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Larry - Any comments would be appreciated, Gary

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As discussed, it would be greatly appreciated if you could fax your comments on the draft attached as soon as possible in order to meet both the publication deadlines and ensure that information is correct.

Thanking you in advance for your kind consideration on this matter.

FROM: E. KOREN (613) 992-4830 DATE: Mar. 26, 1992

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DRAFT/ÉBAUCHE

ARSENIC

ELAINE N.A. KOREN

Arsenic occurs as a minor constituent of polymetallic sulphides mined primarily for their copper, lead, silver or gold content. Major arsenic-containing minerals are arsenopyrite (FeAsS), realgar (As_4S_4), and orpiment (As_2S_3). The arsenic content of the earth's crust is 1.5-2.0 mg/kg; it ranks 20th in abundance in relation to other elements (NAS, 1977). Oxidized forms of arsenic are usually found in sedimentary deposits. The elemental oxidation state, though stable in reducing environments, is rarely found. Table 1 gives some ranges of the arsenic contents of crustal materials. High levels of arsenic may also occur in some coals. The average arsenic content of coal in the Canada was estimated at 0.3-320 mg/kg. In some coal mined in Czechoslovakia, the concentration of arsenic has been shown to be as high as 1500 mg/kg.

CANADIAN DEVELOPMENTS

located within permit zones.

With the continued decline of the arsenic market, current environmental and health considerations, Royal Oak Resources Ltd.'s Giant Yellowknife Mines, located in the Northwest Territories continues to stockpile its arsenic trioxide recovered from dust and residues collected during the roasting of gold ores in permanent underground stope encryptions. Recovery technology includes the electrostatic precipitation of dust, cooling of the arsenic-containing gases and collection of arsenic trioxide in the baghouse which grades 85 to 93 per cent. Approximately 40 tonnes of material was shipped to the USA for testing purposes.

With shifting priorities since the Royal Oak takeover, Giant's white arsenic oxide [WAROX] pilot plant project to treat crude arsenic trioxide [purity currently 85%] to produce high quality industrial product [purity of 99%] has been placed on hold. This project would involve using sintered metal technology_{and refining process} for recovering arsenic ~~pentoxide~~_{trioxide} to be used in wood preservative industry.

Dickenson Mines', Red Lake Division had been recovering the by-product arsenic from dusts and residues associated with the roasting of these ores and collected as impure arsenic trioxide which is either purified on site or sold directly to a refiner. Given current environmental, health and economic considerations, roasting of the arsenic-rich ores has been discontinued since 1980. Instead, arsenic extraction occurs using bulk sulphide flotation yielding up to 50% recovery. Oversize and tailings are stored in underground stopes and tailings ponds respectively.

Future plans involve deciding on the options of using either the bioleaching or

bacterial oxidation [BIOX] or a pressure oxidation process using an autoclave. It is expected that either choice will push the percentage of gold recovery to 95%. Current gold recovery is in the mid-80s. To date, the expected investment of the pressure oxidation process is in the order of \$25 Million whereas the BIOX investment is approximately 25% of the former.

Placer Dome's Campbell mine recently [on July 19] brought an autoclave on stream and shutdown the roaster on July 20. The pressure oxidation process [99.9% O₂ completion] converts sulphides to sulphates. Hence, arsenic sludges can be turned into ferric arsenate, relatively environmentally benign. Furthermore, the process enhances recovery of associated metal residues formerly lost in tailings. The ferric arsenate then passes through a clarifier and the resulting sludge is stored in designated ponds.

It is estimated that Placer Dome's payback will be within two and half years. Additional benefits include increased gold recovery, reduced cyanide and calcine consumption, use of a single stage leach tank compared with the former multi-stage processing and reduced metal losses in the tailings [i.e. from 0.25 - 0.29% oz/t to 0.005 - 0.01 % oz/t].

Nerco Minerals, based in Vancouver, Washington has stated that it will treat and stabilize toxic sludges that were produced at its Con Mine in Yellowknife, Northwest Territories between 1948 and 1970 using the pressure oxidation process. Nerco inherited approximately 40,000 tonnes of arsenic-laden sludges when it purchased the mine from Cominco Ltd., Toronto in December 1986 for \$46 Million.

Nerco Con Mine Ltd., the Yellowknife-based subsidiary that currently operates the mine, has been extracting arsenic-rich ores since June 1990 and stockpiling the mined materials while waiting approval from the Northwest Territories Water Board, which will review the proposed technology in a plan submitted by the company by February 22/91. With approvals given, the company plans to start-up schedule in the first week of July 1992.

Canadian arsenic production is produced as arsenic trioxide as a by-product of the treatment of arsenious gold ores. The value of Canadian arsenic trioxide shipments in 1991 is not available given that 40 tonnes were shipped for laboratory testing in the USA, with the remainder of produced materials being either stored in underground stopes or converted to ferric arsenate for storage.

WORLD PRODUCTION

Although arsenic metal production ceased in 1987 following the closure of Boliden's old polymetallic mine, arsenic trioxide production was stopped only in April

1991. In 1990, the arsenic trioxide plant produced only 2 000 tpy out of its 15 000 tpy capacity from its diminishing stockpile.

According to the U.S. Bureau of Mines, major sources of arsenic trioxide include Peru and the Philippines (from copper ores), Chile (copper-gold ores), and Canada (gold ores). Worldwide arsenic metal reserves approximate 1M tonnes. Further, it is estimated that world resources of copper and lead contain approximately 11M tonnes of arsenic.

USES

In 1991, about 70% of arsenic was used in wood preservatives, 22% in agricultural chemicals, 4% in glass manufacturing, 2% in nonferrous alloys and 2% in other uses. The United States remains the world's largest consumer of arsenic, using over 50% of world production.

The wood preserving chemicals most commonly used are chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA) and fluorochrome arsenate phenol (FCAP). Arsenical wood preservatives are used when ever rot or insect damage may occur such as in building foundations, fence posts, submerged footings and utility poles.

The agriculture share of arsenic use has dropped from over 80% a decade ago to the current 22%. Monosodium methanearsenate (MSMA) and disodium methanearsenate (DSMA) are the most common agricultural arsenical chemicals. These compounds are used as herbicides, plant desiccants and defoliants primarily in the cotton industry where they control grassy and broad-leaved weeds. Arsenicals are considered essential as growth regulators for grapefruit growers and for the control of some grape diseases.

The glass industry uses arsenic trioxide as a decolourizing and a refining agent. Due to environmental concerns the glass industry has been substituting arsenic acid for arsenic trioxide to reduce dust problems associated with handling the trioxide.

Arsenic metal is used as a minor alloying agent (.01-.05) in certain copper and lead based alloys. When added to lead for use in acid storage batteries, arsenic strengthens the lead posts and grids to help withstand sudden jars. Arsenic is also added to lead, in many countries except the US, to make shot for bullets. Arsenic increases the corrosion resistance and tensile strength of copper used in industrial plant piping and auto radiators. Arsenic trioxide can be used in place of arsenic metal in some alloying applications although it is more difficult to use and creates more environmental problems.

High purity arsenic metal (99.999 %) is used in the electronics industry. Gallium

arsenide and its alloys are important semiconductors and are used in such products as light-emitting diodes, microwave devices, solar cells and photoemissive surfaces. Gallium arsenides have higher operating frequencies, lower power consumption, lower noise and higher resistance to nuclear radiation than their silicon counterparts. Integrated circuits using gallium arsenide have extensive military applications.

SUBSTITUTES

Increasingly substitutes are being found for most of arsenic's major end uses, although arsenic may be the preferred material due to lower cost and superior qualities. The wood preservatives pentachlorophenol and creosote may be substituted for chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA) where odour and paintability are not problems. Nonwood alternatives such as concrete and steel may be substituted for arsenical pressure-treated wood.

In agricultural uses, synthetic organic compounds, such as parquat may be substituted for arsenical pesticides, herbicides and desiccants. To date, there are no available alternatives to the of arsenicals as growth regulators for grapefruit and for the control of some grape diseases.

The use of arsenic in the glass industry is declining. Corning Glass estimates that they use nearly 900 tonnes of 75% H_3AsO_4 liquid per annum in their glass operations. Increasingly cerium and cobalt are used mainly in conjunction with selenium as an oxidation-reduction buffer.

Arsenic use in alloying and brass is diminishing with new regulatory requirements to prevent site specific usage, i.e. prohibit the use of arsenic in any substances that may be totally or partly submerged appliances or equipment.

Wide range substitution of arsenic's major end uses may stem from the fact that arsenic is not widely recycled. For example, the losses at all stages of the manufacturing process for LEDs [light emitting diodes] are quite high. Only a fraction of the gallium arsenide in the original ingot ends up in usable devices. Some of these losses could be recycled. Companies specializing in gallium recovery from electronic scrap have begun to appear in Japan, the USA and Europe. The extent to which arsenic is also recycled is not known, however, given current environmental considerations, it is likely that the arsenic is recovered concurrently.

HEALTH AND SAFETY AND REGULATORY DEVELOPMENTS

Environmental arsenic exposure has received attention primarily because of

disease resulting from ingestion of water containing inorganic arsenic. These diseases have been those of chronic arsenic poisoning. Examples include nonmalignant cutaneous changes such as skin cancers, "Blackfoot disease" [a form of arsenic-induced peripheral vascular deficiency leading to gangrene], peripheral neuropathy, plus hematopoietic, renal, and hepatic toxicity. Reports have indicated ingestion of water containing less than 1 000 $\mu\text{g/l}$ of arsenic over a period of years.

An alternate route of arsenic exposure stems from the inhalation and ingestion of arsenic-containing dusts and fumes mainly emitted from smelters. Conflicting evidence suggests that such exposure is associated with an increased incidence of lung cancer. For example, a population survey around the former Tacoma smelter operated by ASARCO indicated a correlation to lung cancer. Whereas, intensive studies undertaken by the Department of Indian and Northern Affairs Canada into the potential health effects of arsenic in Yellowknife, NWT and other mining camps where arsenopyrite is roasted were inconclusive and showed no such evidence. [Lung cancer has not been associated with the ingestion of arsenic-contaminated water.]

In Canada, arsenic and its compounds have been listed in Group 1 of the Priority Substances List. Through the Departments of Environment and National Health and Welfare, arsenic and its compounds have been assessed to determine whether they are toxic according to the definition specified in Section 11 of the *Canadian Environmental Protection Act [CEPA]*. The final report with its conclusions will be made available in the second quarter of 1992.

In the U.S., arsenic and its compounds are regulated by the Occupational Safety and Health Administration (OSHA), which has set an 8-hour time-weighted occupational exposure limit to inorganic arsenic of 10 $\mu\text{g}/\text{m}^3$. Arsenic also falls under the Environmental Protection Agency's (EPA) Superfund legislation as the EPA is particularly interested in groundwater contamination and arsenic emissions.

In September 1991, the Commission of the European Communities issued council directives relating to restrictions on the marketing and use of arsenic and its compounds. These include prohibition of arsenic compounds for the prevention of fouling by micro-organisms, plants, or animals of the hulls of boats; cages, floats, nets and any other appliances or equipment used for fish or shellfish farming; any totally or partly submerged appliances or equipment; in the preservation of wood; [the ban does not apply to solutions of inorganic salts of the CCA [copper - chromium - arsenic] type employed in industrial installations using vacuum or pressure to impregnate wood.

Member States may authorize on their territory the use of preparations of the DFA [dinitrophenol - fluoride - arsenic] type for the retreatment *in situ* of wooden poles already in place and supporting overhead cables. These preparations must be employed by professionals using vacuum or pressure.

PRICES (in \$US)

At the outset, in 1991, the Chinese tried and failed to get a grip on the arsenic market. By the end of January, arsenic had traded up to US\$ 1.40/lb in frantic trade activity that was going against the general trend of the base metals. The Hong Kong traders were sceptical of the price increases which is believed to be the work of a few European traders. Traders in China indicated that arsenic producers are unlikely to bring on stream idled capacity to meet the new demand after last year's experience [arsenic prices went from US\$ 0.50/lb in late 1989 to over US\$ 6.00 early 1990 on similar supply scares]. Many producers which started up after the 1990 price increase shut down again after the price dropped.

Given current economic and environmental conditions, these producers are reluctant to restart operations due to lack of certainty of the duration of the latest bull run. Observers speculate that arsenic prices may rise to approximately US\$ 2.00/lb on the nearby squeeze. At year end, the Chinese material was available in the US free market for as little as US\$ 0.82 - 0.85/lb in a cash market.

OUTLOOK

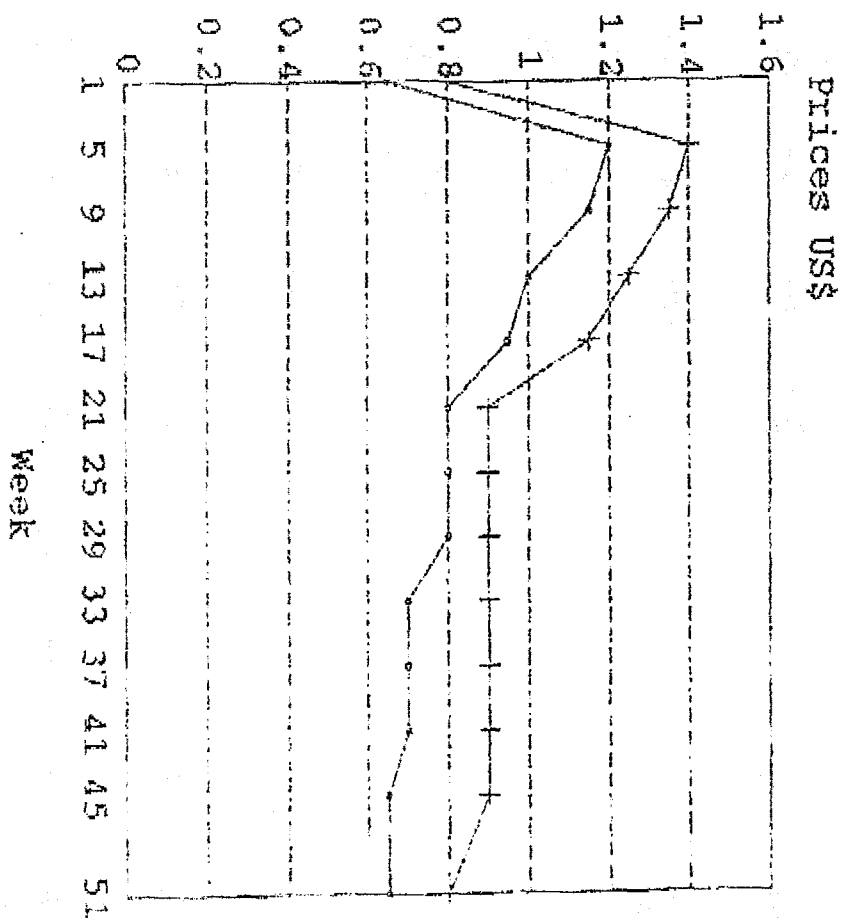
The outlook for arsenic is somewhat uncertain though supplies are abundant and demand is expected to remain relatively flat. As arsenic is produced primarily as a by-product, its production is dependent on the demand for, and production of other metals (copper, gold, lead and zinc). However, environmental concerns have reduced demand for arsenic. Although substitutes exist for most uses, arsenical compounds are either the preferred or only product for specific uses (i.e. grapefruit orchards and grape vineyards).

TABLE 1: Arsenic in crustal materials

Type	Range
Igneous rocks	As [mg/kg]
ultrabasic	0.3 - 16
basalts	0.06 - 113
andesites	0.5 - 5.8
granitic	0.2 - 13.8
silicic, volcanic	0.2 - 12.2
Sedimentary rocks	
limestones	0.1 - 20
sandstones	0.6 - 120
shales and clay	0.3 - 490
phosphorites	0.4 - 188

ARSENIC PRICES FOR 1991

[Weekly Prices from the Metal Bulletin]



--- LOWER RANGE PRICE \$
 +--- UPPER RANGE PRICE \$