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MINING AND AQUACULTURE: A SUSTAINABLE VENTURE

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ABSTRACT

The legacy of mining activities has typically been land "returned to wildlife", or, in some locales, degraded to such an extent that it is unsuitable for any alternate use. Progress towards sustainability is made when value is added to the local environment in terms of the ecological, social and economic well being of the community. In keeping with the principles of sustainable development, the innovative end land use of flooded open pits and tailings impoundments for aquaculture should be explored as it could make a significant contribution to the social equity, economic vitality and environmental integrity of mining communities. As flooding open pits and tailings after mining is a recommended measure for metal mines to inhibit the generation of acid rock drainage (ARD), practicing aquaculture within those pits and tailings impoundments will be in line with government policies for reclamation. In addition, aquaculture in a controlled closed environment may be more acceptable to critics of fish farming who are concerned about fish escapes and viral transmissions to wild populations. The main objective of this venture is to demonstrate that deactivated open pits and tailing ponds from metal and industrial mineral mines in Canada can be used as commercial, recreational or ornamental fish farms. The benefits derived from mining and aquaculture and some of the logistics associated with this venture have spin-off effects. The main concerns about metal bioaccumulation are discussed, as well as ways to mitigate this issue.

Keywords: Mining; Aquaculture; Sustainable development; Mining policy; Abandoned mines; Reclamation

INTRODUCTION

When a mine is closed there can be serious impacts on the local community. In many cases the mine has been a major economic player in the region providing substantial fiscal revenue and many social services to the local community. Hence, the closure of a mine raises concern about the ongoing environmental management of the mine, unemployment, and the continuation of social services (such as water, power, and health care). It is clear that planning for mine closure will not only help mitigate negative impacts but can also create opportunities to bring positive benefits to the local community. It is generally agreed that, while it will be a living document, planning for mine closure should begin as early as possible - preferably before mining begins.

Mines are often the key economic engines of the communities in which they are located. Evidence to date has shown, however, that in many countries the positive impact of foreign direct investment on local communities is often extremely limited due to the lack of automatic spillover effects. However, with appropriate local economic development (LED) instruments, mining projects could bring more than their own direct employment to a community. By voluntarily participating in or even driving a LED program in a community, mining companies and other local stakeholders (local government, education institutions, other businesses) can work together to ensure that the local population, including the poorest segments, can benefit from the presence of new investments and share in the growth potential of the local economy. Importantly, LED strategies and programs have increasingly been seen as an entry point for national level reform especially in countries with weak national government and limited private sector development (for example in Latin America and Africa) (Balkau and Parsons, 1999).

The advancement of alternative sustainable livelihood for local residents through the development of aquaculture in flooded pits and tailing ponds could contribute to sustainable development after the closure of mines, with a number of spin-off benefits to the local community. To diversify the economy of these communities post- closure, the infrastructures left by the mines could be used to support alternative, revenue generating ventures. This is progress towards sustainability. For example, when BHP's Island Copper Mine in British Columbia, closed in 1995, the mine was instrumental in attracting and encouraging entrepreneurs who used buildings, dock facilities and water from the tailings ponds to establish wood processing and aquaculture operations - i.e. sustainable industries made viable by the availability of the mine's infrastructure (Veiga et al., 2001). The main objective of this paper is to demonstrate that, first, alternative end land uses are possible, and second, use of deactivated open pits and tailing ponds from metal and industrial mineral mines for commercial, recreational or ornamental fish farms may be a viable option in some locations.

Aquaculture in open systems

Aquaculture refers to the farming or production of aquatic organisms, by deliberate manipulation of their rates of growth, mortality, and reproduction, with the ultimate objective of harvesting products that have commercial value. Aquaculture in open systems, or cage culture, involves placing a mesh or wire cage in a flowing, open water system, such as a lake, stream, reservoir or ocean. The constant water flow is critical as it renews the oxygen supply and removes waste products with little effort by the aquaculturist. The size of mesh used for the cage is critical, as it must prevent the entry of predators, while holding the

Aquaculture in closed systems

Closed water aquaculture systems are more technologically advanced than the open water pond, cage or raceway structures. Closed systems are essentially huge aquaria in which the water is filtered and re-circulated. Although they are very successful in terms of fish production, these systems require pumps, accessories and are expensive to maintain. Closed systems produce a high quality, reliable, uniform and consistent product at competitive prices. High quality and uniformity come with healthy fish and adequate size grading. Closed systems deliver more fish because it can sort more fish with less time and labour. Intact, calm fish remaining in cages or tanks commonly feed on schedule, continue to grow, and are less likely to incur diseases induced by physical damage or stress. The closed, confined environment can, however, leads to the rapid spread of diseases in these fish populations.

Aquaculture and the environment

Diseases are inevitable in most aquaculture operations. The use of antibacterial drugs to control disease is commonplace today in open, closed or both systems. The antibiotics auremycin, furazolidene, nitrofurazone, penicillin, oxytetracyline, sulphamerizine and terramycin have been used occasionally in fish farms in Europe, North America and elsewhere (Alabaster, 1982; Solbe, 1982). There is also evidence to suggest that much of the antibiotic administered with the feed is going uncaptured because of a probable decline in appetite in sick fish (Bjorklund et al., 1990). Therefore there are significant levels of antibiotics detected in the sediments associated with fish farms (Bjorklund et al., 1990; Jacobson and Berglind, 1988). Repeated use of antibiotics has resulted in antibiotic-resistant bacteria being found in the sediments under fish farms (Bjorklund, et al., 1990; Austin, 1985). Public concern over the use of such products in food fish, and the development of vaccinations to fight diseases, have contributed to the trend of declining use of antibiotics.

A number of other chemicals are also used in aquaculture to control other fish health issues and facility maintenance. Alabaster (1982) and Solbe (1982) documented the frequent use of malachite ($CuCO_3$) and formalin in European fish farms to control ectoparasites and fungus. Tributyltin (TBT), which is extensively used as an antifouling, has received much attention (Avarez and Ellis, 1990; Gabrielides, et al., 1990) as it has been shown to accumulate in the muscle of both finfish and molluscs (Davies et al., 1986). Negative effects of TBT on the growth of shellfish (Paul and Davies; Davies et al., 1987) and the inducement of imposex (i.e. wherein females develop part of the male reproductive system) in neogastropods has been demonstrated (Avarez and Ellis, 1990; Davies et al., 1987). Fertilizers are another category of chemicals that are used to enhance natural productivity in fanned finfish and shellfish. While this is not as widespread an issue as TBT, on a global scale, the possible toxic effect to the cultured species, as well as residues, which are of concern to the consumer, must be considered.

When aquaculture systems are isolated from open waters, these environmental impacts (diseases, chemicals, etc) are not transmitted to wild fish stocks. Aquaculture in mining pits introduces an interesting situation. As the pits are essentially isolated from open waters, more control can be exerted on water quality, food and system additives (e.g. prophylactics, fertilizers, etc), much like the scenario observed for closed systems. Due to the size of the pits (1-3 km^2), however, sufficient natural flushing and consequent dilution is anticipated. The development of a unique ecosystem within the pits (i.e. through the growth of phytoplankton and zooplankton as well as organisms in other trophic levels), conditions may be created that prevent accumulation of waste (e.g. detritus) by breaking down this material. A fish waste recycling system, wherein material is collected and reconstituted into fish food, which is currently being developed by the Canada Department of Fisheries, may also be appropriate for these systems.

POTENTIAL FOR AQUACULTURE DEVELOPMENT

Human population is ever increasing, but the total potential production of fish is limited, even considering the potential improvements of fish-harvesting methods in the future. Despite fluctuations in supply and demand, which are caused by the changing state of fisheries resources, the economic climate and environmental conditions, fisheries and aquaculture remain very important as a source of food, employment and revenue in many countries and communities. Reported global capture fisheries and aquaculture production (Table 1) in 1999 was about 125 million tonnes (FAO, 2000). The production increase of 20 million tonnes over the last decade was mainly due to aquaculture, as capture fisheries production remained relatively stable. For the two decades following 1950, world marine and inland capture fisheries production increased on average by as much as 6 percent per year. During the 1970s and 1980s, the average rate of increase declined to 2 percent per year, falling to almost zero in the 1990s. This leveling off of the total catch follows the general trend of most of the world's fishing areas, which have apparently reached their maximum potential for capture fisheries production. It is therefore very unlikely that substantial increases in total catch will be obtained. In contrast, growth in aquaculture production has shown the opposite tendency. Starting from an insignificant total production, inland and marine aquaculture production grew by about 5 percent per year between 1950 and 1969 and by about 8 percent per year during the 1970s and 1980s, and it has increased further to 10 percent per year since 1990.

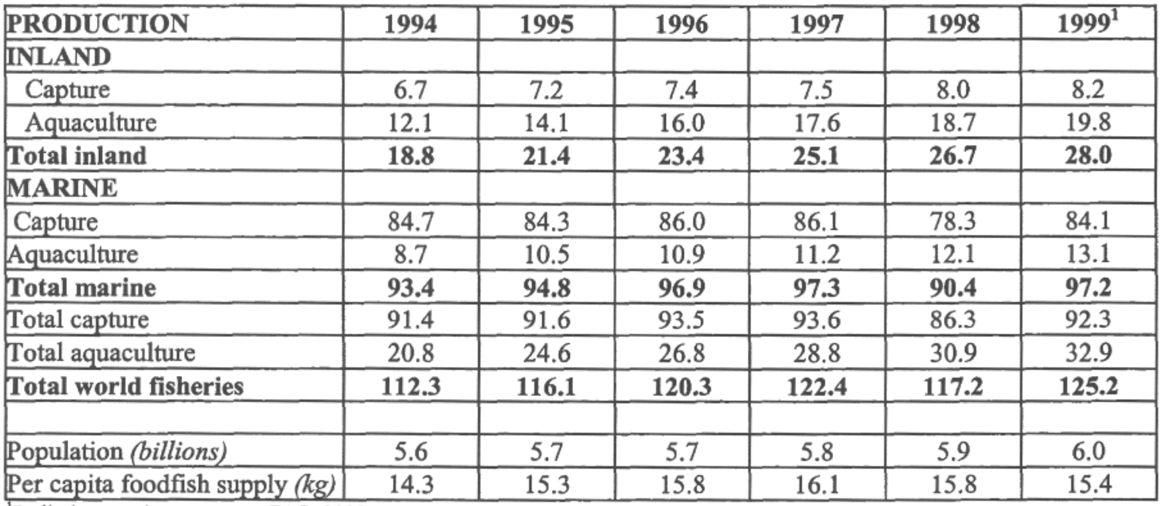
Worldwide employment in the primary capture fisheries and aquaculture production sectors in 1998 is estimated to have been about 36 million people, comprising about 15 million full-time, 13 million part-time and 8 million occasional workers. For the first time, there is an indication that growth in employment in the primary sectors of fisheries and aquaculture has increased (FAO, 2000). Employment in inland and marine aquaculture has been increasing, and is now estimated to account for about 25 percent of the world's total production. Marine capture fisheries account for about 60 percent and inland capture fisheries for the remaining 15 percent.

Aquaculture in Canada

Commercial aquaculture in Canada, which began in the 1970s, has since flourished, becoming an important national industry. In 1986, aquaculture production in Canada was calculated to have earned $35 million. In 1988, values rose to an impressive $433.5 million. By 1995, 7% of the total fish production in Canada originated through aquaculture (Aquaculture Canada 1995). It was during this same time period that fish feed manufacturing, applied scientific research, and this industry of supply and service evolved and expanded into every province. Overall, a 1999 data report by Statistics Canada (2001) indicated that the production of finfish (salmon, trout, steelhead, arctic char, tilapia, perch, walleye) and shellfish (mussels, oysters, clams) increased to approximately 113,000 tonnes with a value of $612 million. Finfish production increased to 85,500 tonnes, an increase of 27% over 1998. Shellfish production increased to 27,600 tonnes, an increase of 15% over 1998. (In terms of world standards, however, Canada is a relatively small producer, estimated to account for about 0.3% of the world aquaculture production). Because of the collapse of many wild fisheries, aquaculture is becoming an increasingly important component of the global world fisheries (Table 1). The growing aquaculture industry provides job opportunities in regions that are hard hit by the decline in the capture fisheries.

Harvesting fish from the natural environment and raising them in a controlled situation is not as easy as it sounds. The fish species, its life cycle, the water source, quality, temperature, chemistry and pollution must all be considered. Above all, the cost of aquaculture must be affordable. One major way in which this affordability could be achieved in countries with flourishing mining industries like Canada, is to turn decommissioned or deactivated open pit mines and tailing ponds into fish ponds for commercial, recreational and ornamental fish farming.

TABLE 1: World fisheries production and utilization
(million tonnes)



PRODUCTION	**1994**	**1995**	**1996**	**1997**	**1998**	**1999[1]**
INLAND						
Capture	6.7	7.2	7.4	7.5	8.0	8.2
Aquaculture	12.1	14.1	16.0	17.6	18.7	19.8
Total inland	**18.8**	**21.4**	**23.4**	**25.1**	**26.7**	**28.0**
MARINE						
Capture	84.7	84.3	86.0	86.1	78.3	84.1
Aquaculture	8.7	10.5	10.9	11.2	12.1	13.1
Total marine	**93.4**	**94.8**	**96.9**	**97.3**	**90.4**	**97.2**
Total capture	91.4	91.6	93.5	93.6	86.3	92.3
Total aquaculture	20.8	24.6	26.8	28.8	30.9	32.9
Total world fisheries	**112.3**	**116.1**	**120.3**	**122.4**	**117.2**	**125.2**
Population *(billions)*	5.6	5.7	5.7	5.8	5.9	6.0
Per capita foodfish supply *(kg)*	14.3	15.3	15.8	16.1	15.8	15.4

[1] Preliminary estimate, source: FAO, 2000.

POST-MINING AQUACULTURE

Mining represents a temporal land use, disrupting relatively small areas of land for a specific (usually short) period of time. Once the ore deposit is depleted, the land is reclaimed for other uses, including recreation. In Canada, of the 30,000 hectares of land disturbed by mining by the end of 1990, only 26% (8,000 hectares) has been reclaimed (Errington, 1991). Over 50% of proposed reclaimed land use objectives are aimed at providing wildlife habitat, grazing and forestry opportunities. In Canada, 128 communities rely exclusively on mining for their livelihood. Aquaculture could be one of the methods for land reclamation and restoration after mining, supporting diversification of the economy in certain towns. One example is found at a hematite iron ore mine found beneath Steep Rock Lake, near

Atikokan, Ontario. When the mine closed in 1980, the site was allowed to return to its natural state. Pumps were turned off and the pits began filling with water. Steep Rock Lake is now host to a commercial fish farm. Fast growing poplar trees and scrub provide wildlife habitat, while local residents enjoy hiking, biking, and rock-hounding (Sowa 2002). At the Granny Smith Goldmine in Australia, an unusual aquaculture venture is an attempt to put something back where mining companies are often criticized for their culture of extraction. Some of the fish found included trout, silver perch and goldfish - all against a massive background of ore crushers and pits (Hayhow and Lamont 2001). The Cobble Hill limestone quarry pit (just north of Victoria) has been used to raise trout, which are used to stock lakes on Vancouver Island. Due to the deep water found in the quarry with very deep water, results have been excellent.

Acid rock drainage (ARD) has been described as "the largest environmental liability facing mining industry. Of the 16 metals mines currently operating in British Columbia, six are producing acid mine drainage and several more have the potential to do so (Errington, 1991). It has been estimated that ARD cost between US$2 to 35 billion in North America (Batterham, 1998). Flooding of pits after mining is often recommended to inhibit the generation of ARD. Island Copper Mine in British Columbia, closed in 1995, was flooded with seawater in July 1996 creating a lake covering 530 acres (Welchman and Aspinall, 2000). In situations where flooding is recommended, either for ARD purposes or for safe closure of the site, alternative uses of these man-made lakes should be explored further.

CASE STUDY: MINING AND AQUACULTURE AT HVC MINE

Highland Valley Copper (HVC) has operated an open pit copper and molybdenum mine in the Highland Valley near Logan Lake since 1962. The ore is a low grade and, as a result, large quantities of waste rock are produced. Stream run-off from the mine site is carefully monitored and controlled so that metal contamination of surrounding region is prevented in accordance with environmental legislation and reclamation permits. HVC has conducted annual environmental monitoring programs in the vicinity of the mine since the early 1970s to monitor the effect of mine operation on local water quality and fisheries resources. These surveys have included the study of benthic invertebrate communities, sediments and rainbow trout *(Oncorhynchus mykiss)* tissues examinations for trace metal concentrations. Rainbow trout are an important sport fish species in western Canada and U.S.A. In the area surrounding HVC, rainbow trout occurs naturally in several creeks and rivers. From 1991 to 1994 some of the pits and ponds were stocked with rainbow trout in order to ascertain their viability in these systems. Pits and ponds throughout the property were stocked with Kamloops rainbow trout from government operated hatchery at Loon Lake and at Abbotford, *BC.* The pit lakes that were stocked included the Highmont West and East pits and two of the three pits, the Huestis and Jersey Pits on the Bethlehem mine site which were very conducive for a successful fishery. Other water bodies where fish stocking has been carried out were seepage collecting ponds from the Trojan Tailings Pond and the Bethlehem Main Tailings (also as Reclaim Ponds No.3 and No,4 respectively). Two other sites of fish stocking were the Reclaimed Reservoir where the effluent from the presently operating tailing impoundment is being pumped to feed back into the concentrator and the other site being the Trojan Tailings Pond which was shut down from active tailings disposal in 1987. Highland Valley Copper has been able to secure an aquaculture permit from the provincial government to raise salmon fries until smoltification. The smolts would then be sold to the fish farms on the pacific coast. These ponds and lakes are not commercial farms.

In monitoring surveys, metal levels were compared to values in rainbow trout from 24 uncontaminated British Columbia lakes as indicators of metal concentrations in tissues of fish from these lakes considered unaffected by human presence (Table *2)* (Rieberger, 1992), Metals levels in fish liver were comparable for the years studied and similar to the BC lakes averages, with the exceptions of Cu and Zn, which often exceeded the average. The level of arsenic was highest at Highmont pits and lowest at Billy Lake, in both situations they were below the BC lakes average concentrations. Manganese levels from Billy Lake, Mamit Lake and Reclaim Pond No. 4 exceeded the uncontaminated BC lakes average. Mercury concentrations on the other hand were relatively low at all locations; almost all the results were an order of magnitude lower than average BC lakes. Iron concentrations were also elevated above the BC Lakes average in the Highmont pits, but as Fe is an essential element there is no health risk hazard associated with these levels.

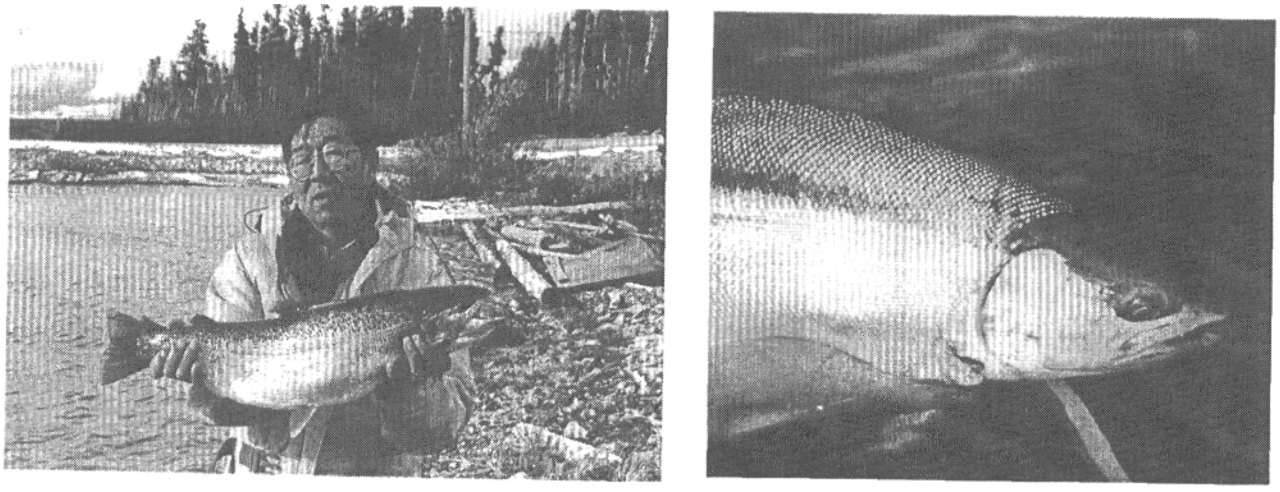


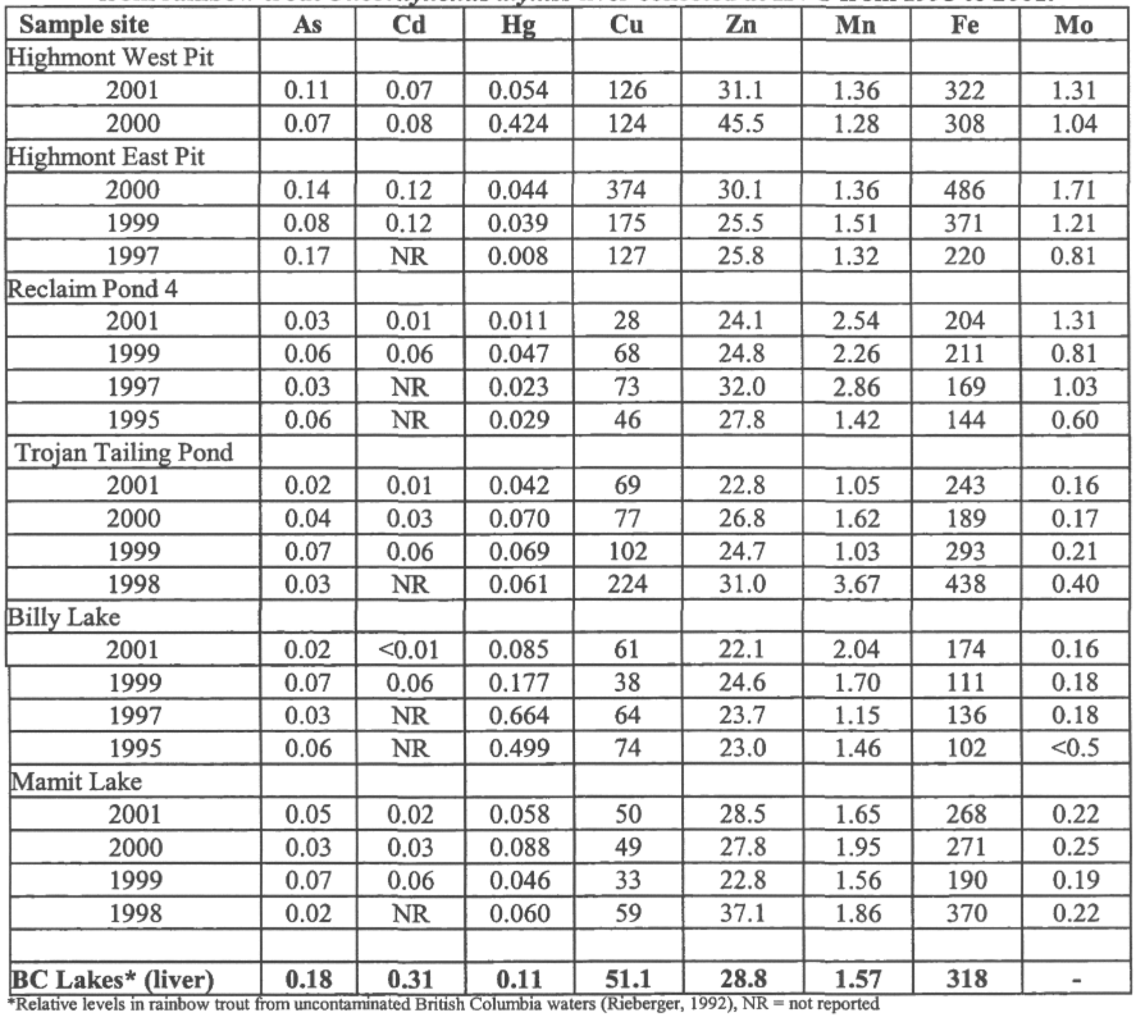
Plate 1 and 2: Trout from the HVC Trojan Pond

These results suggest that metal uptake is not significant for most metals. As metals concentrations in muscles are not known, potential risks (if the fish were subject to human consumption), cannot be ascertained. However, as metals often bioconcentrate more in the liver, low levels in that organ may be indicative of low muscle levels. The results at HVC are particularly interesting as fish food was derived from natural sources, i.e. although fertilizer was added to the systems, no food was given to the fish.

AQUACULTUKE IN MINING - CLOSING THE KNOWLEDGE GAPS

A detailed research program is proposed to further explore the viability of aquaculture in different mining scenarios. This project intends to deliver a methodology to evaluate the suitability of sites for aquaculture, specify requirements for long- and short-term monitoring and identify logistical needs for the successful establishment of aquaculture.

TABLE 2: Summary of average total metal concentrations (mg/kg wet weight) from rainbow trout *Oncorhynchus mykiss* liver collected at HVC from 1995 to 2001.



Sample site	As	Cd	Hg	Cu	Zn	Mn	Fe	Mo
Highmont West Pit								
2001	0.11	0.07	0.054	126	31.1	1.36	322	1.31
2000	0.07	0.08	0.424	124	45.5	1.28	308	1.04
Highmont East Pit								
2000	0.14	0.12	0.044	374	30.1	1.36	486	1.71
1999	0.08	0.12	0.039	175	25.5	1.51	371	1.21
1997	0.17	NR	0.008	127	25.8	1.32	220	0.81
Reclaim Pond 4								
2001	0.03	0.01	0.011	28	24.1	2.54	204	1.31
1999	0.06	0.06	0.047	68	24.8	2.26	211	0.81
1997	0.03	NR	0.023	73	32.0	2.86	169	1.03
1995	0.06	NR	0.029	46	27.8	1.42	144	0.60
Trojan Tailing Pond								
2001	0.02	0.01	0.042	69	22.8	1.05	243	0.16
2000	0.04	0.03	0.070	77	26.8	1.62	189	0.17
1999	0.07	0.06	0.069	102	24.7	1.03	293	0.21
1998	0.03	NR	0.061	224	31.0	3.67	438	0.40
Billy Lake								
2001	0.02	<0.01	0.085	61	22.1	2.04	174	0.16
1999	0.07	0.06	0.177	38	24.6	1.70	111	0.18
1997	0.03	NR	0.664	64	23.7	1.15	136	0.18
1995	0.06	NR	0.499	74	23.0	1.46	102	<0.5
Mamit Lake								
2001	0.05	0.02	0.058	50	28.5	1.65	268	0.22
2000	0.03	0.03	0.088	49	27.8	1.95	271	0.25
1999	0.07	0.06	0.046	33	22.8	1.56	190	0.19
1998	0.02	NR	0.060	59	37.1	1.86	370	0.22
BC Lakes* (liver)	**0.18**	**0.31**	**0.11**	**51.1**	**28.8**	**1.57**	**318**	**-**

*Relative levels in rainbow trout from uncontaminated British Columbia waters (Rieberger, 1992), NR = not reported

Bioavailabilitv And Bioaccumulation Of Metals From Mining Activities

Inevitably, in the event that large scale commercial aquaculture were practiced at mine sites, one of the most significant public concerns with aquaculture would relate to the uptake of metals by fish. Thus, it is of utmost importance to establish protocols to assess metal bioavailability at specific locations.

A number of parameters (e.g. pH, Eh, DOC, etc) have been shown to influence the speciation, and thus bioavailability of metals. For example, at low pH, copper- which is highly toxic to most fish species and other aquatic organisms at relatively low concentrations - tends to be present as a free ion. In ionic form, Cu has been demonstrated to be more bioavailable than Cu complexed with natural organic acids. This is likely due to the competition for free Cu ions between dissolved organics and binding sites on fish gills or gut surfaces. Cu-organic complexes despite lower toxicity than free Cu it can be absorbed by plankton to be accumulated by fish. Conversely, some metals have been shown to be more bioavailable as an organo-metal or metal organic complex. Mercury (Hg), for instance, is readily assimilated by organisms in the organo-metallic form, methylmercury. As well, Hg levels in fish from organic acid-rich waters are considerably higher than those from organic acid-poor waters. It has been suggested that the transformation of metallic mercury into its most toxic form, methylmercury, which is the Hg species found in most edible fish, seems to be mediated by the presence of humic substances in soils and aquatic environments. Preliminary studies on the reaction of metallic mercury with organic acids have indicated that formation of soluble Hg-organic complexes is likely the main pathway for fish pollution. (Veiga et al, 1999). It is evident that the presence and abundance of organic matter plays a significant role in controlling metal mobility and bioavailability. Consequently, the mechanisms influencing organic matter complexation with essential and non-essential metals must be well understood to predict the impacts within a given system. The fraction of organic matter most relevant to metal behaviour in aquatic systems, humic substances, actually consist of a wide range of compounds with similar origins but variable properties. Due to this heterogeneity, predicting the effects on metal complexation and bioavailability can be extremely difficult and will undoubtedly vary from site-to-site (Sparks, 1995).

Survey

This research programs intends to initially conduct a survey to determine the number and location of inactive open-pit mines and flooded tailings impoundments derived from large-scale mining practices. A classification system will be developed wherein pits and impoundments will be indexed on the basis of suitability for aquaculture (e.g., dimensions, "flood-ability", location, climate, etc.) and other relevant characteristics (e.g., accessibility). Physical stability of pit wall rock will be considered to establish the potential for failure. Water from a select group of flooded pits and impoundments will be assessed (i.e. Eh, pH, metal content, etc.) and will be sampled through laboratory analysis to determine its chemical parameters. Survey results must be reviewed to determine the appropriateness of these artificial water bodies for commercial or recreational aquaculture. Local community attributes and the potential socio-economic benefits of aquaculture (e.g., infrastructure, employment, etc) will also be examined during this phase to further contribute to the site selection process. The information compiled on the sites will be presented in a decision-making matrix, and will subsequently be weighed and ranked on the basis of physical, chemical, biological and socio-economic parameters. This decision making must include which type of aquaculture is desired (commercial or recreational). From these surveys two field sites must be selected for initial laboratory studies based on the results of the decision-making matrix. As fingerlings (post-larval stage or juvenile fish) are very sensitive to any disruption in water quality, their responses may be indicative of a worst-scenario case.

Implementing results in the field

A number of initial field tests must be carried out over a 3-month period (two series of tests for 4 week duration, plus set-up and sample collection). Larger scale field tests must also be conducted once results of initial field tests are reviewed. These should take place over a 6-month period, which is typically the maximum allowable growth period for fish grown in fish farms. Metals cycling in the systems must be assessed prior to commencement of fish exposure, and at various. This would involve sampling and analyses of metals in various compartments: dissolved in the water column; associated with particles, dissolved organic carbon (DOC) and in sediments. The composition of DOC (e.g., humic and fulvic acids, detritus, etc.) must be determined through selective extraction in various lixiviants (i.e., NaOH). Run-off water and precipitation must also be analyzed. Tissues from a statistically significant number of fish must be sampled weekly in order to establish a dose-response. Physico-chemical parameters to be determined must include: Eh, pH, TOC, DOC, anions, total metals, and dissolved metals. Hydrological parameters, such as rate of infiltration, flushing within the aquatic system, and groundwater conditions, must also be assessed. The ecotoxicological model must also be supported by bioassays of other organisms. Other species, such as bivalves or benthic invertebrates, must also be used to assess bioaccumulation and toxicity using existing protocols.

CONCLUSION

If lands reclaimed from mining, or portions thereof, could be used for alternative revenue generating ventures - such as commercial fish farming and recreational (sport) fishing, sustainability will be supported. In addition to potential benefits related to economic diversification and the addition of value to the area, establishing aquaculture may strengthen the link between the community and the mine, thereby supporting the inclusion of the community in long-term monitoring programs.

The potential for the implementation of aquaculture in mining scenarios has been the main focus throughout this review, although a number of innovative, alternative end land uses should be explored by mining communities in conjunction with the surrounding communities. Economic hardship experienced by many local communities after the closure of mines can be reduced with new ventures, such as commercial or recreational aquaculture. However, in order for aquaculture to be viable and publicly accepted, a number of issues must be resolved. Metals uptake must be thoroughly assessed at any location considered, as well as the hydrology of the site (as it relates to flushing and chemical exchanges with natural systems) and other environmental issues (e.g. climate). At places where the potential for metal uptake is high, sport fishing or ornamental fish fanning could be encouraged. In addition, artificial feeding would be practiced during the operations thereby reducing contaminant uptake substantially. Fish culture would also be undertaken for the shortest possible period of time, thereby minimizing metals accumulation further. Aquaculture is just one option for alternative end-land uses at mine sites - it is an important example, however, of how mining companies can contribute to long-term sustainability in the communities where they operate.

FOR MORE INFORMATION

If you would like additional information on the *Aquaculture and Mining Research Initiative,* please contact Dr. Marcello Veiga at the University of British Columbia, 517 - 6350 Stores Road, Vancouver, BC V6T 1Z4 (604 822-4332; veiga@mining.ubc.ca).

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