CAMBIOR INC.

FLOODING

AS A RECLAMATION SOLUTION

TO AN ACIDIC TAILINGS POND

the Solbec case

Gail Amyot,

Environmental Engineer

Serge Vézina,

Director, Environment & Research

800 René-Lévesque Blvd. West, Suite 850
Montreal, Quebec, Canada
H3B 1X9

Phone: (514) 878-3166
Fax: (514) 878-0635
E-mail: gail_amyot@cambior.com
serge_vezina@cambior.com

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SUMMARY

The Solbec tailings pond was active from 1962 to 1977. Over 2.5M cubic meters of sulfide waste were deposited at the site, and sporadic sampling performed between 1972 and 1980 confirmed the presence of acid mine drainage (AMD). A 1987 characterization report of the tailings pond tabled proposed flooding of the tailings as the most appropriate solution to the problem. It was at this time that Cambior became involved through its acquisition of the Sullivan Group, owner of the Solbec mine.

A series of experiments and studies followed from 1989 to 1993 to test the efficiency and viability of the flooding as a solution. The work required to achieve flooding was carried out in 1994. Since then, as part of the MEND program, a project has been conducted to monitor the quality of the water cover and groundwater associated with the tailings pond. The monitoring program also includes an evaluation of the oxydizing micro-organisms viability, their activity level activity in the flooded pond and of the hydrology and wave impact on site.

After twelve sampling and analysis campaigns of over 50 samples and ten parameters each, the solution now seems to be effective. The pH is now near neutral and the anomalous concentrations of iron, zinc and copper are resorbing. In addition, the basin retains enough water to keep the tailings submerged and thus prevent harmful wave action consequences.

The effectiveness of the solution is supported by a decrease in the oxidizing microbial population, the cessation of its oxidizing activity and especially the appearance of sulfate-reducing bacteria. These bacteria contribute to the inverse oxidation process by reducing sulfate ions to sulfide ions, which reprecipitate metals in the more stable form of metal sulfides.

INTRODUCTION

The Solbec site is located in Québec, about two hundred kilometres east of Montréal (Figure 1), between Lake Aylmer and Lake St-François. The closest village is named Stratford.

The Solbec mine was operated from 1962 to 1970 by the Sullivan Group, and over 1.9M tonnes of copper, zinc and lead sulfide ores were mined in a sericite schist gangue. The on-site concentrator operated from 1962 to 1977, processing not only the Solbec ore but also more than 2.9M tonnes of similar ores from the Cupra, Weedon and Clinton mines, all located in the same area. A total of 4.8M tonnes of massive sulfides consisting of chalcopyrite, sphalerite, galena, pyrrhotite and pyrite were processed in the concentrator.

The mine tailings were deposited in a 66-hectare site located in a swampy basin one kilometre north of the concentrator. The tailings contain residual values of the various ores, quartz, chlorite, sericite, plagioclases and minor fractions of calcite, dolomite, jarosite, magnetite and limonite. The total tailings volume is estimated at 2.5M cubic meters, or 4.2M tonnes. At closure, about 20 hectares of the pond were submerged in the north, and the water had a pH ranging between 3.0 and 3.5. In 1987, metal concentrations in this water were in the order of 3 mg/l for zinc, 1 mg/l for copper and 10 mg/l for iron; the other metals were not problematic. The tailings were oxidized only on the emerged surface, ranging from a few millimetres, in the north close, to the water pond to a depth of 50 centimetres in the south end of the tailings pond.

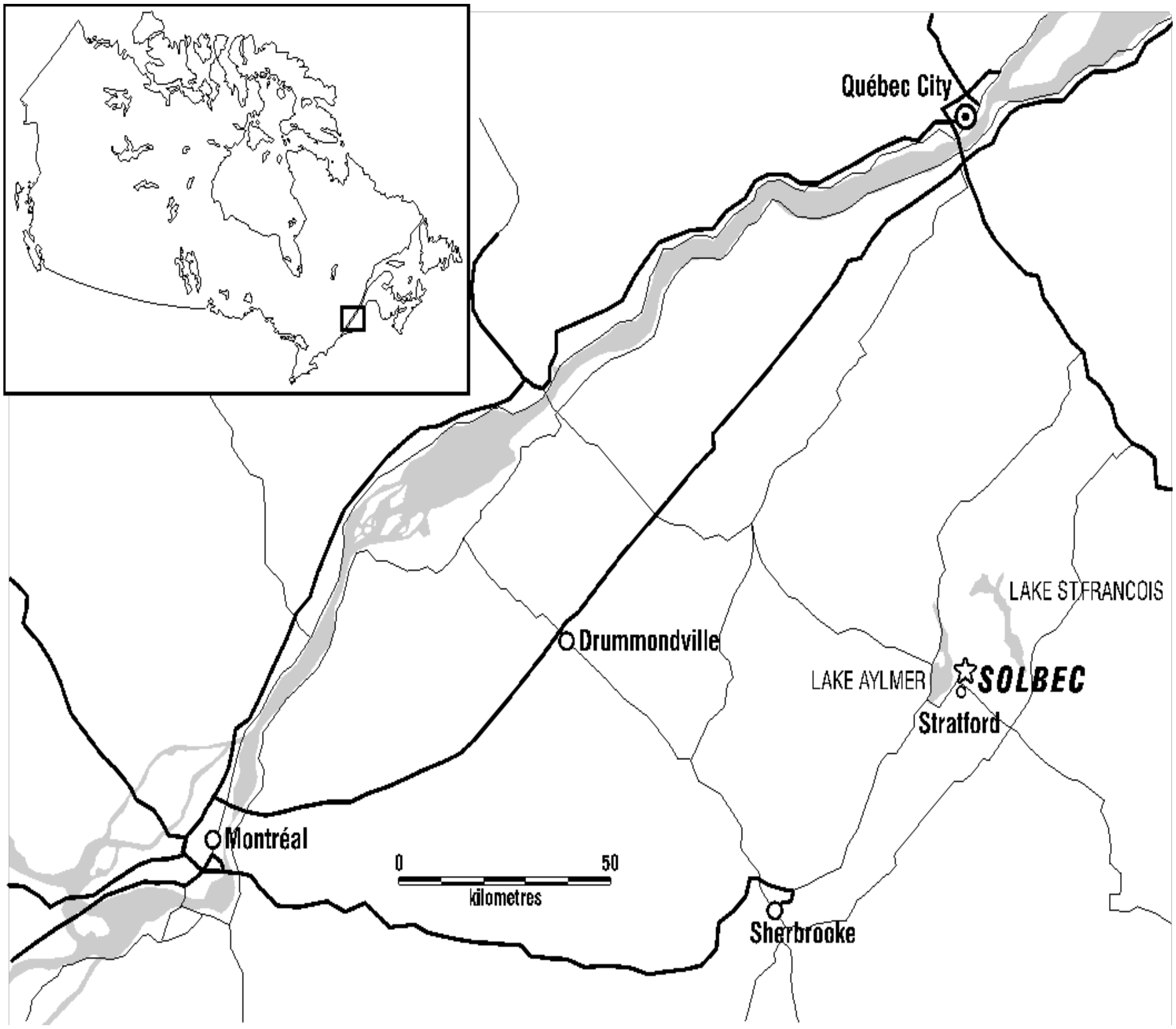

FIGURE 1: MAP SHOWING LOCATION OF SOLBEC SITE

ACID MINE DRAINAGE

In 1983, a panel from the Québec's Ministry of Environment (now the Ministry of Environment and Wildlife) undertook an inventory of all sites that may have received hazardous waste in Québec, and a report was published in 1985 (GERLED, 1985). In the context of this study, the ministry compiled various samplings of the tailings pond water taken since 1972. The results indicated that sulfide oxidation and production of acid mine drainage (AMD) were probably ongoing. Like many other old AMD-generating mine sites, the Solbec tailings pond was classified with a potential high risk to the environment. It was then necessary to take measures for the characterization and the reclamation of the site. In 1986, Québec's Ministry of Energy and Resources (now the Ministry of Natural Resources) sponsored a study on the characterization and various reclamation options for the Solbec tailings pond. The study report published in June 1987 presents flooding as the optimal solution both from an economic and environmental perspective. It recommends that field and laboratory experiments be performed to test the efficiency and viability of this option (Centre de Recherches Minérales, 1987).

Cambior Inc. became involved in October 1987, as it merged with the Sullivan mining group. The work on characterization and reclamation of the mine and concentrator site began in 1988. The various experiments aimed at testing the flooding option to attenuate the DMA from the tailings pond began the following year.

FLOODING EXPERIMENTS

1989

The first experiments to test flooding of the oxidized tailings as a means of reclaiming the Solbec tailings site were conducted in 1989. Ten-centimetre diameter columns testing various depths of water cover were monitored in the laboratory for a period of eight weeks. On-site, 1.22-meter cylinders were sunk into the tailings to the level of the water table to simulate in situ flooding. These were monitored for 17 weeks. The results have shown that acidification can be stopped by flooding once the interstitial water is replaced.

1990

In 1990, a 3m x 3m test basin was built with piezometers located in the various layers to simulate and study flow conditions in the pond and confirm that the circulation of interstitial water was an important element in inhibiting acid generation. Along with a technical-economic feasibility study, monitoring took place over a 15-week period. The geological and geotechnical characteristics of the site were determined as being favourable to the construction of dams and long-term water retention. The ground bearing capacity was reported as good, and since it was demonstrated that the tailings lie on a bed of peat which overlays an impermeable till zone, the long-term water retention capacity seemed realistic.

1991

In 1991, a third phase of experiments was conducted to determine the efficiency and the technical feasibility of flooding as a mean of reclaiming the Solbec tailings site. In other words, this consisted in ensuring that the water cover could be maintained in the long term, i.e. establishing a potential water balance, testing the bearing capacity of the ground under the dams, identifying borrow pits with potential fill material of low hydraulic conductivity, as well as observing the physical-chemical and microbiological evolution of the interstitial water in the tailings. The flooding option was then maintained and confirmed. With the construction of two dams, the water would accumulate from a 5 km^2 watershed in a 1.2 km^2 basin for 18 months before any overflow occurs. Subsequently, an annual water surplus of approximately 3 Mm^3 was anticipated. However, the results from the testing basins were unexpected; the acidification process was still ongoing in the oxydized tailings. Thus, oxidation product leaching arose as a consequence of flooding the oxidized tailings.

1992/1993

In 1992, a fourth phase was undertaken. To offset the leaching of the oxydation products from the oxidized tailings, limestone was added in the testing basins as an attempt to neutralize and stabilize the previously acidified water. In December 1993, flooding of the pond after addition of lime was recommended as the reclamation method. Other studies were conducted to refine the closure project.

The first study (McGill, 1993) seeks to assess the depth of water required to inhibit acid generation given wave action and the possible resuspension of particles. But the model used had been designed for longer fetch and higher wind speed. In addition, the tailings grain size considered was only typical of pond central zone that is finer than the average. Therefore the results were taken as a guideline. The study had recommended a minimum water height above the reactive tailings of 1,34 m or 0,74 m if the tailings were to be covered with sand. With due regard to the tailings grain size, where the future shallow water zones were to be located, a one-meter water cover was determined to be sufficient.

Another study was aimed at assessing the quantity of lime and its application method (Karam et Guay, 1994).

The recommendation was to apply 118 tonnes/ha to an average depth of 15 cm. The final project studied was the effect of flooding on microbiological activity (Karam et Guay, 1994). In the laboratory it was found that maintaining the non-oxidized tailings under water has prevented colonization by *Thiobacillus ferrooxidans*-type bacteria, while artificial flooding of unoxidized and oxidized tailings combined with lime has inhibited microbial activity without destroying cell viability. The author anticipated an effective decrease in the populations over time, but no fieldwork had been conducted on this.

The work conducted from 1990 to 1993 was part of the MEND program and the detailed reports are available.

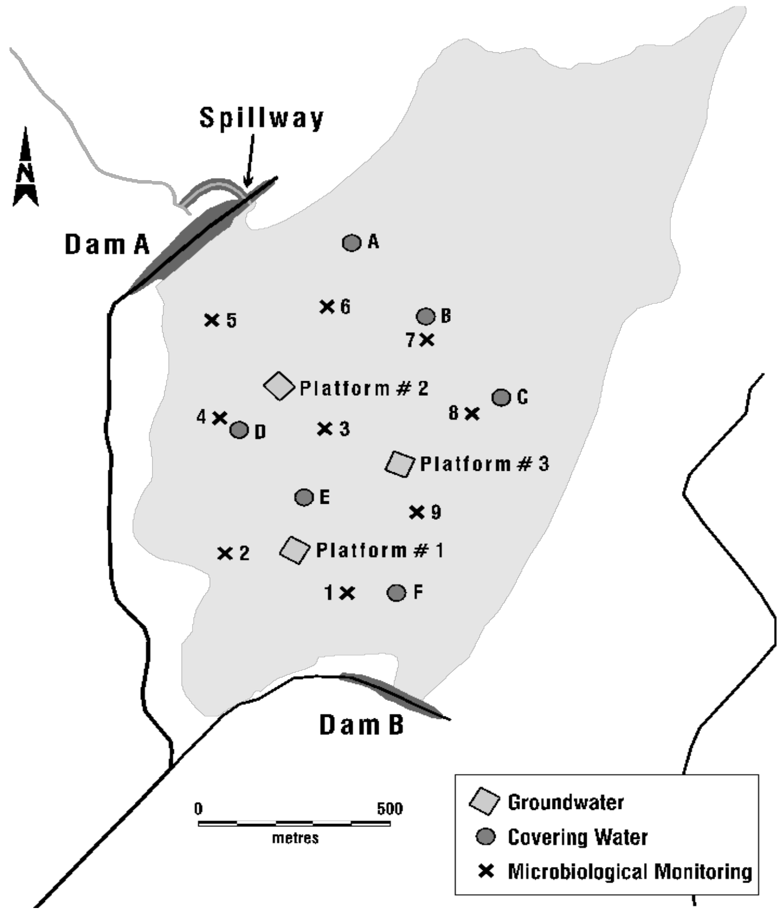

FIGURE 2: **WORKS AND SAMPLING STATIONS**

RECLAMATION WORK

Flooding of the tailings pond, with a minimum cover of one meter of water, was possible with the construction of two dams: a 396-meter long and 9 meter high main dam, and a second 192-meter long and a 2.5-meter high dam (Figure 2).

Work began in August, 1994 with the clearing of 27 hectares of land. This area included access road sites, dams and a portion of the area to be flooded.

At both dam sites, the overburden was stripped and the bedrock was blasted to level the base of the dams. The bedrock was then cleaned and fractures were cemented. The dams were built with an impermeable till core. In the upstream (interior) side, the core was covered with an impermeable geomembrane, while on the downstream (external) side, the core was entirely covered with geomembrane and a filter bed. The slopes were completed with gravel and were covered in riprap.

At the north end of the main dam, a 4-meter wide concrete spillway, was built to handle the century's flooding event.

To minimize the height of the dams, about 50,000 m^2 of tailings located at the southend of the pond were smoothed toward the centre of the impoundment.

Before flooding, the whole surface of the tailings was limed. In the water-covered area, hydrated lime ($Ca(OH)_2$) was dumped in the water. In the uncovered area, the neutralizing agent used was calcite dust and granules ($CaCO_3$). This was incorporated into the tailings by plowing to a depth of 300 mm. It was found to be a difficult operation resulting in an irregular distribution and excess of neutralizing agent by reference to Karam et Guay 1994 calculation. On average, 230 tonnes per hectare of material were applied.

Work ended in November 1994. Complete flooding of the tailings to their highest elevation (329 m) was achieved in September 1995. In February 1996, the 330 m water elevation mark was reached during a mild period, and the first overflow from the basin occurred.

MONITORING

The environmental monitoring program following the flooding of the tailings pond was developed as part of the MEND program. Its purpose is to assess the quality of the water cover, the ground and effluent waters, the water balance, the effect of waves and ice on sediments, bank erosion and beach creation as well as the evolution of the microbiological populations. The program was initiated in the fall of 1994 and is still ongoing. Three sampling campaigns took place each year (1995, 1996, 1997), in spring, summer and fall. In 1998, only two sampling campaigns were conducted.

Water Cover Sampling

In order to determine the quality of the water in the basin, 6 sampling stations were set up with plastic buoys to collect underneath water at three distinct depths. The stations (A-B-C-D-E-F) are located along two transects that are oriented more or less perpendicularly to the axis of the main dam (see Figure 2). The samples are taken on surface, at mid-depth of the water cover and ±150 mm above the tailings' surface.

The 18 water cover samples are subjected to the following analysis without being filtered.

In the field: pH, electrical conductivity and Fe^{+2}

In the laboratory: Metals (Fe, As, Cu, Ni, Pb, Zn), sulfates, suspended matter, alkalinity and acidity if appropriate.

Groundwater Sampling

The water present in each stratigraphic unit are sampled and analysed. The latter include the interstitial water in the oxidized mine tailings on surface, the interstitial water in the unoxidized tailings below, the groundwater in the peat, till and bedrock that lie below the mine tailings.

At each sampling campaign, 27 water samples are taken from three platforms (1, 2 and 3) located within the tailings pond (Figure 2). Each platform has five monitoring wells attached, each extending down to the bedrock and to the various stratigraphic zones. Screened-headed sampling tubes are placed within all the wells, two tubes for each stratigraphic unit except the bedrock, which has only one tube (Figure 3). It is important to note that platform 2 collapsed during winter 1997-98. Consequently, no sampling campaign was conducted.

In this case, the water samples are filtered through a 0.45 micron sieve prior to each analysis. The parameters analyzed in the field and in the laboratory are identical to those of the water cover, except for the suspended matter, alkalinity and acidity that are not performed.

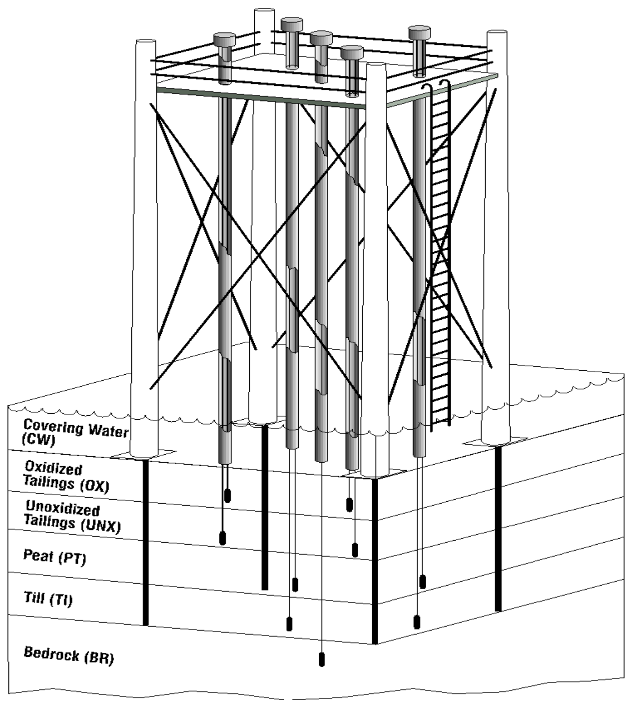

FIGURE 3: PLATFORM

Sampling of Tailings for Microbiological Monitoring

The tailings samples are obtained by coring at nine sampling locations, which are identified with buoy of different colour than those used at covering water stations (see Figure 2). The carefully collected samples, of approximately 250 grams, are placed in sterile bags. Culture media are seeded with a portion of the solid samples to permit the isolation, identification and enumeration of the bacteria present. The inocula are also used to determine the oxidizing potential of the various microbial isolates with respect to iron sulfate (oxidized ferrous iron) and elemental sulfur (product of sulfuric acid and a decreased pH).

RESULTS

The results generated a data bank in the form of various tables. To simplify their presentation, these have been grouped as shown in Figures 4, 5, 6 and 7 for the water samples and Figures 8, 9 and 10 for the microbial population.

The water quality figures show the significant parameters in the form of a snapshot in each stratigraphic unit, for each sampling campaign. They therefore represent the evolution of average concentrations of each of these parameters over time, in each zone. Arsenic, lead and nickel values were present for each sampling campaign, only in very low concentrations and are therefore not shown.

DISCUSSION

The tailings were completely flooded by the fall of 1995 (to the 329 m mark), and in February 1996, an effluent was reported at the spillway (the 330 m mark was reached) where covering water used to be sampled before the flooding. The anticipated fill period of 18 months was as expected. A new equilibrium is now being established in the pond, and this period is represented by the twelve sampling campaigns that have been completed to this day. The results of this discussion are intended to reveal trends that lead to this conclusion.

Two important factors must also be considered. The surface area of the reservoir drainage basin is 500 hectares (5 km^2). The total precipitations measured in the region ranged between 1.1 and 1.2 meters per year and had an average pH around 4.4. The second important factor is the liming of the pond and tailings before flooding. Limestone dissolves slowly and strongly influences the quality of the water cover.

Furthermore, applying the lime was a difficult step and the depth of the mix with the tailings was erratic, as was the quantity of lime or limestone added. As a result, selective readings may be influenced by these discrepancies.

To date, several hydraulic, hydrogeological, wave action and ice impact studies confirmed that the risk of tailing re-emergence or resuspension was not significant. In fact, 210 consecutive days of drought are apparently needed for evaporation and exfiltration to cause the tailings to re-emerge. On the other hand, 64 km per hour winds blowing in the basin axis would be required to resuspend the tailings (Consultants S.M. Inc., Mars 1998). Furthermore, neither the cover nor the semi-solid waters beneath the ice cover reach the tailings.

		Workings			Flooding	Overflow							
		Fall 1994	Spring 1995	Summer 1995	Fall 1995	Spring 1996	Summer 1996	Fall 1996	Spring 1997	Summer 1997	Fall 1997	Summer 1998	Fall 1998
Covering Water	CW	5.0	10.7	6.7	7.6	7.8	7.2	7.3	7.3	7.7	7.8	7.6	7.2
Interstitial Water in Oxidized Tailings	OX	6.8	7.0	6.4	6.5	6.1	6.4	6.1	6.2	7.0	7.5	6.6	6.7
Interstitial Water in Unoxidized Tailings	UNX	7.2	8.6	8.1	8.4	8.3	7.7	8.2	7.4	8.6	8.0	8.3	8.7
Groundwater in Peat	PT	6.6	8.1	6.9	6.8	6.8	6.5	6.8	6.6	7.3	7.3	6.6	6.6
Groundwater in Till	TI	7.4	7.6	7.6	7.8	7.7	7.2	7.7	7.4	7.7	7.4	7.4	7.2
Groundwater in Bedrock	BR	7.7	8.5	7.6	7.5	8.2	7.4	8.2	7.4	7.9	7.4	6.8	7.6

Figure 4:Water Quality, pH

The covering water rose from a slightly acid pH in the fall of 1994 to very alkaline levels in the spring of 1995 following the thaw, once the lime began to dissolve. It subsequently hovered around neutral.

Following the complete flooding of the tailings in the fall of 1995 and the gradual saturation of the tailings, the 1996 spring campaign detected slightly acid pHs (±6.1) in the layer of oxidized tailings. More neutral pH's were observed the following summer.

No anomalies were seen in the pHs measured in the water for any of the other stratigraphic units.

		Workings ↓			Flooding ↓	Overflow ↓							
		Fall 1994	Spring 1995	Summer 1995	Fall 1995	Spring 1996	Summer 1996	Fall 1996	Spring 1997	Summer 1997	Fall 1997	Summer 1998	Fall 1998
Covering Water	CW	142	2.9	1.80	0.35	0.29	0.17	0.30	0.41	0.05	1.4	0.10	0.05
Interstitial Water in Oxidized Tailings	OX	555	99.8	183	373	343	190	150	132	18	38	70	29
Interstitial Water in Unoxidized Tailings	UNX	0.15	0.01	0.04	0.01	49.4	0.04	0.06	0.05	0.24	0.26	0.43	0.50
Groundwater in Peat	PT	0.01	0.01	0.10	0.85	7.8	29.9	34.9	10.4	0.91	0.54	0.09	2.2
Groundwater in Till	TI	<0.01	0.12	0.15	0.06	0.03	0.02	0.15	0.19	0.31	0.98	0.27	1.9
Groundwater in Bedrock	BR	<0.01	0.01	0.35	0.08	<0.01	<0.01	0.03	0.03	<0.01	<0.01	0.09	<0.01

Figure 5: Water Quality, Iron (mg/l)

With the exception of the 1994 fall campaign, the iron concentration of the covering waters have never been above the level set by the Ministry of Environment and Wildlife (Regulation 019). From the time the tailings had begun to be flooded, i.e. after the 1994 fall campaign, the iron concentration within the covering water decreased and now seems to have reached a stable level.

However, it should be noted that in the oxidized tailings layer, iron concentrations were in the order of 100 ppm and over from the outset. With progressive flooding, the dissolution of surface precipitated material and the gradual saturation of the oxidized tailings that enhanced their leaching, the observed concentrations increased to a peak of 373 ppm in the fall of 1995, then fell back to 100 ppm in the summer of 1997.

Once the tailings pond was completely flooded, this migration of iron continued at concentrations in the order of 50 ppm in the unoxidized layer and 10 ppm in the peat zone (spring 1996). By the summer of 1996, iron concentrations in the unoxidized zone had regressed to trace levels while those in the peat zone have also reached low concentration in summer 1997.

To date, the most abundant metal, namely iron, tends to be resorbed into the upper layers and does not appear below the peat horizon, which was to be expected in this type of material. The presence of peat and till underlying the tailings was in fact one of the characteristics of the Solbec tailings pond that led to the selection of flooding as a close-out option to control AMD.

		Workings ↓			Flooding ↓	Overflow ↓							
		Fall 1994	Spring 1995	Summer 1995	Fall 1995	Spring 1996	Summer 1996	Fall 1996	Spring 1997	Summer 1997	Fall 1997	Summer 1998	Fall 1998
Covering Water	CW	0.83	0.11	0.02	0.04	0.01	0.02	0.19	0.03	<0.01	0.02	0.03	<0.01
Interstitial Water in Oxidized Tailings	OX	2.4	17.0	17.6	20.2	23.6	10.0	9.3	7.8	1.8	2.0	1.4	1.4
Interstitial Water in Unoxidized Tailings	UNX	2.0	0.54	0.31	0.07	0.83	0.25	0.12	0.28	0.12	0.17	0.20	0.20
Groundwater in Peat	PT	0.56	0.09	0.31	0.06	0.10	0.24	0.08	0.09	0.03	0.07	0.10	0.09
Groundwater in Till	TI	0.16	0.45	0.02	<0.01	0.63	0.03	0.18	0.03	0.02	0.03	0.01	0.03
Groundwater in Bedrock	BR	0.01	<0.01	0.03	0.01	<0.01	0.03	0.02	0.03	0.02	0.06	0.03	<0.01

Figure 6: Water Quality, Zinc (mg/l)

Zinc has an even more pronounced behavior than iron, albeit in lower concentrations. Since the fall of 1994, prior to flooding of the site, the presence of zinc was noted in the surface water at the original spillgate, in the interstitial water of oxidized and unoxidized tailings, and in the water in the peat zone, all in concentrations in the order of 0.5-2 mg/l.

With the gradual filling of the pond and subsequent saturation of the tailings, concentrations in the oxidized tailings zone rose to a maximum of 24 mg/l in the spring of 1996 and decreased again to 10 mg/l a few months later (summer 1996). Since then, the zinc concentration in the oxidised tailing has been resorbing.

The high mobility of zinc was such that in 1994, it was present down to the peat layer. The concentrations in the peat and unoxidized tailings zones dropped to around 0.3-0.1 mg/l by the summer and fall of 1995, rose in 1996 and then fell again to 0.1 mg/l in the fall of 1996. This phenomenon will probably continue as long as the layer of oxidized tailings has not been purged of its trace values, a tendency that now appears to be emerging. Microbiological activity is expected to have an accelerating effect on the precipitation of metals like zinc, a subject that will be discussed later.

		Workings			Flooding	Overflow							
		Fall 1994	Spring 1995	Summer 1995	Fall 1995	Spring 1996	Summer 1996	Fall 1996	Spring 1997	Summer 1997	Fall 1997	Summer 1998	Fall 1998
Covering Water	CW	0.49	<0.01	0.01	0.01	<0.01	0.02	0.03	<0.01	<0.01	0.07	0.03	<0.01
Interstitial Water in Oxidized Tailings	OX	0.18	1.4	1.0	0.23	0.59	0.54	0.50	0.05	<0.01	0.02	<0.01	<0.01
Interstitial Water in Unoxidized Tailings	UNX	0.06	0.19	0.09	0.05	0.04	0.06	0.05	0.04	<0.01	0.05	0.10	0.10
Groundwater in Peat	PT	0.23	0.05	0.07	0.02	<0.01	0.04	0.04	0.03	<0.01	0.01	<0.01	<0.01
Groundwater in Till	TI	0.20	0.12	0.04	0.01	0.01	0.03	0.02	0.02	<0.01	0.02	<0.01	<0.01
Groundwater in Bedrock	BR	<0.01	0.01	0.03	<0.01	<0.01	0.03	0.02	0.01	<0.01	<0.01	<0.01	<0.01

Figure 7: Water Quality, Copper (mg/l)

In the covering water, copper, like iron and zinc, reached low and stable concentrations in the spring of 1995.

In the groundwater, copper only affected the oxidized tailings zone. It rose to a maximum of 1.4 mg/l in the spring of 1995 but then fell once again to 1.0 in that summer, and to 0.2 in the fall of 1995, to uphold at 0.6-0.5 in 1996. It stayed below average values of less than 0.1 mg/l in all the underlying layers.

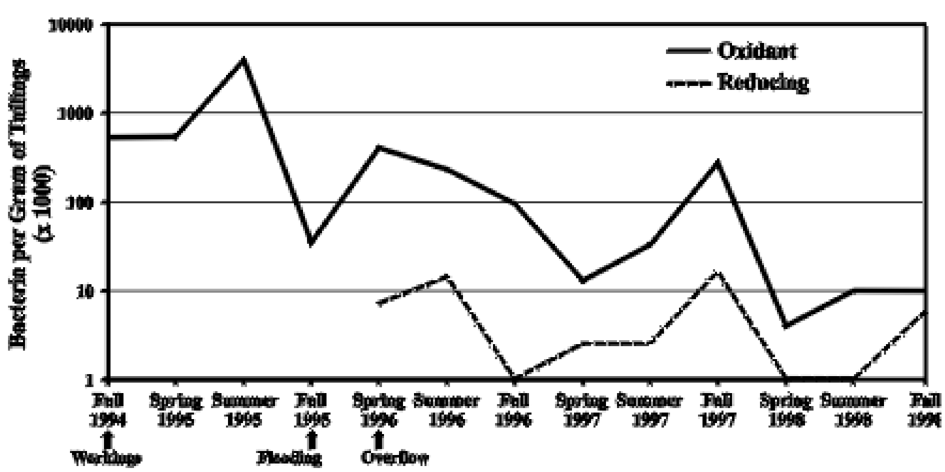

Figure 8: Oxidant Microbial Populations in Tailings

From the outset of the program, various microbial species preponderant in the production of AMD were identified in the tailings. Various species of thiobacillus and other heterotrophic acidifying and acidophilic bacteria were observed.

Figure 8 shows only those species that oxidize ferrous and elemental sulfur ions, as the sulfate-reducing species have only been enumerated this year.

It was found that the oxidizing microbial populations were very high but progressively decreasing in the nine samples of oxidized tailing collected in the pond. They stood at just over 500,000 individuals per gram of tailings in 1994 and 100,000 per gram by the summer of 1998. It should be noted that their reproduction is highly sensitive to temperature, a phenomenon visible in the summer of 1995, when their number rose to nearly four million individuals per gram of oxidized tailings. It appears that their viability has been decreasing since the pond was completely filled in the fall of 1995.

An important element that helps explain the decreasing trend in the oxidant microbial populations as well as the regression in concentrations of metals such as iron, zinc and copper is

the appearance of sulfate-reducing bacteria. These are strictly anaerobic. They were first seen in the spring of 1996, and their population has been evaluated at the nine sampling stations since the summer of 1996 campaign. This phenomenon raises very interesting possibilities, as the inverse process to microbial oxidation of metal sulfides is taking place, that is, the reduction of sulfates available in sulfide ions and the reprecipitation of the observed metals in the more stable form of metal sulfides. Since the flooding, the organic carbon supply, which is an essential element to the viability of the bacteria, has been limited to some small vegetation. Thus, it is thought that the natural supply in organic carbon might not be sufficient to support an increment within the bacterial population.

CONCLUSIONS

The twelve sampling campaigns that followed the flooding of the Solbec tailings allowed to sketch a portrait of the covering water and groundwater, including the interstitial water in the oxidized and unoxidized tailings. Results have demonstrated that the covering waters met all requirements outlined in Regulation 019 (Ministry of Environment and Wildlife) and even those of the drinkable water regulation.

With regard to the interstitial water and groundwater, the only parameters that merit attention are iron, zinc and copper. With the gradual saturation of the tailings following the progressive flooding of the pond, these metals in solution migrated from the oxidized tailings layer to the underlying unoxidized tailings layer and, in the case of iron and zinc, even to the peat layer that comprises the first natural stratigraphic unit below the tailings. No other stratigraphic zone was affected and the phenomenon is now regressing. This tends to indicate that oxidation was inhibited during flooding of the tailings.

The monitoring of the microbiological populations and their oxidizing activity supports this trend. In fact, the populations show less viability, and their oxidizing activity, both on iron sulfate and elemental sulfur, is in latency following a rise in water pH toward neutral. In addition, changes in environmental conditions favored the growth of sulfate-reducing bacteria whose activity is opposite to those initially present in the oxidized tailings. In fact, they allow for the re-precipitation of metals in the more stable form of metal sulfides.

All the results to date therefore show that flooding was effective in attenuating the generation of AMD at the Solbec tailings site.

ACKNOWLEDGEMENTS

This work would not have been possible without the collaboration of the Ministries of Natural Resources of Quebec and Canada, who participated financially through the MEND program. Personnel from these organizations, as well as those from Groupe S.M. and Enviromine, contributed greatly to discussions and to the program. Finally, special thanks to Cambior Inc., who activated and financed the reclamation of the Solbec tailings site and allocated the personnel required for this project.

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