RESEARCH ON TAILINGS IN BRITISH COLUMBIA

U.B.C. EXPERIENCE

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ABSTRACT

For the past several years the Department of Soil Science at the University of British Columbia has been involved in research related to vegetation of mine wastes. The general objective of the research program has been to characterize mine wastes, especially tailings, by physical, chemical, mineralogical and biological properties. In this manner, the research has been oriented towards understanding the inherent properties of mine wastes so that the materials may be transformed to a "soil" that will not only maintain vegetation but also sustain it, without the necessity of continuous management. During 1976-77 the Department of Soil Science, under the auspices of the British Columbia Department of Mines and Petroleum Resources has intensified its research on tailings. This research activity has been oriented towards a better understanding of the various types of tailings, their elemental composition, the elements they release upon weathering, growth limiting factors and vegetative success. The ultimate aim is to develop guidelines for the establishment of vegetation in the various biophysical regions of the province. It was also hoped that the mining industry would become involved in collecting the data, both environmental and laboratory, in order for them to develop their own expertise as well as help plan future reclamation programs. This integration of government, university and private sector has much to offer in terms of efficiency of utilization of resources, training and obtaining a base-line upon which British Columbia reclamation programs can be patterned.
INTRODUCTION

The establishment of a vegetative cover that will sustain itself is one of the major concerns in reclamation of mine spoil. For many years vegetation establishment was carried out by what may be termed agronomic techniques, namely seeding, fertilizing and irrigating mine wastes. This process has been of some success, especially when applied to overburden and rock dumps and in some instances mine tailings. However, too frequently what appeared as a success in establishing a vegetative cover was a failure a few years later, unless management — fertilizers, irrigation and sometimes re-seeding — was continued. In the short run, this type of reclamation appeared sound. In the long run, however, the industry and government began to seriously question such things as: How long must management be applied to a mine waste area before it is reclaimed? In what state of vegetative cover should an area be left before it can be said to be reclaimed? What about the other values of a region in relation to the reclamation program?

To answer some of these questions it was believed that some research was necessary. Like other reclamation projects, mine spoil, especially tailings, offers a real challenge. Tailings and, to a lesser extent rock dumps, are not at equilibrium with their surroundings. Tailings materials were formed geologically at high temperatures and pressures within the earth. Tailings materials have been affected by man's activities of blasting, grinding, chemical extraction and deposition into a new environment of low temperature and pressure. The minerals composing the tailings are no longer stable and they begin to change, or weather, to form new compounds that are more in equilibrium in this new environment. During this weathering process, tailings, and other mine wastes, are changed chemically, physically, mineralogically and biologically. This changing process is usually slow to start, gains momentum for several years and then begins to slow down, just like natural soil forming processes.
Our goal in the Department of Soil Science at the University of British Columbia has been to study mine wastes in a manner that will allow an understanding of the soil forming processes. It is only through an understanding of the soil forming processes that one will be able to predict what the material will be like in the future, what chemical, physical, mineralogical and biological changes will take place and what the effects of these changes will be on the material. If the establishment of a self-sustaining vegetative cover is the object of reclamation, then it is obvious the kind of vegetative species used, the management practices employed and the chemical quality of the vegetative cover must be tied to the soil material that is forming. Tied to this overall objective, the Department of Soil Science has also been conducting more immediately applicable research programs to bridge the time gap before soil forming processes in mine spoil are better understood. For example, evaluation of chemical analysis to assess fertilizer requirements. Many methods developed by agronomists for agricultural crops are not directly applicable to mine wastes, because the mine wastes are not really soil. Other studies have resolved around assessments of limiting nutrients for vegetative establishment, namely growth chamber and greenhouse studies and evaluation of moisture retention and release from tailings and rock dump materials.

For two years, the Department of Soil Science, co-operated with the Government of Canada, Department of Energy, Mines and Resources, in studies of mine wastes in British Columbia. The aim of the program was to characterize mine wastes in Canada in the context of developing some guidelines for reclamation by vegetation. Under this program nine mines were visited and characterized by physical, chemical and mineralogical analyses. The mines studied were all grouped as sulfide mines. The results of the Canadian program are in draft and should be available to us by the end of March 1977 for review. The program outlined above was a broad general over-view of the situation in Canada. Although, hopefully
of benefit, it will not meet all the needs of the mining industry in a complex biophysical province as British Columbia.

RESEARCH PROGRAM 1976-77

The research program initiated in 1976-77 with funding from the British Columbia Ministry of Mines, was an extension and intensification of our previous two years of work. In consultation with the Technical and Research Committee, a program was begun to look more specifically at mine tailings in British Columbia from a wide variety of biophysical environments. Ten mining sites were chosen, namely Bethlehem, Lornex, Sullivan, Endako, Kaiser, Similkameen, H.B., Emerald, Gibraltar and Brenda. It was hoped that the respective mines would co-operate in the research program. One of the goals was to help the mining industry to develop their own data base and expertise in relation to reclamation. To be candid, co-operation ranged from bare acceptance to enthusiastic support. One of the main problems faced was that most of the tailings disposal areas were still active. It was difficult to convince some that, although the disposal area was active, sometime in the future a similar surface would have to be reclaimed. Thus the sooner one obtained data on the tailings material the better the understanding would be when reclamation was attempted. We were interested in providing some coordination in relation to tailings reclamation and to carry out our objective of understanding soil formation as it is the resultant soil which will have to sustain the vegetative cover.

METHODS

The team from the University visited each mine site and examined the tailings disposal system. Transects were established whenever possible and tailings were examined for their vertical and horizontal variation. Contrary to common belief, tailings ponds are not uniform in their properties,

Samples of tailings were collected and returned to the laboratory for analyses. Vegetation surrounding the tailings ponds on tailings materials
were documented and in some cases sampled for chemical analysis. In the laboratory chemical, physical, mineralogical and biological studies were conducted. Each mine was asked to conduct some routine data collection on climate, water quality and tailings characteristics. It is hoped that once this data is collected guidelines for vegetation establishment may be developed that would better suit the particular biophysical environment in which the mine is located.

RESULTS AND DISCUSSION

In the field, tailings were characterized as to their particle size (texture), layering and colour to a depth of about one metre. Texture is important as it is one of the most significant parameters that affects erodability of the material by both wind and water, as well as controlling the available water storage capacity of the tailings material. Layering in a tailings pond of different particle size class materials is important in understanding water and air movement. The movement of water and air in materials is critical to vegetative growth. Every time there is a layer of contrasting particle size, there is a reduction in the rate of water and air movement in the material. This in turn affects the oxidation-reduction potential of the media with concomitant effects on the solubility of some of the elements and changes in mineralogy. The aspect of layering and the position of the water table are both critical parameters to measure in order to understand, and possibly control, this oxidative weathering. As stated earlier, mine tailings originally were formed under high temperature and pressure and under reducing conditions. When exposed to the earth's atmosphere the minerals change due to the oxidizing conditions and the lower temperatures and pressures. A notable example of this phenomenon is the oxidation of mine spoil containing pyrites to sulfates with changes in pH values of 6 to as low as 1.5. High water tables tend to keep the media in a reduced state and thus pH changes may not be so drastic. However, many elements are more soluble under reducing conditions and may,
therefore, go into solution and be taken up by plants in excess amounts, (e.g. Mo) or move from the tailings pond into the surrounding water bodies with potential deleterious environmental effects. Colour of the tailings material is important as colour affects heat absorption which controls the rates of chemical reactions. In general, colour has not by itself been found, in our studies, to be a limiting factor with the exception of very black colours associated with coal mining. Most tailings materials are sand sized and thus prone to wind and water erosion, this is because of the low surface area sand sized particles possess.

In the laboratory, tailings samples were subjected to chemical, physical, mineralogical and biological analyses. The chemical analyses included pH, cation exchange capacity, exchangeable cations, total elemental analysis and available nutrients. These procedures were conducted to assess the "fertility" of the tailings materials. For example most plant nutrients are in the available form in the pH range 5.5 to 6.5. Cation exchange capacity is a measure of the holding ability of materials for positively charged chemical elements and exchangeable cations gives a measure of the positively charged elements that are actually being retained by the material. As an example in our studies in 1976-77 pH ranged from 8 or 8.5 to a low of pH. Cation exchange capacity ranged from less than one me/100 g to about 18 me/100 g. Cation exchange capacity tended to increase as pH increased. Exchangeable cations are generally low, with calcium being dominant.

Total elemental analysis is an essential parameter to determine as this gives an idea about the elements that are present in the tailings materials and thus aids in making predictions, about amendments and potential toxicities that may exist. These were related to the weathering and fertility studies that were conducted. The measurement of available plant nutrients was carried out to assess the inherent nutrient content of the tailings that plants may be able to extract. This included total nitrogen; available phosphorus, calcium, magnesium and potassium. In general, nitrogen is limiting in tailings materials as is phosphorus. The main reason is the
general lack of organic matter. Any method that would increase the organic matter content of tailings would be beneficial as it not only improves absorption of nutrients but also increases water retention and decreases the susceptibility to erosion.

Physical analyses included particle size distribution, bulk density, particle density and available water storage capacity. These parameters are important in order to assess porosity, erosion susceptibility and water supplying power. Obviously if plants are to be established it is essential to know the kind of support medium that is present. In general, the most severe factors in relation to plant growth were found to be the coarse texture of the tailings and their very low water storage capacity. Only in a few cases was bulk density (low porosity) found to be a problem.

Mineralogical analyses was conducted by means of a X-ray diffractometer. The kinds of minerals present, along with their chemical composition allows prediction of what changes will occur over time, as well as, gives indications of immediate problems. In an attempt to estimate what changes would take place artificial weathering studies were conducted. These included shaking the tailings with various solutions and using the soxhlet apparatus. It was surprising to learn that some tailings materials were not affected adversely by weathering and will probably not cause severe problems as they naturally weather. On the other hand, some tailings materials liberated high amounts of heavy metals and changed their pH dramatically. This, of course, is important to know when considering long term reclamation programs. Once again the studies have shown that tailings materials are quite different in their properties.

Another aspect of our program has been greenhouse work. This work has as its objective the determination of chemical growth limiting factors. As stated earlier, most tailings are deficient in nitrogen and phosphorus,
in some cases other nutrients. In all treatments employing the use of organic amendments the success of plant establishment was enhanced. Organic amendments included sawdust, manure and peat moss. We are convinced that organic matter amendments, at least initially, are necessary for good success in vegetation establishment. One problem faced in our greenhouse operations is the short time our studies have been ongoing. It is planned to continue these studies, growing more than one crop on the same tailings material in an attempt to obtain information on long term effects of amendments. This is felt necessary to continue before test plots are established in the field.

It is admirable to establish a vegetative cover that will sustain itself. However, one must know something about the chemical quality of the produced vegetation. To this end, we have been looking into one nutritional problem that may arise if ruminants feed for a substantial portion of their diet on vegetation grown on tailings. The condition we have looked into, in a preliminary way, is called molybdenosis. This condition is caused by high molybdenum in plants or a low copper to molybdenum ratio. Analyses have been conducted on vegetation growing on tailings as well as natural vegetation in the region, in an attempt to avoid bias and over generalization. In some cases it appears molybdenosis may be a problem. It is rather easily amended if it is known. More work is planned in this area.

The last aspect of the 1976-77 research program to be mentioned is the importance of biological oxidation processes in mine tailings. There is evidence in the literature that microorganisms may play an important role in affecting the properties of tailings. Also, the kinds of organisms change with time as the tailings material ages. The present thrust has been to assess the effects of bacteria on sulfur and iron oxidation. These studies have shown, for example, that tailings of initially low sulfur content have sulfur oxidizing bacteria present. The study is too preliminary to attempt any further interpretation.
SUMMARY

The above has attempted to give some insight into the research program on-going in the Department of Soil Science at the University of British Columbia. Everything that has been done was not discussed in this address. Our philosophy has been to co-operate in activities in reclamation with government and industry. This is mainly to, train and educate personnel to conduct reclamation programs, to devise techniques that are suitable for mine wastes and to understand the basic processes that take place in these ‘unnatural’ materials; with the aim that eventual realistic guidelines may be established. I believe that one of the most efficient methods by which our knowledge and the practice of reclamation can be enhanced is by a co-operative approach. We, at the University, can offer some elaborate equipment for research, some evaluation of which parameters to study and why, some modification of methods of analytical work to better suit mine wastes and, most importantly, people who can work and advise on reclamation procedures. This 'people product' is not only graduates but also personnel to share ideas and discuss problems.

Industry can play a more important role by carrying on some of their own studies, both environmental and analytical, so that a solid base of information is generated, one which will serve in good standing and be predictive of conditions in the future. Also, industry has a responsibility to train its own in-house-personnel. Government, in my opinion, should continue to co-ordinate, co-operate, and fund research in all aspects of reclamation. In addition, they should play a dominant role in ensuring that well designed and pragmatic guidelines are established for reclamation for the various biophysical environments that are encountered.

In my opinion, the "sock it and see" approach to reclamation is a thing of the past! It is overdue not to work together, so that scientifically and technically sound reclamation programs become real.