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Iron Ore And Taconite Mine Reclamation And Revegetation Practices On The Mesabi Range In Northeastern Minnesota

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Introduction

One of the world's richest deposits of iron ore is located in central North America on the Mesabi, Cuyuna, and Vermilion Iron Ranges in northeastern Minnesota. Iron mining operations began on the Mesabi Range in 1884 where strip mining was the most common method used to gain access to the ore. The open pits mines and spoils banks formed from the removal of overburden to gain access to the ore are still present today. As the rich ore was depleted taconite mining operations began. Taconite mining operations produce 40 million tons of pellets annually by crushing, grinding and magnetically separating the ore from the host rock. The average grade of the ore is 25% magnetic iron, about three-quarters of the material must be disposed of as tailings (Eger, 1998).

Mining, forest products, and recreation and tourism are the principle economic factors determining uses in the region. The reclamation of abandoned open pit mine sites and taconite tailing basins is essential for both environmental and economic reasons. The drastic nature of the land disturbance during mining operations presents major public safety concerns as well as environmental problems resulting from wind and water erosion. Re-contouring and re-vegetation of open pit mines and the re-vegetation of taconite tailing basins are essential for a safe and healthy community. This paper provides an overview of the current methods used in the re-vegetation of abandoned open pit mines and taconite tailing basins on the iron range in northeastern Minnesota.

Site Conditions Prior to Revegetation

Examination of the pre-reclamation condition of the sites, goals and requirements, and substrate characteristics before re-vegetation is essential to provide the framework for successful reintroduction of plant cover. Open pit mines with their spoils banks and taconite tailing basins produced as byproducts in taconite mining present different challenges in successful reclamation projects.

Many of the abandoned open pit mines with vertical walls have filled with water and pose serious hazards to residents in the community. Due to safety concerns for residents in the area and the need to control water erosion, re-contouring of the steep side walls of the pit mines and the spoils banks using heavy earth moving equipment is often required as the first step in the reclamation process. Re-establishing a drainage pattern with the use of terraces with benches and Curlex wood fiber matting on highly erosion prone areas sets the stage for the implementation of the re-vegetation phase.

The spoils banks which are formed during the construction of an open pit mine are composed of the overburden which is removed to expose the iron ore deposits. This overburden is composed

of glacial till, up to 350 feet in depth, deposited during the Wisconsin Period of the Cenozoic Era. This glacial till consisted of three types that vary in texture and pH: a brown sandy till, a red clayey till, and a gray or buff till. The first two are slightly acid in reaction while the last is slightly alkaline to neutral (Leisman, 1957). The low fertility of the spoils banks results from the reverse stratification of the soils as compared to the undisturbed soils in the area. This reverse stratification occurred as topsoil was removed and deposited on adjacent land and the remaining overburden was deposited on top of it, exposing glacial till with extremely low amounts of organic material and plant available nitrogen and phosphorus. Current reclamation laws require the topsoil to be stored separately from the rest of the overburden (Gould, 1996). The infertility of the soils after mining or re-contouring is the dominant factor affecting the successful re-vegetation of the mine site.

Today there are 28,000 acres of taconite basins in Minnesota and as mining progresses, the basin area continues to increase. There are two methods of disposal of taconite tailings that substantially influence the physical properties of the basin. Tailings may be separated into coarse and fine particle sizes or remain as an unseparated composite. When the tailings are not separated, they form a stratified soil texture in the tailing basin of sandy to fine gravel at the point of discharge to silt at the lowest elevation from the point of discharge. The interlacing of the composite layers can inhibit root penetration and nutrient movement. In operations that separate the coarse and fine tailings, the coarse tailings are used to construct dams around the basins into which the fine tailings are pumped. This produces substrates that are nearly homogenous in size (Dewar, 1989). Analyses of the tailing material shows it to be alkaline, low in organic material, cation exchange capacity, and soluble salts, as well as in the concentration of plant available nitrogen and phosphorus (Dewar, 1989). Low fertility is the major obstacle in the re-vegetation of taconite tailing basins. Organic and inorganic amendments are required to produce sustainable vegetative cover.

Revegetation Goals and Requirements

While end uses envisioned for reclamation sites vary, the principle reasons for reclamation are: erosion control, safety, and the improvement of water and air quality in the area. In 1980, Minnesota enacted legislation that required mine operators to permanently reclaim sites as they are completed. These rules are administered by the Department of Natural Resources, Division of Minerals. Areas that have been permanently reclaimed are required to have a 90% ground cover consisting of living vegetation and its litter within three growing seasons after its initial establishment. Within ten years, reclaimed areas must contain vegetation which is self-sustaining, regenerating or at a stage in a recognized vegetation succession which provides wildlife habitat or other land uses such as pasture or timberland (Dewar 1989). The Iron Range Resources and Rehabilitation Board (IRRRB) was given the authority to reclaim abandoned minelands in 1978 and is funded by the Taconite Area Environmental Protection Fund. Six areas of concern are addressed by the IRRRB: safety, water pollution, erosion, air pollution, lack of vegetation, and aesthetics.

Substrate Characteristics

Identification of the stressors that will inhibit the reintroduction of plant cover is the phase to be completed before re-vegetation is attempted. The relief of the spoils banks varies greatly depending on the method of soil deposition (trains, trucks, or conveyor belts). Spoils banks reach heights of 150 feet with steep slopes that produce harsh environments for the re-establishment of vegetative cover and increase the incidents of soil erosion by water and wind. The glacial till soils exposed by the formation of spoils banks or during the re-contouring process are devoid of organic matter, plant available nitrogen and phosphorus, and microbial life forms. These conditions have a detrimental effect growth of establishing vegetation.

Taconite tailings basins are almost devoid of organic matter, plant available nitrogen and phosphorus, and microbial life forms, which makes re-vegetation very difficult. Physical limitations on the coarse fractions of taconite tailings include structureless substrate, low water holding capacity, compaction, and were prone to crusting (Hossner, 1992). Tailing basins where higher levels of fine materials were deposited have better water retention characteristics but experience rooting problems due to the layering of fine materials over layers of sand and gravel. The lack of water holding capacity was most pronounced in the coarse tailing substrate. Even in years of ample precipitation, drought-like conditions appeared on the dams constructed from coarse taconite tailings because of the substrates inability to retain moisture.

Spoils banks and taconite tailings exhibit similar chemical characteristics. Taconite tailings are alkaline, non-toxic and extremely infertile (Hossner, 1992). An analysis of the raw materials (Table 1) shows that both coarse and fine tailings are alkaline and low in organic matter, soluble salts, cation exchange capacity, nitrogen, phosphorous, and zinc (Dewar, 1989). All other nutrients are available in sufficient quantities for plant growth.

Table 1. Chemical analysis of some coarse and fine tailing. (Dewar, 1989)

Tailings	pH	Organic Matter	Soluble salts	CEC	NO_3-N	P	Zn
		%	mmhos/cm	meg/100g	lb/ac	lb/ac	ppm
Coarse	8.0	0.7	0.3	6.0	25	18	0.1
Fine	8.1	0.4	0.3	6.7	14	11	0.2

Re-vegetation

Efforts to reestablish sustainable vegetative cover on abandoned open pit mine and taconite tailing basin sites in accordance with current state laws is facilitated by a comprehensive analysis the stressors that affect plant growth and development. The addition of organic and nutrient amendments is required to successfully re-establish vegetative cover because of the drastic nature of the soil disturbance prior to and during re-contouring. The IRRRB uses a hay slurry (a mixture of ground up hay and water) in their hydro-seeding operation. Mixed in with the hay

slurry is the seed mix consisting of *Trifolium pratense* (red clover), *Trifolium repens* (white clover), *Trifolium hybridum* (Alsike clover), *Phleum pratense* (Climax timothy), and *Festuca arundinacea* (Tall Fescue). A standard fertilizer (i.e.18-46-0) is also applied during the hydro-seeding application.

In addition to planting grasses, the IRRRB is reforesting their reclamation sites. The IRRRB has two growth chambers from which it produces 300,000 seedlings per year. These growth chambers allow for total control of the seedling's environment and produce superior seedlings in containerized blocks when compared to bare root seedlings. Providing twenty-four hour light under optimal temperature and humidity conditions reduces the time required to produce seedlings for planting. The two growth chambers allow for the production of two dissimilar crops requiring different temperatures, light, and moisture needs. The primary species produced are *Pinus banksiana*, *Pinus resinosa*, and *Picea glauca*, however a total of 44 different species have been grown in the chambers.

According to Gibson, the principle sources of seed rain in natural re-vegetation of abandoned minelands are wind and birds (Gibson 1982). It appears that reclamation efforts in northeastern Minnesota rely mainly on wind as the principle sources for natural re-vegetation because of the species selected during the initial seeding of the sites. There does not appear to be an attempt to plant fruit producing plant species that would attract a variety of wildlife.

The re-vegetation of taconite tailings, especially the coarse fractions, requires more attention in the areas of organic and nutrient amendments. Typical cover on coarse tailings after 5 years has ranged from 40% to 60%. Companies often have to reapply fertilizer and seed but despite these efforts, less than 10% of the coarse tailing areas have been able to meet the standard of 90% cover in three years and self-sustaining in ten years. In the early 1990's a cooperative research program was begun between the United States Bureau of Mines and several mining companies, United States Steel (USX), Eveleth Mining (EVTAC), and National Steel Pellet Company (National), to examine the use of organic amendments to improve re-vegetation on coarse tailings in Minnesota. The organic amendments included: peat, yards waste compost, municipal solid waste, and waste from paper mills. All of the amendments were alkaline (pH 7.3 to 8.1) with the exception of the peat which was acidic (pH 5.3) and had C:N ratios of 9:1 to 36:1. The paper waste had much higher C:N ratios of 69:1 to 196:1. All sites in the research project were low in organic material, nitrogen, phosphorus, and water holding capacity. All of the composts meet the Minnesota Pollution Control Agency standards and can be spread without restrictions (Eger, 1998).

This cooperative research program was designed to determine the best and most economical rates of application of different organic amendments and fertilizer concentrations to meet the requirements of the reclamation laws. Standard farm and reclamation equipment was used in the application of the amendments and fertilizer except on 3:1 slopes where a Knight side slinger was used. Cool season grass mixtures were applied at a rate of 50 lbs/acre of pure live seed (PLS). Although the mixes varied slightly, they consisted of species such as brome, alfalfa, sweet clover and timothy.

The result of this cooperative research program confirms that as little as 10 to 22.4 mt/ha of organic material were sufficient to successfully re-establish vegetation on the coarse taconite tailings and meet the reclamation requirements after five years. It also demonstrated that some of the organic amendments applied at higher rates could meet the requirements in three years. Most of the amendments do not have the nutrients necessary for plant growth. Therefore, the addition of fertilizers is also required to meet the reclamation requirements. The main role of the organic amendments is to increase the water holding capacity of the substrate. Organic amendments conserve moisture as well as moderate soil temperatures, reduce erosion, and improve soil properties. Water holding capacity of unamended coarse tailings is about 4.5%, less than 20% of the value for fine tailings. In most instances, 90% cover on fine tailings can be accomplished in three years by using fertilizer alone because of the increased moisture holding capacity of fine taconite tailings.

The addition of organic amendments will increase the cost of site reclamation by approximately $1000/ha when applied at a rate of 44.8mt/ha. Lowering the amount of organic amendments applied per acre can reduce project cost. Also, when compared to the cost of reapplication of seed and fertilizer, the use of organic amendments is a cost affective procedure that meets reclamation law requirements within 5 years.

Evaluation

The primary goal in the reclamation of minelands in northeastern Minnesota is the rapid stabilization of the site with vegetative cover to reduce erosion and eliminate safety concerns. Secondary succession of plants and the maturation of the ecosystem do not appear to be a major concern for the reclamation of minelands in northeastern Minnesota.

The major factors affecting the successful establishment of vegetative cover on minelands are nutrient deficiencies, primarily nitrogen and phosphorus, and moisture retention. These plant growth inhibitors can be amended by the use of organic matter and fertilizer amendments. The amount of amendments applied has a direct effect upon the time required to achieve the desired results. Coarse taconite tailings require a minimum of 10 mt/ha of organic matter and fertilizer if they are going to be able to meet reclamation requirements and sustain vegetative cover.

The Judson Mine in Buhl was the first pit to be totally reclaimed. Reclamation proceeded in phases over several years, being completed in 1990. A survey of the site in October of 1999 revealed successful re-establishment of vegetative cover. There was evidence of secondary succession illustrated by the invasions of populations of *Populus sp.*, *Betula sp.*, and *Aster sp.* on the uplands and *Typha sp.* along the water's edge. The lake formed by the pit has become a designated trout lake and a popular place to scuba dive. Evidence that the erosion control practices were effective was illustrated by no changes in water clarity after heavy rains during spring and summer, 1999.

Summary

The reestablishment of self-sustaining vegetative cover can be accomplished by using organic and inorganic nutrient amendments. The requirements set forth in the Minnesota legislative act

can be attained, but the plant community lacks in diversity and resemblance to the undisturbed native community in the surrounding landscape. The inclusion of plant species that attract a diverse bird population would increase the potential of seed dispersion from the surrounding area. Also, stimulating the growth and abundance of microbial life forms would enhance the substrates ability to breakdown plant litter and supply plants with essential nutrients. Emphasis on an ecosystem basis should be part of the long term goals in mineland reclamation as well as the short term goals of rapid establishment of vegetative cover.

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