

November 21, 1995

FAXED
NOV 21/95

SEACOR
ENVIRONMENTAL
ENGINEERING, INC.

Royal Oak Mines Inc.
5501 Lakeview Drive
Kirkland, WA
98034-7314

Attention: Larry Connell, P.Eng.
Manager of Environmental Services


Dear Sir:

RE: GUIDELINE DOCUMENT ON ARSENIC: PROGRESS REPORT
SEACOR JOB NO. C0440-001

Enclosed are the Table of Contents and the first two sections: "Objectives and Scope" and "Organization of the Report," of the document as it currently stands. We are 95% complete and expect to be formatting the final edits within the next week. Attached is an invoice for the work conducted to date. We will submit a final invoice upon receiving approval from Royal Oak on our final report.

Please contact me directly with regards to the enclosed. We expect to have a draft copy of the report to your office, with an additional copy to Erik Madsen, by November 30, 1995.

Yours truly,
SEACOR Environmental Engineering Inc.



Serena Domville
Principal Scientist

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OBJECTIVES AND SCOPE

SEACOR Environmental Engineering Inc. (SEACOR) has been retained by Royal Oak Mines Ltd. to prepare a reference document on arsenic, covering its properties, methods for detection and speciation, toxicology and fate, as well as the current regulations controlling its release to the environment. This document is not intended to provide exhaustive coverage on the topics under review but rather an updated and comprehensive account of current understanding and practice.

The word arsenic apparently is derived from the Greek word *arsenikon* meaning potent. Arsenic has had numerous industrial and medicinal uses over the centuries: as a paint pigment; in cosmetics; as a fungicide; algacide; pesticide; slimicide; bacteriacide; dessicant; herbicide; homocidal and suicidal poison; in the production of glass and enamels; in the manufacture of transistors, lasers, semiconductor devices; and as a therapeutic agent for numerous medical problems, including psoriasis and syphilis.

The distribution and abundance of arsenic in surface and subsurface environments exhibit wide geographic variation. It is important, therefore, to consider natural arsenic abundance when assessing anthropogenic impacts. This is particularly important when considering the impacts of mining activities in areas of arsenic mineralization. The physical, chemical and bioavailability properties of arsenic compounds present in natural settings are often distinguishable from those produced. These distinctions in properties can be determined through sensitive analytical and extractive techniques.

Identifying the composition and properties of arsenic compounds is essential for assessing the potential for transformation, mobilization and incorporation of these compounds into environmental substrates and biological fluids and tissues. Methods for determining the total abundance of arsenic are available for most media. Distinguishing between valence states and relative reactivity of arsenic compounds under natural and anthropogenic conditions is less straightforward and requires substrate-specific protocols.

The toxicological responses resulting from arsenic exposure, as exhibited in different organisms and ecosystems, is dependent on many factors. Differences in toxicity are reported for different inorganic species of arsenic and between inorganic and organic arsenicals. The chemical and physical properties of the affected substrate itself can influence the fate and behaviour of arsenic within affected organisms and biota.

Standard toxicity and epidemiological tests are used to measure the toxicological responses of test organisms to arsenic exposure. Extrapolations to predict the responses in organisms similar or distinctly different from those used in these tests are often complicated. The metabolism of arsenic differs from one organism to another. Some species have developed detoxification mechanisms for specific forms of arsenic which are important for assessing net toxicological implications. Certain organisms develop specific sensitivities (hypersensitivity) upon to arsenic chronic exposure. Both synergistic and antagonistic agents have been identified and are important to recognize in assessing risks and chronic exposure responses.

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Canadian regulations controlling the amount of arsenic released to the environment presently only refer to *total* arsenic and do not distinguish between the species, valence, state or reactivity, mobility, toxicity or bioavailability of arsenic forms present in environmental media. Changes in provincial and national regulations to include these considerations will require the identification and acceptance of appropriate protocols for the full range of regulated media (air, soil, rock, sludges and slags, water, biological fluids and tissues). Movement towards more species-specific regulations will probably also require pressure from industry, environmental groups, universities, government agencies and/or the mining community itself.

This document provides a comprehensive overview of the issues and current practices associated with arsenic: sources; fate and transport; methods of detection and speciation; toxicology to humans and ecosystems and a survey of current regulations pertaining to arsenic. Methodologies being developed by industrial research groups, universities and by some government agencies are summarized and, in certain cases, appended for reference.

ORGANIZATION OF THIS REPORT

2.A. GLOBAL AND REGIONAL ARSENIC BUDGETS

Global and regional arsenic budgets are reviewed under this section, in terms of both natural and anthropogenic contributions. The abundance and distribution of arsenic as a result of natural background conditions must be appreciated prior to any attempts to quantify anthropogenic loadings. The concentrations of arsenic in environmental substrates vary widely geographically, due in part to natural factors. Some of the more important natural and anthropogenic factors governing the distribution and abundance of arsenic within atmospheric, terrestrial, estuarine, marine and human environments and substrates are discussed in this section.

2.B. PROPERTIES OF ARSENIC

In this section, the properties governing the fate and mobility of arsenic species in different substrates and environments are discussed. The normal valence states of arsenic under site-specific and substrate-specific conditions are discussed here as well as the thermodynamic stability of one state over another under prevailing conditions. The properties of arsenic which determine its bioavailability to terrestrial and aquatic organisms, as well as to human populations, are presented.

2.C. FATE OF ARSENIC

The relative significance of natural background levels, compared to those arising from anthropogenic activity, is assessed with respect to the species and concentrations of arsenic present in various substrates. The factors controlling the fate and mobility of different arsenic species and the relative abundance of arsenicals in different environmental settings are discussed in the context of geographic, climatic and site-specific conditions.

2.D. TOXICOLOGY OF ARSENIC

The relative toxicity of different arsenicals to vegetation, freshwater and marine organisms, terrestrial animals and human populations is presented. Under each of these population categories, the apparent *mode of action* through which toxicity is expressed and manifested is discussed. Our current understanding on various toxicological subjects is presented along with areas warranting further research.

2.E. METHODS OF DETECTION AND ANALYSIS

In this section of the report, analytical methodologies specified by regulatory agencies as well as those being employed by universities, government departments and industry for determining *total arsenic* and/or for differentiating potential *species* are summarized for different media. Protocols which have broad acceptability or potential applicability as the means for quantifying arsenicals in different media are appended for reference.

2.F. REGULATORY CRITERIA AND GUIDELINES

Current regulations pertaining to arsenic in air, water, soil, biota and biological fluids are summarized in this section of the report. A comparative analysis of these limits is presented for regulatory jurisdictions across Canada and the USA. The extent to which *species* of arsenic, such as inorganic, sulphidic or methylated arsenicals, are distinguished from *total* arsenic in current regulations is discussed. The direction that arsenic regulations are expected to take in the future are projected from a limited survey of regulatory agencies within Canada.

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DATE 11/03/95

SEACOR
ENVIRONMENTAL
ENGINEERING, INC.

Royal Oak Mines Inc.
5501 Lakeview Drive
Kirkland, Washington 98033

Attention: Larry Connell

I N V O I C E

Description: Royal Oak Mines Inc.
Document on arsenic properties and behavior

BILLING PERIOD TO 10/27/95

LABOUR

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Staff	142.50 @ \$60.00	\$8,550.00
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\$13,826.80

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Larry Connell
November 28/95

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