DEVELOPMENTS PAST, PRESENT AND FUTURE OF LANDS STRESSED BY THE MINING INDUSTRY.

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ABSTRACT

A review of the relative impact of the four basic wealth creating industries and their impact on the environment and ecosystems.

This paper presents a review of the author's involvement in the reclamation of land stressed by the mining industry for the past 50+ years in various parts of Canada and to a lesser extent in other countries. The problems associated with the processing of ores in the more settled and populated regions of the country as well as in the more remote mining sites are discussed.

Current procedures and problems are touched on, as well as, a forecast of possible future developments in this field.

Introduction

It is difficult to realize while attending this Conference in the comparative luxury of this urban surrounding, that the wealth which permits this, is founded on four basic industries. The four are agriculture, the fishery, forestry and mining. The first three, agriculture, fishery and forestry are renewable resources. The fourth, mining, is a finite resource, although recycling of previously extracted minerals is a factor in meeting the ever increasing demand for these basic elements.

Although we can not create the products of the basic industries, we can increase their value by applying our time and labour to them.

Over the centuries and even currently man's mismanagement of the three renewable resources is evident to even the casual observer. Until this past century, what appeared to be unlimited new land or untapped resources were endless and were there to be exploited. We do not have to go far to see the folly of accepting these premises as they can readily be found in Canada. In agriculture, the continuance of practices causing the salination of our surface prairie soils or the ever increasing urban sprawl are but two examples of this folly. In the fishery, the depletion of the Atlantic cod stocks are equally matched in the forestry practices of the past 100 years of cutting and moving on without, until very recently, any replacement planting. This has reduced the amount of readily accessible sizeable timber to almost nil. In the case of of these renewable resources, we, as people tend to blame our predecessors, the changing climate, or the government for past mismanagement.

However, the mining industry, which adversely impacts on a much smaller, almost infinitismal, portion of the earth's surface compared to the other three, does not have that advantage. During the past 50 years, various levels of government through their regulatory processes have required mining companies to remove almost all traces of their activivites on a site. In addition, the disturbed area must be returned to a condition which will not adversely impact on the local environment in the future. This requires the establishment of an ecosystem on the site which is comparable to the one that existed prior to any mining activity on the site.

The purpose of this paper is to examine what has happenned during the past 50 years, the base conditions from which we started, some of our successes and failures, current trends, and to take a look at the future, with particular reference to sulphide ores and the Sudbury, Ontario, mining area.

Discussion

The Past

The change from the roast yard smelting of sulphide ore, where the picked over ore was placed on cordwood piles and burned to eliminate the contained sulphur, took place at Inco in 1930. The introduction of the Herreschoff Roasters required a finely ground metal concentrate as feed. To obtain this quality of feed, it was necessary to grind the ore and extract a concentrate by a selective flotation process. The non metal bearing material (mill tailings) settles to the bottom of flotation cells and is pumped as a slurry to large holding areas known as tailings ponds.

Production at most Canadian mines during the 1930's was low. The tailings were usually deposited close to the mill in a small valley or in the case of gold mines, they were often deposited in lakes or ponds. However, the Canadian mines responded to the Allies call for minerals in World War II with greatly increased production. The Sudbury area mines supplied over 80% of the nickel required for the Allies' armament needs in ships, tanks, guns, aircraft, etc. By the end of the War, the tailings area at Copper Cliff, as in many other mining areas, had reached or surpassed the height of the surrounding hills. This height exposed the surface of the tailings to the prevailing winds and, under certain weather conditions, the small waste rock particles became airborne. This dust was a nuisance to the local residents and also affected adjacent industrial operations.

The mining companies soon realized that something had to be done and began experimenting with the use of snow fencing to minimize surface wind velocity, capping with bituminous sprays, limestone chip covers, etc, with little or no success.

My introduction to the problem began as a student employee in Inco Limited's Agricultural Department in the summer of 1947. I was assigned the task of planting some Twitch Grass (Agropyron repens) roots and rhizomes in a small test plot in the CD area. This test was unsuccesful. Thus, I became involved in a 50 plus years search for an economically viable self sustaining procedure and material to stabilize tailings areas. The path of this reclamation/restoration program was to have many twists and turns as we were soon to discover.

As experience was gained from year to year, a list of practical procedural steps was developed. Although these procedural steps are now considered to be more or less site specific, their continual review and refining produced the following basic principles which are applicable to developing revegetation programs for any site (Peters,1995):

"1. Establishment of initial plant communities using available species that are tolerant of factors characteristic of the tailings. These factors include drought, low pH, poor soil texture, and the lack of organic materials and nutrients.
2. Modification of the local microclimate to benefit plant establishment.
3. Establishment of soil invertebrate and microbial communities. These assist in the soil building process and decompose naturally accumulating organic matter.
4. Establishment of nutrient cycles.
5. Establishment of a rich diverse plant community that can support wildlife and other natural assets."

The foregoing principles were, and are, much easier to successfully apply to non sulphide ore tailings such as the high silica tailings of the gold mines or the tailings of some of the copper or iron ores in which limestone is disseminated.

In the late 1970's, as answers to the problems of establishing a vegetative cover on tailings to control dust were being resolved, the downstream environmental problems associated with effluent seepage from sulphide tailings were becoming apparent. The mining industry recognized the need to find and implement a solution to this problem. This seepage became known as Acid Mine Drainage (AMD) or as Acid Rock Drainage (ARD). The continuous oxidation of the waste sulphides in the tailings or the piles of waste development rock was the initiating cause of the problem. Sulphides in the presence of atmospheric oxygen, some moisture, aided and abetted by various sub-species of the bacteria, Thiobacillus ferroxidans, progress through a complex series of chemical reactions which result in the generation of sulphuric acid.

This generated sulphuric acid, as it enters the interstitial soil solution, significantly lowers the pH of the seepage water thus allowing the heavy metals, copper, zinc, nickel, iron, etc., to come into solution. This solution became effluent as it seeped through the base of the dams or from the base of the waste rock piles. The elevated metal content of this seepage had a pronounced adverse effect on the indigeneous flora and fauna as it entered natural water courses.

During the latter part of the 1970's, two committees were formed to seek solutions to this problem. These were the National Uranium Tailings Study (NUTS) and the Reactive Tailings Study (RATS). They were composed of members from the federal Department of Energy, Mines and Resources and various mining companies. Both groups carried out some jointly funded research and met periodically to discuss results as they strove to solve the problem.

These two programs were replaced in the mid 1980's by the Mine Effluent Neutral Drainage (MEND) Program. Under this program experimental research projects, which were jointly funded by the federal government and individual mining companies, were undertaken. Although the program was centred on the theme of eliminating acid mine drainage, the individual research project was usually related to a particular problem at the site of the participating mining company. Immediate solutions based on engineering principles was the objective of most of the research work under this program. The information derived from the various research projects was freely exchanged.

In addition to the tailings related environmental problems, the mining industry was involved in finding solutions to problems caused by smelter, mine and other milling discharges and their impact on downstream air, water and soils.

Present

Today, as we look into the whole field of the restoration of land, water and air which has been stressed by the mining industry, we find that some solutions have been found but that we are still faced with challenges of related problems to be solved.

In the field of smelter emissions, the technical improvenments in the smelting processes has considerably reduced both the gaseous and particulate emissiions. Similarly, the required technology to treat process effluent water to meet the exacting government standards prior to its discharge to a natural water course is available. Waste rock piles will ultimately be deposited in abandoned mine shafts or open pits with any surplus rock being covered with overburden and vegetation. It still has to be borne in mind that there is a historic legacy of these problems, remaining at the many sites of past mining activities, which still have to be rectified.

The knowledge gained from the tailings research initiated under the MEND program of placing sulphide tailings under water has provided us with an alternative reclamation/restoration method. Mining companies can now make a choice of whether to use a vegetative or water cover. The choice which they make will have to provide a long term economically viable self sustaining solution. This is particularly true in remotre areas where the land will undoubtedly eventually revert to the Crown. In the short term, providing and maintaining a sufficient depth of water cover and maintaining the integrity of the tailing dams and the overflow effluent water discharge points will be the work of the engineer. However, in the natural cycle of events, various species of flora and fauna will voluntarily invade the site and proceed to develop a site specific ecosystem. The managemnent and manipulation of the factors to accelerate the development desired components in this ecosystem requires the input of knowledgeable life scientists.

This new development of the use of water for a tailings cover has greatly increased the number of factors which must be considered in order to make the final decision of the procedure to be followed for a particular site. Although the addition and acceptance of the use of a water cover may be considered by some as a complication, it has certainly made the work of the present day reclamationist more interesting and challenging. There are now at least three basic types of cover which may be used, either singly or in combination. A knowledge of the basic characteristics of three covers, dry. vegetative and water is essential to making the correct selection of the one to be used at a particular site.

Dry or hard covers are an engineered covers which are designed to prevent, usually through the use of multiple layers, the infiltration of moisture or the surface growth of vegetation. In some countries where climatic conditions permit, they are used to cover uranium tailings. They are not too practical in Canada where moisture delivered by the annual precipitation usually exceeds the moisture lost by evapotranspiration at most sites. They are usually expensive to construct and to maintain.

The use of vegetative covers on tailings was initiated originally as a form of dust control on areas which had reached their final elevation. The first attempts were made using common agricultural practices to prepare and nutritionally ameliorate a seed bed 10 - 15 cm. deep. On sulphide tailings, vegetation establishment varied from site to site and from complete failure to reasonable success. Some sites require a layer of topsoil or clay of a sufficient depth to prvide an adequate seed bed. In certain areas, the outside tailings dam slopes with a south or south-westerly exposure require a 15 - 30 cm layer of clay to provide an adequate moisture retaining layer for plant growth. Costs will vary depending on the amelioration requirement of each site. As there is the potential for the introduction of undesirable elements into the food chain, an adequate monitoring program must be kept in place to assess this possibility. Although a transitional period is necessary to pass from the initial grass and legume cover, the final cover should be as close to and as diverse as the indigenous cover on the adjoining natural land. In the long term, the development of a self sustaining low maintenance cost oxygen barrier of decaying organic matter is the principle for using a vegetative cover. The plants ability to stablize the tailings surface and to intercept precipitation by providing suraces for evaporation plus the water transpired by the growing plants reduces the water infiltration into the tailings with the consequent reduction in seepage.

Water covers, as stated previously, form an immediate oxygen barrier over the tailings and in the case of uranium tailings, eliminate the escape of radon and other members of the radionuclide group. Physically water has many of the characteristics that are sought in an engineered cover (Kirkwood, 1996). Water is flexible, can deform and remain intact. This is essential under the wide range and fluctuations experienced in the climate of northern Canada. Aestheically, a water cover does not seem out of place in northern mining areas where wetlands, ponds and lakes are integral features of the landscape. Provisions must be made to monitor and maintain the dams and related structures for the years to come. Arrangements to remove excess water during flooding conditions and supplementing the supply of water during drought conditions must be included in the plan of operation. The cost per acre to establish and maintain a water cover is, similar to a vegetative cover, high. Conversion of established tailings area to a water covered one, can be costly. It often involves new dam construction, recontouring the tailings surface, moving tailings to specific areas and the construction of new effluent discharge and treatment facilities. An insight into these costs can be gleaned from a review of the Dennison Mines Ltd. and Rio Algom Mines Ltd. Environmental Impact Statements for the closing out of their waste management areas at Elliot Lake, Ontario. On the other hand, costs can be more reasonable if the plan to use a water cover is an integral part of the planning of a new operation.

Before considering the future, I would be remiss if I did not mention the success achieved of the Greening of Sudbury Program in the restoration of the land stressed by smelter emissions. The Regional Municipality of Sudbury, under the Chairmanship of the late Tom Davies, establihed the Vegetation Enhancement Technical Advisory Committee in the early 1970's. Representatives from various government ministries, local colleges, Laurentian University, the local mining and other companies, local organizations along with some interested citizens make up the Committee. The necessary administration duties are handled by the Region's Planning Department. Under its aegis, some 3,000 + hectares have been treated with over 3 million trees planted. In addition the Committee has worked with different groups to solve the problems associated with the revegetation of this stressed land. Ideas have freely discussed over the years and an overall will to get the job done prevails on this Committee.

Among the many successes in the Program, there are two which stand out in my opinion. Although both were anticipated in the long term, their early and rapid development was unexpected. The first was the rapid and successful invasion of locally indigenous species of trees. Paper birches (Betula papyrifera) and trembling aspen (Populus tremuloides)voluntarily invaded the area in large numbers once the seed bed had been nutritionally ameliorated and persisted where the soil surface had been stabilized by the seeded grasses and legumes. The other was the rapid improvement in the water quality and ph of the lakes whose surrounding slopes and shores had been revegetated and planted with trees.

Graduate and undergraduate students from many universities have undertaken research in their varied disciplines on the many problems encountered in the land restoration work in the Sudbury - Elliot Lake areas. Both VETAC and the mining companies have benefitted from their work.

The Future

As I look into the future, I am impressed with the speed of transition with which the knowledge gained from research projects is integrated into practical field applications. The review of past practices have led to their modification and in some cases, the discovery of unpredicted benefits. The unforeseen and and not anticipated benefit of the water retention capability of the clay spread as a cover of the southerly oriented outside slopes of the tailings dams at Copper Cliff is but one example. The clay was originally installed to provide an adequate moisture reserve for seedling establishment has doubled as a partial oxygen barrier reducing the oxidation rate of the tailings underneath and the subsequent acid generation.

The threshold from research to field application of the use of large scale water covers has just been crossed. The knowledge and experience to be gained, particularly from the Mineral Waste Management Areas at Elliot Lake, has many facets from which we can learn as they unfold in future years. Preliminary reports (Payne and Ludgate, 1998) indicate that the improvement in the surface effluent water discharge from these areas is meeting or exceeding expectations. Research continues on the selection and methods of establishment of aquatic vegetation. There has been a slow but steady invasion of aquatic plants which indicates that these ponds will eventually in time develop a vegetative complex similar to the natural ponds and lakes in the surrounding area.

It is not practicable or economically justifiable to place many existing tailings areas under water. In the case of non-sulphide ores, acid generastion is not a problem. Many of the historic abandoned sites are in remote areas where the former access roads have become overgrown or eroded, thus the cost of establishing access for regular routine inspections and maintence in these cases is usually not acceptable. The use of a vegetative cover remains a realistic solution for these sites.

In order for a vegetative cover to be considered a success, it must be self sustaining with the capability, when covering sulphide wastes, to build up and maintain a sufficient depth of organic matter to form a continuous oxygen barrier. This ability, along with climatic and geographic factors, is of prime concern when selecting the plant species which are to be used in the cover. Throughout the Laurentian Shield, conifers are accepted as the climax vegetative cover. However, in its evolution this coniferous forest was preceded by a transition period when deciduous species formed the dominant portion of the cover. The vast amounts of leaf detritus from their annual shedding was the major source of the organic material which facilitated the early soil formation in the area. The inclusion of more deciduous tree and shrub species in our reclamation programs is, in my opinion, a practice which should be implemented. This will also assist in the development of a more biologically diverse ecosystem at each site. In order to recycle the nutrients in this increased abundance of organic matter, attention will have to be given to developing methods to naturally increase the amount and availability of nitrogen present to the level required by the increased activity of the decomposition. The sooner our management practices reflect the acceptance of this need, the sooner our objective of a self-sustaining maintenance free system will be achieved.

It is worthy to note that Inco Limited has foreseen this need, and although it has successfully revegetated its inactive tailings areas, has undertaken a joint research progeram with Laurentian University to determine the quantity and diversity of the flora and fauna present in the Copper Cliff Tailings Area (Bagatto, Shorthouse, Beckett, Winterhalder, 1998). The information gained will be utilized in developing future management programs.

There are even more interesting challenges to be considered in the slightly more distant future. Due to the rapidly increasing world population and the corresponding acceleration in the need for food and fibre, there is a possibilty that our industrially stressed areas could be used to meet some of this need.

For many years, the "spoils" from the tin mining operations in South East Asia have been reclaimed as cattle pasture or used as rice paddies (Kitching, 1978). Various governments in that part of the world have investigated the potential for production of various agricultural crops for home consumption or for revenue producing export. Shrimp have been produced in some mine waste ponds. In this densely populated part of the world there is a great need of protein. As we progress, the possibility of using reclaimed/restored land or ponds for meat and fish production must be further pursued.

In the Philippines, consideration has been given growing certain leguminous trees andd shrubs to stabilize tailings areas. The leaves and twigs of these tree can be used as cattle fodder while the larger branches and trunks can be utilized for firewood or manufactured into charcoal for cooking (Kitching, 1978). Both beef and dairy cattle are pastured on reclaimed land which had been previously disturbed in the production of aluminum.

Closer to home in the Kamloops area of British Columbia, the use of vigorous stands of alfalfa (Medicago sativa) forming the vegetative cover on extensive acreages of copper tailings is is being investigated for its potential of providing additional acreages of high quality pasture for local ranchers (Jones, 1996, Gardner et al, 1996). The current relaxation of the federal regulations on the growing of industrial hemp (Cannabis sativa) for fibre, has brought forth inquiries from some entrepreneurs to consultants about the use of tailings areas as producing fields.

Maybe the mining industry will become a small but important source of food and fibre in the future. When we consider that the amount of arable food producing land per person on this globe has fallen from 3/4' of an acre to 1/2 of an acre in the last 25 years, the need to consider and implement this end use is glaringly evident.

In closing, I would remind all who are or who will become engaged in land restoration of industrially stressed sites to remember the following words "Adapt, not Adopt" the practices followed and observed at other sites to the conditions with which you are facing on your current job site. I would also remind everyone to consider and remember the motto of the British Columbia Mining Association "If it can't be grown, its got to be mined".

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September 27th – 30th, 1998
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