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from: Stephen Schultz

date: March 9, 1999

subject: **Dillon and Brodie Reports on Cost of As_2O_3 Permanent Disposal**

pages: 12

Larry,

8 pages from the Dillon (October 1997) report (note table on last page).

And, for comparison, 3 pages from the Brodie (November 1997) report.

Both make reference to alternative disposal methods in the hundreds of millions range, but where the specific figure of $250 million came from, I've got no idea.

Regards,

Stephen.

Arsenic Trioxide Management Feasibility Study

Report

October 6, 1997

Arsenic Trioxide Management Feasibility Study
Yellowknife, NT

Indian and Northern Affairs Canada

95-2832-04-01

Submitted by

Dillon Consulting Limited

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OCTOBER 1997

EXECUTIVE SUMMARY

Dillon Consulting Limited was retained by the Department of Indian and Northern Affairs Canada (DIAND) to assess and prepare a report on the current market, technology and feasibility for managing arsenic trioxide currently stored underground at the Giant Mine site in Yellowknife. The report is not intended to be a detailed assessment but is to provide indications of current technologies, first order estimates and initial economic requirements for the Departments planning purposes.

Information was obtained from several sources. The Internet was a primary source for initial information pertaining to companies handling arsenic trioxide in some capacity which then directed further inquiries. Information accuracy was confirmed by contacting named companies directly and by cross checking with government databases. The U.S. Geological Survey Web site contained a large quantity of current information regarding the economics, usage and the outlook for arsenic as a marketable commodity. The Economics of Arsenic, 1990 edition, published by Roskill Information Services in the UK was another useful source of data for all aspects of arsenic trioxide usage. Technical information on the processing and handling of arsenic trioxide was extracted from case studies and scientific reports authored by various groups.

The prospect of selling arsenic trioxide on the open market looks hopeful. Arsenic trioxide has been used for many purposes in the past including: agricultural chemicals (pesticides and herbicides), wood preservatives, glass manufacturing and metal alloys. Environmental concerns have reduced the use of arsenic trioxide in all sectors with the exception of wood preservatives. Three wood preservative companies: Hickson Corp., Osmose Corp. and CSI all located in the United States have the capability to accept large, continuous shipments of arsenic trioxide from Giant. All three companies expressed some interest in the product during information inquires. Hickson Corp. received approximately 20,000 tons of crude arsenic trioxide in the 1980's from Giant and were interested in the results of Giant's research into upgrading the crude material. This interest has been renewed in the past year with intermittent correspondence. Osmose Corp. received arsenic trioxide from Miramar Con Mine, Yellowknife, NT., treatment plant until about 1990. CSI has not had dealings with mines in the NWT but expressed interest. All three companies would require the crude product in Giant's storage vaults be upgraded to a minimum of 95% arsenic trioxide and a number of other impurities (particularly antimony and iron) would have to be reduced before it would be considered as an acceptable product. The electronics Industry has an increasing market for pure arsenic metal, but only uses small volumes of product and requires very high purity of the material, 99.9999%, making it an unlikely target market for the material stored by Giant.

The stored arsenic trioxide would have to be upgraded to a minimum of 95% before being widely marketable. Purities of 99% or higher would command a better price. Two purification methods are currently in common use, sublimation and solvent extraction. Sublimation involves a process of heating the arsenic trioxide containing material to a high enough temperature sufficient to convert the trioxide to a gaseous state. The gas is then passed through a series of condensers to produce a purified product. An alternate method uses hot water to dissolve the arsenic trioxide, leaving behind impurities. The trioxide is then recrystallized as a product with at least 99% purity. Con Mine in Yellowknife constructed a processing plant to purify arsenic trioxide from a tailings pond sludge using the hot water leach method. The plant was in operation through the 1980's and successfully treated Con's stockpiled arsenic trioxide to produce 99.7% pure arsenic trioxide. The material was sold to Osmose Corp. in the U.S.. The gold and silver present in the treatment residue were successfully reclaimed, contributing to the economic success of the plant.

Approximately 137,000 ounces of gold are believed to be present in the baghouse dust kept in the arsenic trioxide storage vaults at Giant Mine. Several metallurgical processes have been developed to recover precious metal values from mine wastes containing high levels of arsenic. Con Mine successfully developed a method to extract gold and silver from the residue produced in the arsenic trioxide treatment plant. Rough calculations suggest that removing the arsenic trioxide would leave a gold concentration in the dust greater than that currently being mined by Giant. Economic factors suggest that any attempt to purify the arsenic trioxide for sale should probably include recovery of the gold contained in the dust.

Accessing and conveying the material to the surface for processing would require careful design to minimize health and environmental hazards. The primary concern would be the generation of dust. Inhalation of the arsenic or absorption through the skin can be fatal. The recovery of arsenic will present a number of technological challenges because, while Giant has considerable experience placing the arsenic trioxide underground, it has not moved or recovered significant material. A small quantity of material was successfully accessed in the 1980's and sent to the U.S. for sale and testing.

A number of technologies and methods are available to complete on-site treatment of the material to render it environmentally inert. The most environmentally stable form of arsenic is as a ferric arsenate. Arsenic naturally occurs in this form. The cost of converting arsenic trioxide into ferric arsenates can be high as a molar ratio of 3 or 4:1 iron to arsenic is required. The conversion is carried out in an autoclave as the process requires temperatures of 130-140°C and a pressure of 100 psi. A process under development at McGill University will use ratios of 1.1:1 iron to arsenic. Iron arsenate sulphate hydroxy compounds are another stable arsenic form produced in an autoclave but they also require a large amount of iron and some sulphur. Arsenic sulphates can be produced in a roaster and are considered stable enough for long term disposal. A pilot scale process has been developed to produce arsenic sulphide in a bioreactor with an efficiency rate six times that of chemical means. Conversion of the waste to calcium arsenate is no longer considered a suitable disposal method as the calcium reacts with CO_2 in the atmosphere to form calcium carbonate, thereby releasing the arsenic into the environment. A potentially low cost method for on-site disposal may be to combine the arsenic trioxide with a chemical cement to produce a hardened product. In some instances the cement may be reusable for structural purposes, eg. road beds. The substances produced from any of these processes could be disposed of safely in tailings ponds.

Off-site treatment or disposal options appear to be quite costly, with initial estimates in excess of 750 $/ton. The amount of material to be disposed of and the resultant cost make this option unlikely.

The problem of handling large amounts of arsenic trioxide appeared in most literature regarding precious metal mines. Several case studies were obtained discussing options for disposing of arsenic trioxide and have been included in Appendix H of this report. The most pertinent study was carried out by Nerco Con Mine and outlines the methods used to dispose of a large amount of arsenic trioxide in an economically and environmentally acceptable manner. Giant has also studied the options for marketing the arsenic trioxide and has produced a number of reports detailing the technological requirements to handle and process the waste material. Copies of these reports were not obtained but would provide specific information on the Giant Mine case.

5.0 SUMMARY

Dillon was retained to provide a brief assessment of options for managing the arsenic trioxide contained in underground storage vaults at Giant mine in Yellowknife, NT. The study was intended to provide indications of current technologies available for all aspects of handling the waste.

The research suggests that the market for arsenic trioxide lies chiefly with the wood preservative manufacturers. The prevailing trend is to develop safer alternatives to arsenical products, but the wood preservative industry has remained consistent in its demand for arsenic trioxide. The demand for arsenic is not expected to grow much beyond current levels. Three companies contacted expressed interest in purchasing material from Giant, but marketing the large volume of material stored by the mine will require careful planning.

Osmose Corp., Hickson Corp. and CSI in the U.S. would be the most likely purchasers of any product from Giant. Hickson purchased material from Giant in the early 1980's, and Osmose purchased material from the Con mine's treatment plant until 1990 when Con's stockpile of arsenic trioxide material was exhausted. All three companies required the product to be at a minimum purity level of 95% with 99% being most favourably priced. CSI indicated that some lower grade material was purchased to blend with higher quality material but 95% was the purity most often purchased. The purification can be carried out using a hot water leach or a sublimation process. In 1981, Con chose the hot water leach process for use at its' treatment plant as they felt it was the more environmentally responsible option.

Any purification method chosen should incorporate extraction of residual gold from the arsenic containing dust. Approximately 130,000 ounces of residual gold are contained in the waste material. The economic success of the Con mine treatment plant was due in part to the successful reclamation of the residual gold and silver with the arsenic trioxide.

Accessing the material and conveying it to the surface or otherwise gaining access to it for management purposes would require careful monitoring. Arsenic trioxide is a known carcinogen, potentially fatal if inhaled or ingested and can be absorbed through the skin. Precautions would be required to minimize direct worker contact with the material and keep dust generation low. Routine biological monitoring of staff and constant air and water monitoring are required at facilities processing arsenic trioxide. Giant has had considerable experience handling arsenic trioxide and currently processes the material safely.

A number of technologies are available to render the material environmentally inert either for long term surface storage or for storage in containment vaults. Arsenic trioxide is very soluble, and must be converted to a less soluble form if contact with water is a possibility during long term storage. Iron arsenic compounds produced in an autoclave tend to be the most insoluble. Large amounts of iron are required for the process which results in higher costs for this method. Arsenic sulphur compounds also have low solubility and have the advantage of being produced in a roaster or by biological means. Calcium arsenates are no longer considered acceptable for arsenic storage due to reactions with atmospheric carbon dioxide. The arsenic trioxide can be mixed with chemical cements to form a stable product. The cement physically and chemically binds the arsenic, rendering it unavailable to the environment. In some cases the cement can be reused for structural purposes (e.g. roadbeds). Studies have shown cement encapsulation to be the most economically viable long term disposal option.

Initial estimates for off site disposal started at $Cdn. 750.00 per ton, before considering transportation costs which range from $Cdn. 40 to 120 a ton. Considering the large volume of arsenic trioxide to be dealt with, this option is not economically feasible. The total cost for off-site disposal would be in excess of $Cdn. 220 million.

Case studies indicate the material can be dealt with in several ways. One method is to convert the arsenic into a more stable form to reduce the potential environmental impact. Processing costs for this option can be high. The preferred method is to convert the arsenic trioxide into a saleable product, thereby at least partly recovering processing costs. A program is currently underway at the El Indio mine in Chile to market arsenic trioxide produced from a roaster unit. Con mine treated 70,000 tons of stockpiled arsenic trioxide sludge starting in 1981. The project ended in 1990 when the supply of arsenic trioxide was used up. During this period, the sale of arsenic trioxide combined with the value of recovered gold and silver covered the cost of operating the plant.

Table 1
Disposal Cost Summary*

Disposal Method	Feasibility	Capital Cost (a)	Operating Cost	Transport Cost	Cost Recovery	Estimated Total Cost
Secure Landfill (b)	Difficult	0	$750/ton	$40-120/ton	0	$205-225 million
Offsite Treatment (b)	Yes	0	$1600/ton	$40-120/ton	0	$425-445 million
Off-site Incineration (b)	No (Impossible)	0	$1300/ton	$40-120/ton	0	$347-368 million
Bioremediation	Under Development	$20 million	$7390/ton	0	0	$1,542 million
Cement Stabilization (c)	Yes	$20 million	$20-80/ton	0	0	$25-31 million
Phytoremediation (d)	Under Development	N/A	$40-694/ton	0	0	$10-180 million
Ferric Arsenate (e)	Yes	$20 million	$5.09/lb of As removed	0	0	$1,684 million
Arsenic Sulphide (e)	Yes	0	$2.19/lb of As removed	0	0	$725 million
Marketing	Yes	$20 million	$650/ton	$40-120/ton	$202 million	$10-30 million profit

* The cost of accessing the material has not been included as general information on this process could not be obtained.

(a) Capital costs are based on the Con mine's treatment plant capital cost, scaled up to meet Giant's processing requirements.

(b) Off-site disposal method values were based on costs supplied by Proeco.

(c) Cement stabilization values were supplied by Stark Encapsulation.

(d) Phytoremediation capital costs are included in operating costs. Values were supplied by Phytotec Inc.

(e) Stefanakis and Kontopoulas, Pg. 289, Table II. Prices were adjusted to 1983 levels.

for reference: 3 pages from the Brodie report (Nov. 1997)

REPORT ON

GIANT MINE CLOSURE COST ESTIMATE

Submitted to:

Department of Indian Affairs and Northern Development
Water Resources Division
Box 1500
4914 - 50th Street
Yellowknife, NT, X1A 2R3

Prepared by:

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November 27, 1997

TABLE 1
SUMMARY OF CLOSURE OPTIONS FOR ARSENIC TRIOXIDE

OPTION	DESCRIPTION	COMMENTS	ORDER OF MAGNITUDE COST
1	"Do nothing"	not acceptable, excessive release of arsenic	nil
2	Cooling with winter air	unlikely to be effective, would require perpetual effort to maintain ventilation system and mine dewatering	$12,450,000
3	Additional bulkheads	beneficial if existing bulkheads leak, will be difficult to significantly reduce gross permeability around chambers	not effective
4	Grout curtains	beneficial if existing fracture zones intersect chambers, will be difficult to significantly reduce gross permeability around chambers to be a stand-alone option	not effective
5	Ice plugs	unlikely to be effective as a stand-alone option, would require perpetual effort to maintain ventilation system and mine dewatering.	not effective
6	Thermosiphons to induce permafrost	high capital cost, passive long-term solution, periodic maintenance required.	$7,044,000
7	Perpetual mine dewatering	probably insufficient as a single control measure, would be required in perpetuity, cost included in option 2.	not effective
8	Hydraulic isolation	proven concept, could be achieved with drain system around chambers, may require additional bulkheads, no perpetual maintenance, caps on ground surface over chambers may be required to reduce infiltration	$8,150,000
9	Removal, on land storage	very costly, would require significant improvement over secure underground containment to justify risk of removal, would be difficult to remove all arsenic trioxide.	> $200 million (ref. Dillon Consulting Ltd.)
10	Removal, conversion to ferric arsenate	prohibitively costly	>$700 million (ref. Dillon Consulting Ltd.)
11	Removal, gold recovery & preservative product	beneficial in that the liability is completely removed, based on past experience and current gold prices this option seems unlikely to viable, would be difficult to remove all arsenic trioxide.	$40 to $90 million (ref. Dillon Consulting Ltd.)
12	Long-term water treatment	conceptually viable, primary concern is sludge disposal. (not included in this cost)	$8,300,000 + sludge disposal

< selected

The estimated closure cost presented here should be the basis for reclamation security until such time as the company's plan has been submitted and approved.

A summary of the reclamation cost estimate is presented in Table 2. Note that the amount for monitoring and maintenance would be required in cash as part of the reclamation security so that the fund for perpetual operations could be established.

TABLE 2
RECLAMATION COST SUMMARY GIANT MINE

MINE COMPONENTS	ESTIMATED COST
Open Pits	$215,196
Quarries	$3,245
Underground Mine	$365,356
Waste Dumps	$0
Old Tailings Impoundment	$323,015
Northwest Tailings Impoundment	$196,400
Yellowknife Bay & Baker Creek Tailings	$4,864
Mill & Surface Facilities, includes townsite & roads	$1,040,658
Wastes, Chemical & Contaminated Soil	$630,856
Water Management & Treatment	$365,098
Contractor's Mob/Demob	$50,000
Arsenic Trioxide Chambers	$7,044,000
Sub-Total	$10,238,688
Project Management, @ 3%	$307,161
Engineering @ 3%	$307,161
Contingency @ 20%	$2,047,738
Reclamation Research	$250,000
TOTAL - CAPITAL COSTS	**$11,103,009**
Monitoring & Maintenance, annual cost	$300,176
Monitoring & Maintenance, Net Present Value annual payment of $300,176 every year for 20 years; interest =5%, plus 20% contingency	**$4,789,224**
TOTAL RECLAMATION LIABILITY	**$15,892,233**

I trust that this report addresses your current requirements. Should you have any questions please call. I would be pleased to revise this estimate of reclamation liability should additional information become available.

Yours truly,
Brodie Consulting Ltd.

M J Brodie

M.J. Brodie, P.Eng.