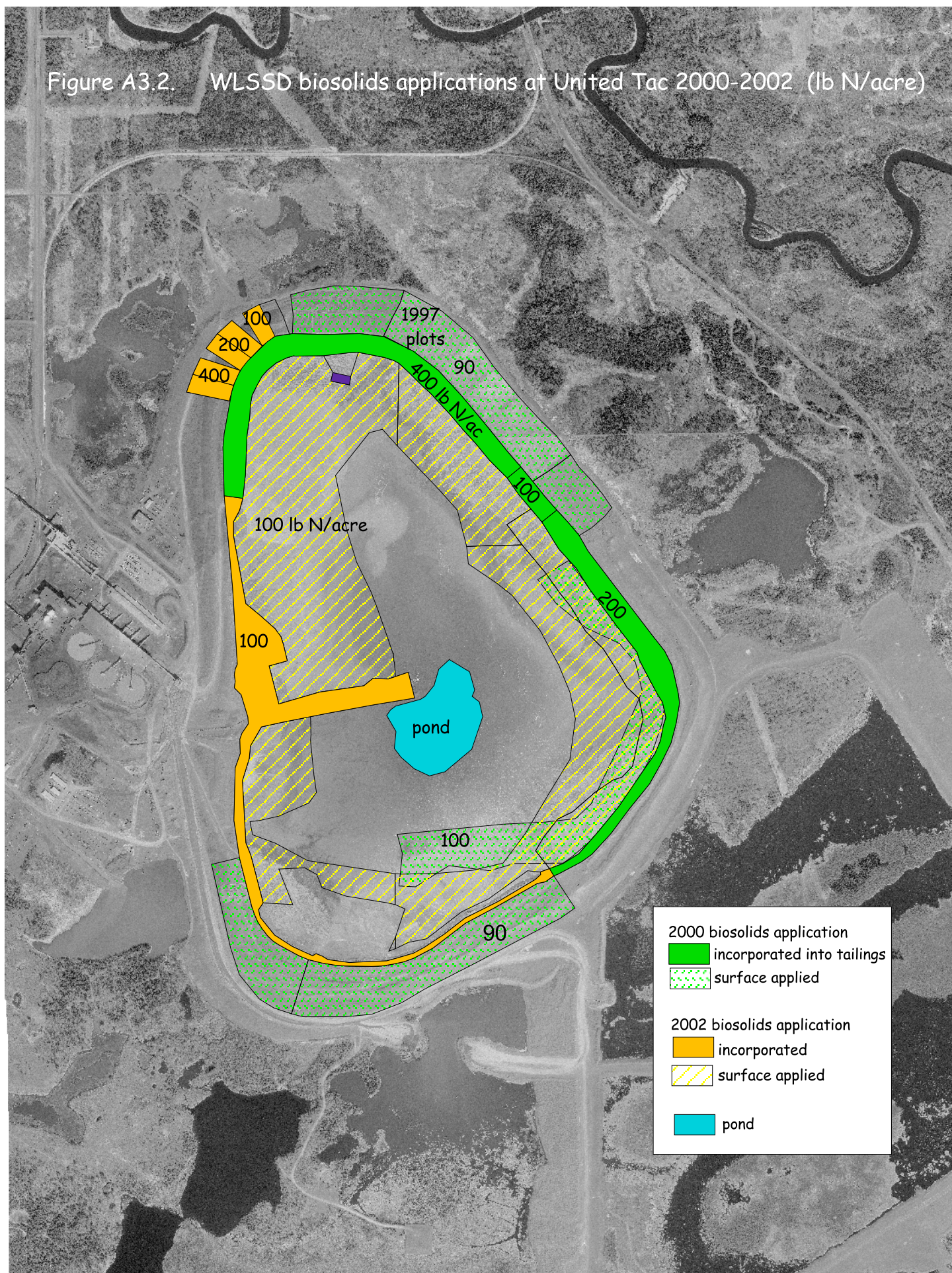


Table A3.1. 1997 United Tac biosolids study. Soil fertility analysis of tailings and organic amendments.

Parameters ¹	Tailings	Paper Residue		Quad City Biosolids	MSW
		Blandin	Consolidated		
pH	8.0	7.8	8.1	7.9	7.7
% Organic Matter	0.5	35.9	45.0	15.0	24.8
Nitrate-N (mg/kg)	1.0	1.0	3.0	75.5	31.5
% Solids, Total ²	99.7	36.4	46.8	34.8	61.8
%Solids, Volatile Total ²	2.66	51.2	50.2	24.1	49.7
Nitrogen, Kjeldahl (mg/kg)	16.5	2910	1270	13700	12700
Nitrogen, Ammonia (mg/kg)	<0.06	95.9	57.3	239	223
Organic Carbon (mg/kg)	10900	257,000	252,400	147,300	172,700
Total Nitrogen (mg/kg)	17.5	2911	1273	13776	12732
C:N Ratio	623:1	88:1	198:1	11:1	14:1
Phosphorus (mg/kg)					
Bray 1:	30	13	27	85	85
Olsen:	10	14	19	76	76
Potassium	300	20	20	150	720
Calcium	600	2400	4200	3700	5600
Magnesium	190	120	250	9600	1200
Sodium	40	70	110	120	200
Iron	29.2	7.5	12.4	64.1	47.5
Manganese	7	1.1	1.1	14.6	8.5
Copper	1	0.6	0.9	3.5	3.4
Zinc	5.2	5.5	8.2	11.4	11.9
Boron	0.7	1	0.7	1	2.8
Sulfate-S	3.0	2.0	30.0	5.0	14.0
CEC	5.5	13.3	23.6	98.4	40.6

¹ Metals are extractable values in this table. All values are measured in mg/kg, dry weight basis.

² This result reported on an as-received basis. Note: Samples were analyzed by MVT Laboratories, New Ulm, MN

Table A3.2. Standard mineland reclamation (SMR) seed mix used at United Tac, 1997.

Common Name	Latin Name	Lbs/acre
Smooth Bromegrass	<i>Bromus inermis</i>	10
Red Fescue	<i>Festuca rubra</i>	7
Perennial Rye Grass	<i>Lolium perenne</i>	7
Timothy	<i>Phleum pratense</i>	5
Alfalfa	<i>Medicago sativa</i>	5
Birdsfoot Trefoil	<i>Lotus corniculatus</i>	5
Sweet Clover	<i>Melilotus officinalis</i>	5
Total:		44

Table A3.3. 2002 United Tac biosolids study. Soil fertility analysis of tailings and organic amendments.

Parameters ¹	Tailings	WLSSD Biosolids	Stora Ensa Paper mill residue
pH	8.4	6.8	8.0
% Organic Matter	0.2	40	41.4
Nitrate-N ² (mg/kg)	2.0	113	1
Nitrogen, Kjeldahl (mg/kg)	42.6	20800	821
Nitrogen, Ammonia (mg/kg)	<8	6480	<8
Organic Carbon (mg/kg)	10900	248000	124000
Total Nitrogen (mg/kg)	44.6	20913	822
C:N Ratio	244:1	12:1	151:1
Phosphorus (mg/kg)			
Bray 1:	5	178	8
Olsen:	2	228	26
Potassium	402	876	64
Calcium	612	6284	8750
Magnesium	202	1008	444
Sodium	15	216	53
Iron	45.2	393.6	92.0
Manganese	16.8	88.0	29.6
Copper	0.2	26.4	3.2
Zinc	1.5	99.2	23.2
Boron	0.8	14.4	6.4
Sulfate-S	8	676	513
CEC	5.8	43.7	47.8

¹ Metals are extractable values in this table. All values are measured in mg/kg, dry weight basis.

² This result reported on an as-received basis. Note: Samples were analyzed by MVT Laboratories, New Ulm, MN.

Table A3.4. Four years of vegetation measurements on 1997 tailings dike slopes.

Percent Cover of 1997 Demonstration Plots on East Tailing Dike at United Tac

Amendment	1998	2000	2001	2002	2002 comments
SMR	39.2	38.7	42.1	41.9	Very little litter here
SMR*	NA	NA	51.0	58.8	Less litter than other plots, more fescue, less chewed on
Biosolids	46.4	75.3	71.5	71.5	
Biosolids*	NA	NA	90.8	90.0	
Blandin/BS	53.6	85.0	89.9	91.8	
Blandin/BS*	NA	NA	97.4	93.9	2nd and 3rd slopes almost solid brome chewed byoppers
Blandin	66.7	73.7	63.9	35.4/52.3a	
Blandin*	NA	NA	79.8	79.3	This plot looks better than consolidated
Consolidated	24.9	59.7	74.8	65.9	
Consolidated*	NA	NA	58.1	66.6	Russian thistle has colonized some formerly bare spots.
MSW	61.7	89.3	92.8	60.8/81.9a	Grasshopper damage severe. about 40% or more is litter
MSW*	NA	NA	95.1	93.4	Much is litter

*WLSSD biosolids surface applied during Fall 2000. a- these were resurveyed on 8-26 because the initial cover numbers appeared to be anomalous, the resurvey numbers appear more in line with previous estimates and the overall appearance of the slope

NOTE: Treatments in **Bold** meet the three year cover standard.

Table A3.5. Water quality results (average concentration per treatment) of infiltration. United Tac bin study 1997 to 1999

Amendment	Control Plots	MSW Compost	Blandin Paper Mill Residue	Consolidated Paper Mill Residue	Blandin Paper and Biosolids	Biosolids	SMR	Surface Water Standards	Drinking Water Standards
pH	8.45	8.34	8.41	8.37	8.42	8.38	8.39	6.5 to 9.0	6.5 - 8.5 (S)
Alkalinity	320	290	310	360	360	330	340		
Specific Conductance	540	780	610	650	720	620	630		
Major Cations/Anions:									
Calcium	7.1	17.7	9.1	7.7	7.4	15.4	8.6		
Magnesium	85.9	102.7	91.1	84.7	100.7	86.8	85.3		
Potassium	1.3	3.4	1.9	1.2	1.4	1.3	1.7		
Sodium	2.3	14.2	3.0	2.0	2.5	1.7	2.6		
Chloride	2.0	38.7	9.3	6.2	6.2	6.7	5.5	230	250 (S)
Sulfate	55.2	97.6	59.7	41.6	71.1	63.2	51.2		250 (S)
Nutrients:									
Total Kjeldahl N	0.12	1.41	0.72	0.56	0.98	0.58	0.50		
Ammonia-Nitrogen	0.01	0.03	0.02	0.02	0.02	0.01	0.01	0.04	
Nitrate-Nitrogen	1.3	4.3	2.0	1.5	3.6	3.2	2.9		10
Total Phosphorus	0.02	0.04	0.04	0.03	0.04	0.02	0.03		

Table A3.6. Water quality results (average concentration per treatment) of infiltration. pH is standard units and concentrations are in ppm. United Tac 2002 water quality bin study.

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Amendment	Control	Standard Mineland Reclamation	Biosoids (100N)	Biosolids (200 N)	Biosolids (400 N)	Biosolids (200 N) + Paper mill residue	Biosolids (400 N) + Paper mill residue	Surface Water Standards ^A	Drinking Water Standards ^B
pH	8.39	8.32	8.34	8.37	8.28	8.32	8.20	6.5 to 9.0	6.5 - 8.5 (S)
Specific Conductance	610	729	793	810	1155	876	1147		
Calcium	16.0	19.7	21.4	19.0	30.9	23.1	33.2		
Magnesium	84.8	105	106	108	153	114	145		
Chloride	0.55	0.9	6.6	9.9	26.6	16.0	28.9	230	250 (S)
Sulfate	84.4	91.7	134	159	262	194	260		250 (S)
Arsenic	0.002 ^D	0.002 ^D	0.002 ^D	0.002 ^D	0.002 ^D	0.002 ^D	0.003 ^C	0.053	
Copper	0.0025 ^D	0.0025 ^D	0.005 ^C	0.003 ^C	0.0025 ^D	0.007 ^C	0.010 ^C	0.015-0.023	
Zinc	0.010 ^D	0.011 ^D	0.009 ^C	0.010 ^D	0.010 ^D	0.010 ^D	0.014 ^C	0.191-0.343	
Cobalt	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.007	0.016	0.005	
Total Kjeldahl Nitrogen	0.10 ^D	0.19	0.24	0.31	0.60	0.72	1.06		
Nitrate-Nitrogen	1.8	14.5	13.7	17.2	48.5	7.5	10.2		10
Total Phosphorous	0.009	0.017	0.01	0.009	0.01	0.01	0.013		

^A Surface water quality criteria (chronic standard) for 2B waters (aquatic life and recreation, non-drinking water). Standards for the trace metals are a function of water hardness. A range of 200 mg/L to 400 mg/L was used to compute chronic toxicity values for Cd, Cu, Pb, Ni, and Zn. Metals that do not currently have a standard were left blank. Reference: Minnesota Rules, 1999, Chapter 7050.0222, Waters of the State (<http://www.revisor.leg.state.mn.us/arule/7050/0222.htm>).

^B US EPA Office of Ground Water and Drinking Water. Current Drinking Water Standard: National Primary and Secondary (S) Drinking Water Regulation(revised September 11, 1998), <http://www.epa.gov/OGWDW/wot/appa.html>.

^C Half the detection limit was used to calculate the average.

^D Value represents an average of half the detection limit value.

Table A3.6. Water quality results (average concentration per treatment) of infiltration. pH is standard units and concentrations are in ppm. United Tac 2003 water quality bin study.

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Amendment	Control	Standard Mineland Reclamation	Biosoids (100N)	Biosolids (200 N)	Biosolids (400 N)	Biosolids (200 N) + Paper mill residue	Biosolids (400 N) + Paper mill residue	Surface Water Standards ^A	Drinking Water Standards ^B
pH	8.53	8.49	8.46	8.48	8.49	8.50	8.40	6.5 to 9.0	6.5 - 8.5 (S)
Specific Conductance	811	774	863	875	1045	924	1113		
Calcium	11.2	13.8	13.1	12.8	13.1	13.0	17.4		
Magnesium	91.5	92.9	107	100	102	106	110		
Chloride	0.38	0.38	0.38	0.38	0.44	0.69	0.73	230	250 (S)
Sulfate	94.8	102	166	129	155	128	178		250 (S)
Arsenic	0.0017 ^D	0.001 ^D	0.0017 ^D	0.0019 ^D	0.0017 ^C	0.0012 ^D	0.0017 ^C	0.053	
Copper	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.0025 ^D	0.0025 ^D	0.015-0.023	
Zinc	0.006 ^D	5.00 ^C	0.008 ^C	0.008 ^C	0.009 ^C	0.008 ^C	0.009 ^C	0.191-0.343	
Cobalt	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.001 ^D	0.005	
Total Kjeldahl Nitrogen	0.10 ^D	0.15	0.10 ^C	0.15 ^C	0.10 ^D	0.45	0.55		
Nitrate-Nitrogen	3.78	6.5	10.9	12.5	32.1	11.1	19.7		10
Total Phosphorous	0.005 ^D	0.0063 ^C	0.0075 ^C	0.005 ^D	0.005 ^D	0.0075 ^C	0.0075 ^C		

^A Surface water quality criteria (chronic standard) for 2B waters (aquatic life and recreation, non-drinking water). Standards for the trace metals are a function of water hardness. A range of 200 mg/L to 400 mg/L was used to compute chronic toxicity values for Cd, Cu, Pb, Ni, and Zn. Metals that do not currently have a standard were left blank. Reference: Minnesota Rules, 1999, Chapter 7050.0222, Waters of the State (<http://www.revisor.leg.state.mn.us/arule/7050/0222.htm>).

^B US EPA Office of Ground Water and Drinking Water. Current Drinking Water Standard: National Primary and Secondary (S) Drinking Water Regulation(revised September 11, 1998), <http://www.epa.gov/OGWDW/wot/appa.html>.

^C Half the detection limit was used to calculate the average.

^D Value represents an average of half the detection limit values.