CONTROLLING ACID MINE DRAINAGE USING AN ORGANIC COVER:[1] THE CASE OF THE EAST SULLIVAN MINE, ABITIBI, QUÉBEC

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Abstract: The East Sullivan site holds 15 million tonnes of tailings which generate significant acid mine drainage. The tailings pond covers a surface area of 150 hectares, and spillage extends over an additional 70 ha. The interstitial water at the centre of the pond is characterized as follows : ph= 2.3; Cu= 261 ppm; Zn= 23 ppm; SO_4= 13 500 ppm; and Fe= 3200 ppm. In order to stop acid drainage from being generated, plans have been made to cover the entire tailings pond with an organic blanket comprised of two metres of softwood and hardwood bark. This type of covering has proven effective in preventing oxygen from reaching the tailings. In fact, oxygen concentrations drop from 16.1 % near the surface to less than 1.5 % some 70 cm below it, while the CO_2 concentrations at the same depth rise from 8.2 % to 50.8 %. A grass cover is planted on top of the bark to reduce water seepage. Sludge from a municipal waters treatment plant is incorporated into the first 30 centimetres of the organic material as a conditioner and then seeded. A containment dike will be built around the entire site (6 km) to divert fresh water and carry drainage from the pond to a water treatment system. Studies have shown that some organic contamination results from bark decomposition. Phenol and tannin concentrations of 5.7 ppm and 95 ppm respectively have been measured to date. Tests are under way to determine the best passive treatment system for controlling both organic and mineral contamination caused by the tailings. A multimedia filter was installed a year ago and work will begin this year on experimental wetlands. The ultimate objective of the East-Sullivan mine site reclamation plan is to abandon the site as quickly as possible in an environnemtally benign manner. So far, 30 % of the mine site is under organic cover and the remaining 70 % should be covered within five years at most. The containment dike will be completed within the next three years, and the water treatment system should be operational the following year.

Additional Key Words: Reclamation, tailings, dry barrier, wood waste.

Introduction

Between 1946 and 1966, the East Sullivan mine, which lies 500 kilometers north of Montreal, produced 15 million tonnes of ore. From this ore 141,000 tonnes of copper, 73,000 tonnes of zinc, 3.9 tonnes of gold, 119 tonnes of silver were extract, and, between 1950 and 1956, 172,355 tonnes of pyrite were produced (Lavergne, 1985). Other sulfide minerals in the ore included chalcopyrite, sphalerite, galena, arsenopyrite, pyrrhotite, and marcasite; these were found in lenticular masses in the altered volcanic rock.

In 1980, after some clean-up work, the site was returned to the Provincial government. Since 1984, the tailings pond has been used for the dumping of wood wastes (bark), and, since 1985, sludge from septic tanks and from the Val-d'Or sewage treatment plant. In 1990, the serious management of these materials was undertaken within the framework of an overall trial reclamation plan financed, since 1992, through the Canada-Québec subsidiary agreement on mineral development.

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Description of the site

The site of the East Sullivan mine (fig. 1) covers an area of 228 hectares (ha) of which 205 ha are buried under mine waste (tailings and spillage). A waste-rock dump of 5 ha contains nearly 200,000 cubic meters of oxidized material. The area of mine buildings, of which only the concrete shaft head-frame survives, occupies 18 ha. The mill-tailings pond is a vast plateau whose rim rises about 5 m above a peat bog. The original dikes were built with tailings and extended according to the needs of the moment. The thickness of the tailings varies between 2 and 11.5 m.

The spillage, found especially on the south side, dates from the start of operations, when a pond was filled with tailings upon which the dike was later constructed. A break in this dike in 1980 contributed to an increase in the quantity of material spread beyond the tailings pond. This material covers an area of about 68 ha, but its thickness rarely exceeds 50 cm at a distance of 50 m from the original dikes. In the northeastern part of the site, one can observe the formation of dunes and ripples that bear witness to the importance of aeolian erosion. Clouds of dust reaching hundreds of meters in height are visible above the site on dry and windy days in the summer. The wind also sweeps the area in winter, so that very little snow rests on the tailings.

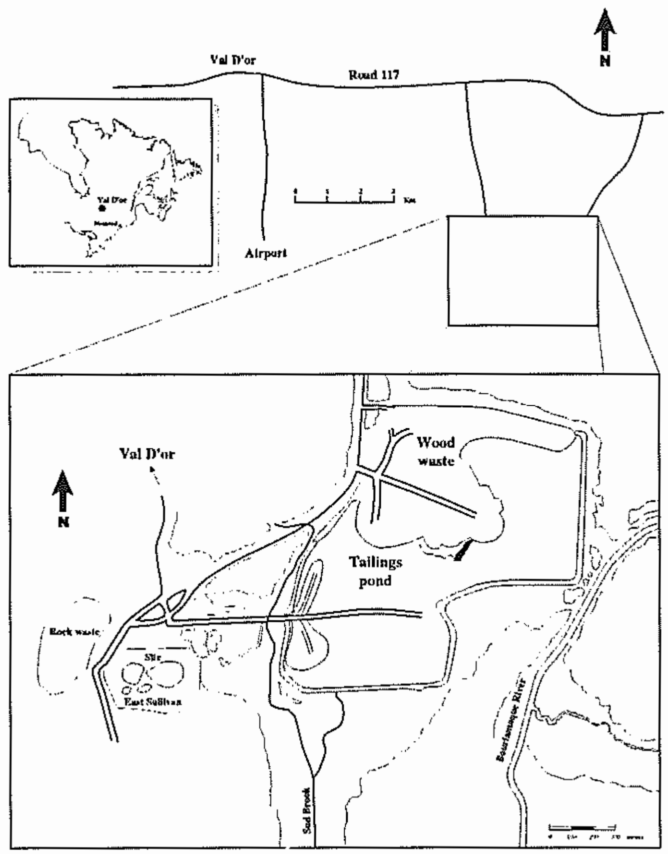

Figure 1. East Sullivan mine site.

The drainage of the site is mainly accomplished by Sud Brook, which runs along the west dike and crosses the zone of unconfined waste before joining the Bourlamaque River. Drainage on the north is by a small north-flowing brook, and a few gullies drain the east side of the area into the Bourlamaque River (fig. 2).

The granulometry of the tailings varies from fine at the centre of the area (50% silt and clay) to coarse-sand size near the edges, close to the dikes. At the surface, the material has a rusty color characteristic of the effects of oxidation. This color is found to depths of 30 to 40 cm in the fine material and to more than a meter in the coarser waste.

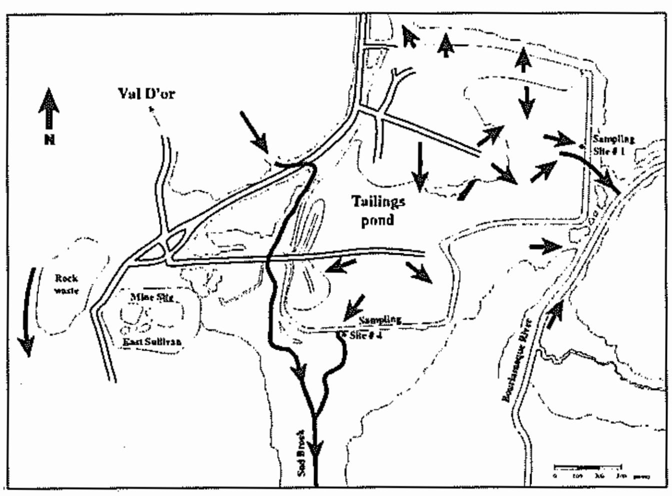

Figure 2. Drainage of the East Sullivan mine site.

In 1990, the pH of the material was between 2.9 and 3.5 and the impact of the site upon the environment was considerable, based on the quality of runoff waters (Paquet 1991) (fig. 3). During a program of surface water sampling carried out regularly in April and May, 1990, the maximal values obtained for zinc were 540 times the acceptable limits defined by Directive 019 of the *ministère de l'Environnement* (270 mg/L vs 0,5 mg/L). Similar comparison can be made for iron (367 times : 1,100 mg/L vs 3

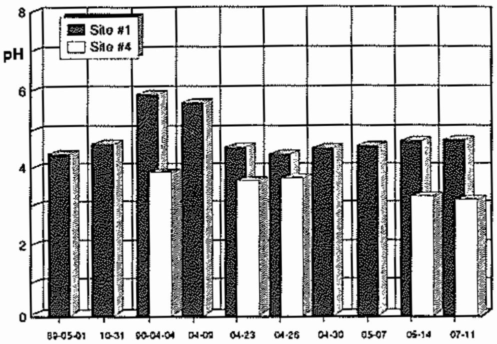

Figure 3. Variation of pH at the East Sullivan site.

mg/L), for material in suspension (292 times : 7,290 mg/L vs 25 mg/L) and for copper (97 times : 29 mg/L vs 0,3 mg/L). These results pointed up the urgency of proceeding with reclamation of the site in order to eliminate contamination of the Bourlamaque River. The interstital water at the center of the pond contained 261 mg/L of Cu, 23 mg/L of Zn, 13 500 mg/L of SO_4 and 3200 mg/L of Fe.

Reclamation plan

In February 1992, the *ministère des Ressources naturelles du Québec (MRNQ)*, in response to the results of numerous studies, prepared an overall program of reclamation trials for the East Sullivan mining site. The program had three principal phases : the construction of a watertight dike for the containment of the pond tailings and the spillage; the covering of the pond with ligneous waste, and the enrichment of the surface to permit the planting of a vegetal cover; and the establishment of a water-treatment system at the final outflow (fig. 4).

Construction of a watertight containment dike

In order to capture the runoff waters from the pond as well as the percolation waters that seep out at the base of the original dikes, the construction of a watertight dike to confine the tailings has been underway since 1992. With a total length of 6 km and an average height of 2 m, this dike will also confine all the waste that has flowed beyond the pond over the years. It contains a geosynthetic liner of bentonite, anchored in the underlying clay, which is found on the average a meter below the surface of the peat bog (fig. 5).

The dike will serve to divert clean waters from the site, and to channel the contaminated waters within the site towards a single point for treatment. The diffuse contamination of the Bourlamaque River by percolation waters from the pond will thus be significantly reduced.

A special arrangement will permit the containment, within the reservoir thus created, of all the water accumulating within the site over the period of a year. Thus, even though water treatment will be possible for only a few months each year, the dike will retain snow meltwaters as well as rainwater. A plantation within the reservoir will promote evapotranspiration and diminish the quantity of water to be treated.

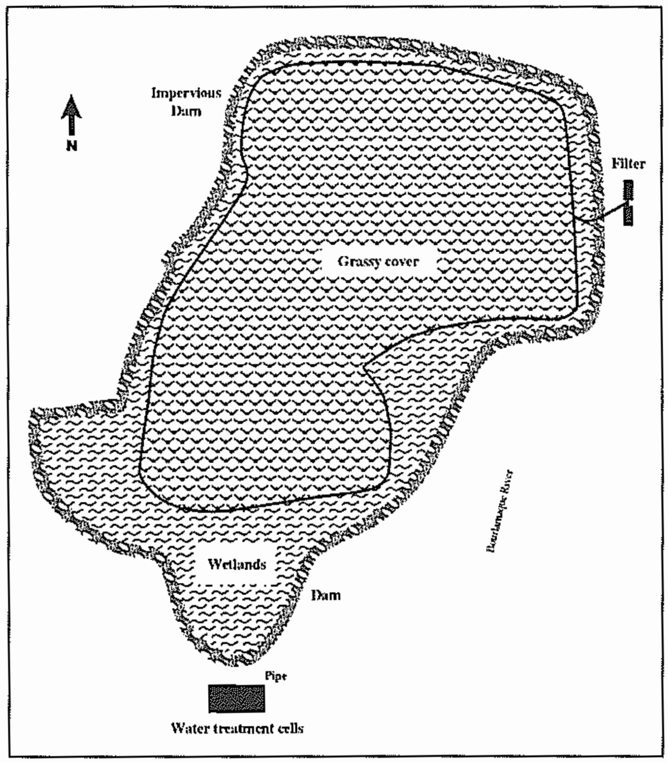

Figure 4. Draft of reclamation concept of East Sullivan tailings pond.

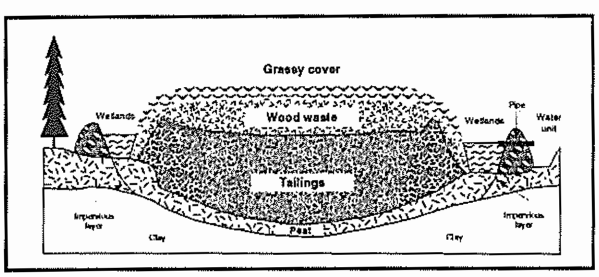

Figure 5. Section of reclamation concept of East Sullivan tailings pond.

Organic cover

The covering of the mine tailings with ligneous waste, begun in 1984, will be continued through with more careful control of the material used. In 1989, the cover was approaching a thickness of 8 m in places, and fires were starting frequently in the waste material wich was composed of bark, fiber-board, pulp-wood, and sanding dust.

By 1990, the thickness of ligneous waste had been reduced to 2 m and the material was composed only of bark (85%), pulp-wood (10%), and sawdust and sanding dust (5%). In origin, the waste is about equally divided between coniferous species (mainly spruce) and leaf-bearing species (mainly aspen).

The ligneous waste is now being covered by sludge from a sewage treatment plant, which is being incorporated into the top 30 cm of bark, and seeded with grasses. The main purpose of this vegetal cover is to diminish the quantity of runoff, by promoting evapo- transpiration, but of course it also greatly improves the aesthetic quality of the site, and renders it useful to wildlife. Infiltration ponds for septic tank sludge have also been created on the site, in order to increase the quantity of material available for enriching the surface.

Water treatment

A water treatment system will be installed at the south end of the containment dike. Since the objective of the trial reclamation program is the earliest possible permanent abandonment of the site, only a passive system is envisaged. By «passive system», we mean a system needing little maintenance and capable of eventually purifying the water without human intervention. The design of these systems is still experimental, and since each site has its own characteristics, it will be necessary to verify the feasability of such a system at the East Sullivan site. A research project for the development of a passive system for the treatment of mine wastewaters has been completed. The project includes the preparation of plans and specifications for a pilot project integrating the chosen technology.

A multimedia filter was installed in 1992, but, after a month of satisfactory service, exfiltration problems began to compromise the effectiveness of the system. The filter will be relocated and used to treat water coming from the northern part of the tailings pond.

Effectiveness of the organic barrier

The covering of the tailings by an airtight blanket aims essentially at preventing the oxydation of sulfides by restricting the entry of oxygen. The use of bark and sawmill waste is an attractive alternative to the usual dry covers. The material is relatively abundant in many areas where the exploitation of both forest and mining resources is a major activity. The ligneous wastes can form an effective barrier while conserving a high level of humidity and consuming some of the available oxygen.

In 1991, a series of piezometers and thermocouples was installed on a limited portion of the ligneous waste to evaluate the effectiveness of the organic barrier in isolating the mine waste from the ambient air. The following graphs (figures 6 and 7) show the evolution of the pore waters since the beginning of the covering process. They are based on sampling by several workers, and illustrate a rise in pH that seems to be directly related to the organic cover. Thus, for the north part of the tailings pond, which is now about 50% covered by organic material, one notes relatively constant values of pH, around 4.5 for the month of May, whereas the values for the month of October increased from 4.5 in 1988

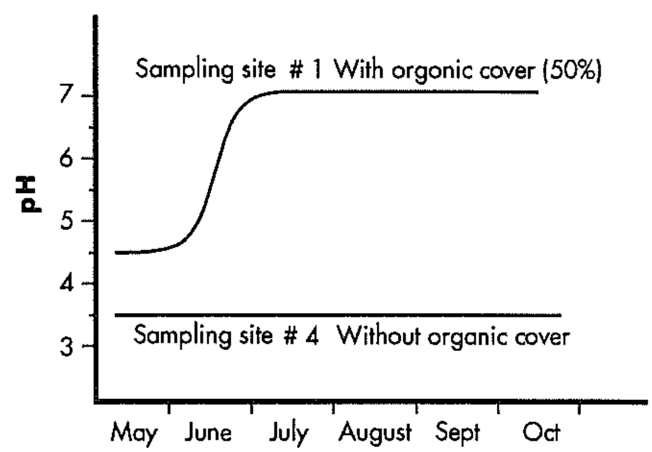

Figure 6. Monthly evolution of pH at the East Sullivan site during 1992.

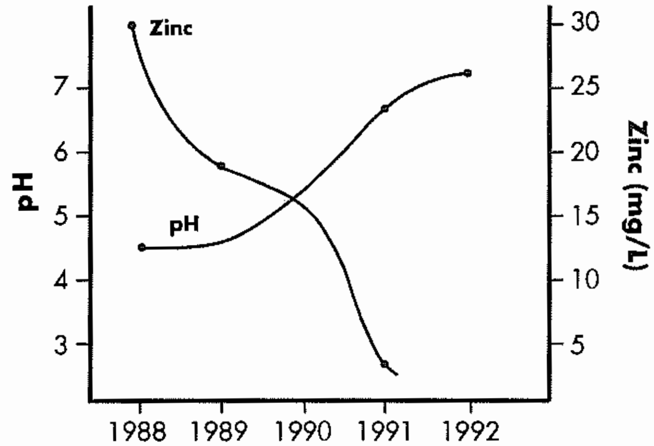

Figure 7. Annual pH and Zinc variations at East Sullivan sampling site #1 (october).

to 7.0 in 1992. In 1992, in fact, the pH was already at 7.1 in July.

In the southern part of the tailings pond, where no organic material was spread before 1992, the pH has remained stable, between 3.1 and 3.7, over the last three years. The metal content of the effluents has shown a similar pattern (fig. 7).

On-site plot instrumentation

In 1991, the MRNQ undertook an evaluation of the effectiveness of the cover at the East Sullivan tailings pond, within a plot some tens of meters from the southern limit of the ligneous waste (*Tassé et al.* 1993). The sampling in the ligneous waste was carried out in August and in October, using aluminum tubes. The content of free water in the samples was measured after extraction by centrifuge, and the total porosity obtained by calculating the volume of the interstices.

The contained gas was sampled by syringe and analyzed the same day. The gases detected were oxygen, methane, carbon dioxide, and nitrogen. The temperature of the waste was measured by four thermocouples installed at 40, 80, 120, and 150 cm below the surface.

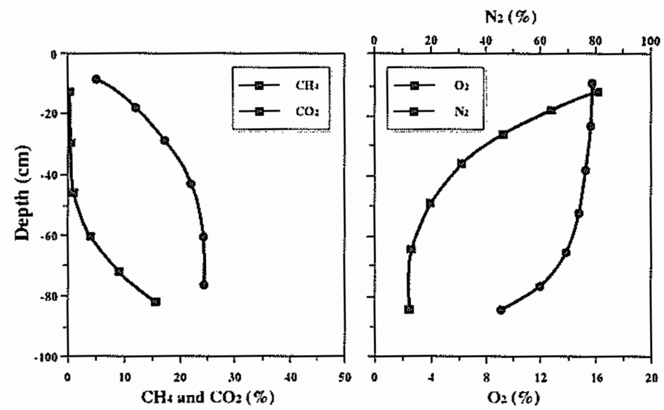

Figure 8. Proportion of gases in a 100 cm wood waste cover.

The results obtained demonstrate the effectiveness of a 100-cm-thick cover of wood chips (fig. 8). All the profiles show the same general tendency : diminution of the oxygen concentration from 16.1 % to 1.5 % an increase of carbon dioxide from 8 % up to 50 % and an increase of methane from 0 % to 15 % at a depth of 70 cm. Thus, the cover effectively blocked access of oxygen to the underlying sulfides. However, secondary reactions should be investigated in more depth before using the same technique at other sites (Germain *et al.* 1992).

Construction of supplementary plots

Following these observations, six experimental plots were constructed, in order to determine the effect of the cover on the process of acidification and on water quality. The *Centre de recherches minérales* of the *MRNQ* has coordinated the construction and supervision of the project (Paquet 1992). The plots were located in a sector of the tailings pond free from covering, in order to avoid any contamination. They were constructed as follows:

1 - **oxidized** tailings alone;
2 - **fresh** tailings alone;
3 - 1 m of conifer bark over **oxidized** tailings;
4 - 1 m of conifer bark over **fresh** tailings;
5 - 2 m of conifer bark over **oxidized** tailings;
6 - 1 m of conifer bark over **oxidized** tailings, with the addition of 30 cm of sewage plant sludge at the surface (fig. 9).

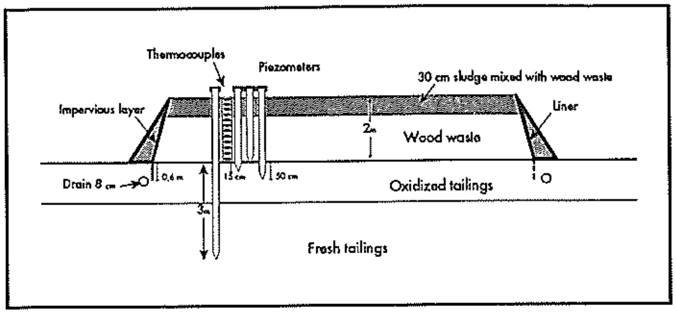

Figure 9. Scheme of #6 plot.

Each plot measures 20m X 20 m, and is separated from the next plot by 5 m. For each, a synthetic liner was installed on three sides, while a geotextile permits drainage to the south.

Plot 1 represents the present state of the site, 25 years after it was last used; plot 2 represents a site at the moment of its abandonment, at the end of mine exploitation. Plots 3 and 4 simulate an organic barrier covering an old and a recent tailings pond respectively; plots 5 and 6 represent possible variants on the technique of covering a tailings pond that is generating acid mine drainage.

Piezometers placed in each plot will permit the measurement of the physico-chemical quality of interstitial water and of ground water. They are installed so as to permit the sampling of the different levels of the plots. A program of gas monitoring is also being carried out in order to track the evolution of interstitial gasses over the next few years.

Observations and conclusions

Continuing observation of the experimental plots will permit the measurement of oxygen diffusion in the organic barrier, and its degradation in a controlled environment. If the various soluble organic compounds migrate into the mine waste, they could promote the reduction of sulfates and the fixation of metals in sulfide form, which could explain the observed decreases in dissolved metals and increased pH.

The present study will permit the measurement over the next few years of the effect of an organic cover used as a humid barrier to control acid mine drainage. The effectiveness of such a barrier would justify the extension of its use to other sites, particularly in regions like Abitibi-Témiscamingue, where both mining and forest exploitation are widely practiced. In addition the usefulness of organic wastes in reducing the impact of acid drainage from mine wastes merits consideration.

Acknowledgments

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