SCIENCE INTEGRITY KNOWLEDGE

HAZARD ASSESSMENT OF CHEMICAL CONSTITUENTS FROM THE MARLIN GOLD MINE, GUATEMALA

FINAL REPORT

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FROM THE MARLIN GOLD MINE, GUATEMALA**

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1.0 INTRODUCTION

The Marlin Mine is a gold mine and ore processing facility, owned, managed and operated by Montana Exploradora de Guatemala S.A., a fully owned subsidiary of Goldcorp, Inc. The Marlin Mine is located at Caserio San Jose Nueva Esperanza, San Miguel Ixtahuacan, San Marcos, Guatemala.

On Common Ground Consultants, on behalf of the Human Rights Assessment (HRA) Steering Committee for the Marlin Mine, contracted Dr. R. Willes of Intrinsik Environmental Sciences Inc. (Intrinsik) to conduct a hazard assessment of the available data, and identify chemical constituents of potential concern (*i.e.*, COPCs) to the health and safety of the work place at the Marlin Mine. This hazard assessment report focuses on the identification of COPCs based on their potential to cause health hazards because of their toxic potentials or potencies. This report does not assess possible risks to the health of workers and nearby residents, which would be determined by comparisons between the toxic potencies of the COPCs and the actual historical and future levels of exposure of people to them.

The identification of COPCs is one of the first steps in determining whether or not a health risk study should be conducted to evaluate possible historical and future risks to people working in the mine and those living nearby from exposures to the COPCs.

2.0 SOURCES OF INFORMATION USED IN THE REVIEW OF THE COPCS

The following sources of information were reviewed to produce a list of COPCs related to both the processed ore and process chemicals used in the mine:

- The information on the composition and characteristics of the ore, and process chemicals used in the mine and refining process on which this review is based was provided by the Regional Environmental Manager of Goldcorp Inc (see Attachment A).
- Information from the International Cyanide Management Code website (http://www.cyanidecode.org).
- Telephone conference call discussions between Intrinsik Environmental Sciences Inc, On Common Ground Consultants and Montana/Goldcorp including Marlin's Project Engineer about:
    - The Merrill Crowe process currently used at the mine;
    - The Occupational Health and Safety program currently provided for workers to follow during the mining and processing operations;
    - The characteristics and chemical composition of the ore used in the Merrill Crowe process at the Marlin Mine (provided by e-mail of a scan of the ore composition documentation used by Montana Exploration);
    - The chemicals used in the mine and the processing facility; and,
    - The workplace procedures established to guide the workers in their handling and use of materials in the mine and processing facility.

- A review of the hazard potential and toxicology of the chemicals in the ore and used in Merrill Crowe process based on recently published scientific literature identified on the PubMed database (http://www.ncbi.nlm.nih.gov/pubmed/). Epidemiological studies identified from the PubMed database on the possible adverse health effects reported in gold miners in various locations around the world were also reviewed.

3.0 BASIC SCIENTIFIC PRINCIPLES FOLLOWED IN THIS REVIEW

All chemical substances have inherent toxicity, including:

- Chemicals that are essential nutrients which must be consumed in sufficient amounts to maintain the health and well-being of people, other animals and plants;
- Chemicals that occur naturally as part of the earth's crust and environment; and
- Chemicals produced by and used in various types of human activities.

Different chemicals have different hazard potentials (referred to as toxic potency). Therefore the expression of their hazardous effects will depend on the amount and duration of exposure or intake into the body (*e.g.*, by ingestion, inhalation, dermal absorption). The information on their toxic potency and the characteristics of the toxic response is obtained from various types of scientific studies. These studies include controlled laboratory studies of isolated cell systems and of various species of animals and plants exposed to the chemicals, and epidemiological studies of human populations (workers and the public) exposed to the chemicals in the work place and/or the general environment.

Depending on the characteristics of the hazardous effects of the chemicals, there are sufficiently low exposure levels (intakes into the body) for some chemicals that do not result in adverse (hazardous) effects. For other chemicals, there are levels of exposures where the risk (likelihood) of adverse effects is extremely small but may never be zero. For example, chemicals that are nutrients (*e.g.*, proteins, carbohydrates, fats, vitamins, and essential minerals like copper, zinc, calcium, iron, and selenium) can cause adverse effects if exposures are too high, but at some lesser exposure is essential for good health and well-being.

Based on the principles outlined above, the full assessment of potential risks from a particular exposure situation, such as people working in the Marlin mining operation, would involve:

- Identifying COPCs associated with mining operations that could cause adverse health effects (*i.e.*, the purpose of the current report).
- Estimating or measuring the levels or rates of exposure of the mineworkers to the COPCs. These levels of exposure correlate directly with the concentrations of the chemicals in the air in the workplace, the concentrations of the chemicals in contact with the worker's skin and the potential intake of the chemicals from unintended ingestion. Since all of the chemical elements in the ore *per se* occur naturally as part of the earth's crust, the rates of exposure of the mineworkers from the concentrations of the same COPCs from the natural environment in the vicinity of the mine would also be required to enable a comparison between exposures from the natural background (separate from the mine) and from the mining operations.

- Estimate the risk of occurrence of adverse health effects by comparing the hazard criteria of each of the COPCs against the worker's level of exposure from sources due to the mining operations and from the natural background sources in the area. If workplace practices keep exposures low, the risks would be low. If exposure were zero, the risk would be zero.

This review focuses on the identification of the COPCs at the Marlin mine and processing operations identified from information provided on the chemical composition of the ore, and the identification of chemicals used in the mining and processing of the ore from which gold and other metals are extracted. This review does not provide recommended workplace or environmental exposure limits, or estimates of exposure to the COPCs and therefore the review does not provide an assessment of the potential levels of risk that adverse effects might occur. The conclusions of this review did consider the documented safety procedures in practice in the mining and processing operations at the Marlin mine.

4.0 IDENTIFICATION OF COPCS

4.1 COPCs in the Ore

Table 1 in Section 8 provides a list of the key elements reported in the ore and a brief statement of their hazard characteristics. A separate assessment was also prepared on those elements identified that have unique hazard potentials when suspended in air as particulate material (dust). Since the major route of exposure to the elements from the ore *per se* would be by inhalation (*i.e.*, breathing dusts from the ore), many of the available scientific studies on adverse effects to metals in the ore may not be relevant since their routes of exposure may not be comparable (*e.g.*, oral exposures through food and drinking water). In addition, the form of the metal may be different in foods (*e.g.*, organic mercury and arsenic compounds in fish and marine species). These types of issues, as well as comparisons to natural local background concentrations of the COPCs, are beyond the scope of the current hazard assessment, and would typically be addressed in a detailed quantitative risk assessment of the metals in the ore.

Of the 24 elements reported in the ore analyses, ten (10) were selected as COPCs that are naturally present in the ore *per se* because of their documented hazard concerns and the potential for exposure of workers. The ten COPCs included:

- Arsenic (As)
- Cadmium (Cd)
- Chromium (Cr)
- Lead (Pb)
- Manganese (Mn)
- Mercury (Hg)
- Nickel (Ni)
- Selenium (Se)
- Thallium (Ti)
- Zinc (Zn)

Three of these COPCs (*i.e.*, manganese, selenium and zinc) are nutrients essential for normal health and well-being. They were included as COPCs because exposures substantially greater than the intake needed to maintain health and well-being have been associated with adverse health effects. Such elevated exposure levels could occur from occupational exposures and from excessively high concentrations of these metals arising from dispersion of the ore into the local environment (e*.g.,* through inadvertent transfer from truck tires and other equipment while travelling outside the processing area).

The remaining seven (7) COPCs are common to a range of industrial processes and for which significant adverse health effects are known based on epidemiological studies of workers in a range of industries (references provide in Section 9, Table 1). All ten (10) COPCs would be a concern if present in fine particulate material (dust) based on published studies showing associations between exposures and adverse effects on the respiratory, cardiovascular and in some cases the nervous system.

4.1.1 Hazard Characteristics of Particulate Material

Since all of the ore COPCs would be present in any dusts from the ore originating within and outside the mine facility, there is reason for concern about their potential adverse effects arising from exposure of workers and the public to dust from the ore. There are a number of epidemiological studies on various non-occupational populations that show a range of adverse health effects associated with exposures to airborne, "urban-type" particulate material, especially fine particulate matter less than 2.5 microns in diameter ($PM_{<2.5}$) and less than 1.0 microns in diameter ($PM_{<1.0}$) (Gerlofs-Nijland *et al.*, 2007; Makkonen *et al.*, 2010; Schmid *et al.*, 2009). Urban-type particulate material contains a range of different metals, products of petroleum combustion, emissions from industries and other air-borne substances found in urban environments. The composition of the particulate material is an important factor in determining the potency of the material in causing adverse effects (Schmid *et al.*, 2009). A number of metals are commonly present in urban-type particular materials (Cohen *et al.*, 2007; Muller *et al.*, 2010; Ogami *et al.*, 2009; Warheit *et al.*, 2009; Worle-Knirsch *et al.*, 2007; Yanagisawa *et al.*, 2009), although a clear causal linkage to the observed health effects to specific metal species has not been demonstrated (Duvall *et al.*, 2008). Some of these metals are included in the ten (10) COPCs.

In the telephone conference call at the initiation of this review, the Senior Project Engineer for the Marlin Mine stated that the mined ore as it leaves the mine and enters the processing area has a high water content (*i.e.*, it was visibly wet), and that there was virtually no dust associated with the handling and processing of such wet ore. In addition, the Engineer stated that the workers processing the ore had air-filter masks that they were instructed to use if, for any reason, the ore became dusty. This procedure would limit the inhalation of the dusts by the workers, providing the air-filter mask were appropriate for the size of the dust particles arising from the dried ore.

Based on the information outlined above, there is a potential health concern from possible exposures to dust arising from the dried ore (*e.g.*, ore in areas at the edges of the ore transporting/processing systems could dry and become particles in dust; wet ore adhering to tires/wheels of truck and other equipment would be transferred around and outside the mining facility where it could dry and become a component in dust both within and outside the immediate area of the mine). Such sources of dust could provide a route of exposure to workers within the mine area, and to the public living in close proximity to the mine. The potential for exposure would be greater for workers than the public, and wearing appropriate personnel protection equipment (*e.g.*, air-filter masks) would reduce breathing such dusts by the workers. The potential for and magnitude of exposure to the public would likely be less than for workers; however, protection from exposure by wearing dust masks would not be expected for the people not working at the mining facility. Appropriate air quality monitoring, including dust composition, would provide data to determine if airborne dust from the mining activities is a concern to workers and/or the public, and provide a basis for evaluating the measures currently followed to control the amounts of dust in the workplace and the community adjacent to the Marlin mine.

4.2 COPCs from the Merrill Crowe Process

The Merrill Crowe process involves grinding the ore and mixing the ground ore with water, lime (to raise the pH), and sodium cyanide. The gold-cyanide complex formed by this process is soluble in the high pH solution. The solubilize gold-cyanate complex is separated from the ore in the liquid leachate. After isolation of the leachate from the remaining solids, treatment with zinc compounds and decreasing the pH by adding acids, the gold becomes insoluble and precipitates from the liquid enabling its recovery. The cyanate is recycled from the leachate and re-used in combination with pH adjustment to solubilize more gold from unprocessed ore.
The main COPC in the Merrill Crowe extraction process is cyanide. There are acids and lime, and materials in the water used in the process that are quite different to cyanide as discussed below.
Cyanide is a potent acute toxic chemical and sufficient exposure by virtually any route (*e.g.*, oral, inhalation or dermal) can result in rapid onset of adverse symptoms such as dizziness, vomiting (nausea), heartburn, increased heart rate (tachycardia), dyspnea, erythemia, headache and contact dermatitis due to irritation (Nelson, 2006; Schep *et al.*, 2009). The toxic effects of cyanide are caused by cyanide inhibiting the use of oxygen by the cells of the body; a syndrome known as chemical asphyxia (Nelson, 2006). If exposures to cyanide are sufficiently high and prolonged, the continuing cascading effects from the inability of the tissues of the body to use oxygen results in central nervous system and heart failure and death (Nelson, 2006).

Another COPC utilized in the process is sodium metabisulphite. Sodium metabisulfite is used as a food additive, sanitization/cleaning agent, and in home brewing and winemaking to sanitize equipment. While generally non-toxic, sodium metabisulfite can cause allergic reactions in asthmatics and sulphite-sensitive individuals.

The acids (*i.e.*, hydrochloric acid and sulfuric acid), sodium hydroxide and, to a lesser extent, lime (CaO) used in the Merrill Crowe process are also hazardous because they are strong oxidizing agents and irritants, primarily causing skin irritation and burns if exposure control procedures are not adequate to ensure acceptable levels of contact with the skin, inhalation or ingestion. A variety of other chemical materials are used in the mine process that have low toxic potency (*e.g.*, diatomaceous earth, anti-scalants, Borax, flocculants, soda ash, hydrogen peroxide, zinc dust, sodium nitrate, lead nitrate, sodium hyopchlorite).

However, it should be noted that the chemicals employed within the Merrill Crowe process (*i.e.*, cyanide, acids, strong bases, lime, sodium metabisulphite, diatomaceous earths) are all used in a closed processing system. According to the Senior Project Engineer, the only time the process system, equipment and machinery is open to the work environment is during repairs/maintenance. Currently, this is done by specially trained and protected workers following procedures set down by the International Cyanide Council (ICC). Regardless, the safe use of all the chemicals used in the Merrill Crowe Process depends on following appropriate occupational health and safety procedures, recommended precautions listed on their individual Material Data Safety Sheets (MSDS), and ensuring that the workers understand and follow this information as part of a trained safety standard of care.

4.3 Summary of Epidemiological Studies of Gold Mine Workers

A number of epidemiological studies of gold mine workers, primarily in mines in Africa and Indonesia, have been published (Bose-O'Reilly *et al.*, 2009a; Bose-O'Reilly *et al.*, 2009b; Eisler, 2003). These studies focus primarily on the actual mining operations, and indicate that silicosis, a lung condition related to exposures to quartz, silicates and other “rock-based” dusts, is a significant concern to the heath of gold miners. The studies also conclude that gold miners suffer from an increased incidence of various cancers and respiratory diseases compared to control populations. In addition, there is an increase in a number of health conditions caused by factors secondary to any exposures from the mining *per se*. Factors such as HIV/AIDs, tuberculosis, tobacco use, alcohol consumption, socio-economic factors, adequacy of nutrition and others. These are health issues in the general community, and their consideration is important in evaluating potential risks from the COPCs arising from mining operations. There are a number of studies (Bose-O'Reilly *et al.*, 2009a; Bose-O'Reilly *et al.*, 2009b; Girdler-Brown *et al.*, 2008) demonstrating that health problems in communities increase the susceptibility and sensitivity of affected individuals to the adverse effects from exposures to materials in the workplace (Eisler, 2003). Since workers are also members of the community, such sensitive individuals can be workers in the facility where there is potential exposure to the COPCs.

5.0 DOCUMENTATION OF OCCUPATIONAL HEALTH AND SAFETY PRACTICES AT THE MARLIN MINE

Attachment A contains the documentation provided by Montana Exploration on the Occupational Health and Safety practices at the Marlin Mine. Procedures are also in place at the Marlin Mine that outline in some detail how workers are to handle potentially hazardous materials, and procedures to follow if there is any uncertainty in the workers mind about proper procedures to follow. In addition, during the initial conference call, the Senior Project Engineer provided assurance that the documented procedures of the Health and Safety Program are followed by the workers. Frequent training/educational sessions are conducted for new employees and refresher training for regular employees, to ensure employees are aware of the programs and have opportunities to discuss them with supervisors and managers at the mine.

The program described above being the case, the levels of exposure of workers to the COPCs identified should be well controlled and within the appropriate occupational health and safety criteria. In addition, the practices outlined would provide workers with the knowledge and practical methods for working safely and keeping exposures to the COPCs to levels consistent with good occupational health practices.

For cyanide, a COPC with high toxic potency, the Marlin Mine can rely on the support and audits by the International Cyanide Management Code to provide the best available knowledge and technologies for the safe use of cyanide in gold ore processing, combined with ongoing company surveillance and due diligence, provides some assurance that workers are complying with the recommended code of practice. The International Cyanide Management Code website (http://www.cyanidecode.org/about_code.php) documents the procedures followed for upgrading processes for handling and working with cyanide, and for disseminating this information to members of the code. Comments provided during the initiation conference call by the Senior Project Engineer indicate that the Cyanide Management Code is currently being followed at the Marlin Mine.

6.0 CONCLUSIONS

This hazard assessment review has identified ten (10) COPCs in the ore from the Marlin mine, and one (1) COPC associated with the Merrill Crowe process which may require further consideration. There are also several additional caustic chemicals in used in the Merrill Crowe process which could be of potential concern. However, the occupational health and safety, material handling and process management procedures documented for the Marlin Mine outline the procedures for workers to follow that would ensure adequate control over work place exposure to the COPCs and other process chemicals within the workplace.

There are always concerns about the effectiveness of the practice of the work place procedures and whether the workers actually follow the documented procedures under all circumstances. Nothing was evident in the material reviewed to indicate that the workplace safety program was not effective. However, to ensure the program is effective it is critical that the worker's training and education enable them to understand the written documentation, or even the verbal communication of the procedures, particularly if there are any language comprehension issues between workers and supervisors. The work place health and safety process and procedures can only be effective if consistently and properly executed by the workers.

The Senior Process Engineer stated that the ore was wet with water when entering the processing facility from the mine. However, the residuals of the wet ore could dry, or wet ore on tires and equipment could dislodge when vehicles and other equipment move around the mine site, and possibly the adjacent community. Once dislodged and dried, the ore could become suspended in the air as dust. Such dust, containing the various elements - including the ten (10) COPCs - would then contribute to the airborne dust on the work-site and the adjacent community, and potentially pose a health concern.

7.0 RECOMMENDATIONS

Based on the results of the hazard assessment review, three (3) recommendations are presented:

1. Implement a program to provide regular, documented, unannounced, independent, third party audits of the occupational health and safety procedures, chemical handling procedures and general environmental practices of the Marlin Mine. Complementary to this program, implement procedures to ensure that workers truly understand the workplace safety procedures, and encourage open/free discussion of workplace safety without worker concerns of reprimand, real or imagined, from the supervisors and managers of the Marlin Mine. This process would ensure the maintenance of optimal workplace practices and make certain that both the workers and management on the Marlin Mine can be confident that the procedures outlined in the existing plan are applied, and update as necessary based on international and local standards. Qualified third party auditors will also provide information that will assist both management and workers in the progressive improvement of the safety of the work environment to the benefit of both the employees and the Marlin Mine.

2. Implement a program to improve the general health and well-being of the community where the employees and their families live. The epidemiological studies on gold miners demonstrate that health issues occur in the worker population that are secondary to the mining activities *per se*. This means they occur in the community. The studies show that the miners suffer from respiratory disorders related to tobacco and alcohol consumption, HIV/AIDS and associated conditions, and various consequences of inadequate nutrition. These conditions directly affect general health and well-being of the community of which the workers are part.

   In addition, there is substantial evidence (Bose-O'Reilly *et al.*, 2009a; Bose-O'Reilly *et al.*, 2009b; Girdler-Brown *et al.*, 2008) that such health conditions as reported in communities increase the susceptibility/sensitivity of affected individuals to the adverse effects from exposures to materials in the workplace. Community health programs can be undertaken that use information from health risk assessments to guide the development of specific procedures designed to improve the health and well-being of all members of the community, including the employees. The result is improved safety in the workplace through the reduction of potential effects from community-based health and socioeconomic situations that indirectly affect workers and thereby the safety of the workplace *per se*.

3. Investigate the potential of the presence of ore chemical elements in dust on the mine/processing site and in the adjacent community, particularly in airborne particulates in the <2.5 and <1.0 micron size ranges. If such airborne particles prove to be present, and a human health risk assessment shows undue risks, adopt procedures to improve mitigation measures already in place in a manner consistent with the data and risk assessment information. For example, such transfer of ore chemicals in dust could occur if the wet ore on equipment dislodged around the mine/processing site and in the adjacent community where it will dry and contribute to the dust in the local environment. If this scenario proved correct, improvement of the mitigation measures currently followed for dust control would correct the situation.

8.0 CHEMICALS REPORTED IN MARLIN MINE ORE AND HAZARD CHARACTERISTICS

Table 1 Naturally Occurring Chemical Elements in Marlin Mine Ore

Chemical	***Hazard Characteristics***
Aluminum (Al)	Low toxic potential - high exposures have been associated with potential adverse effects on the nervous system and brain (Deschamps *et al.*, 2009; Kiesswetter *et al.*, 2009).
Antimony (Sb)	Medium toxic potential - the toxicity of antimony depends on its chemical form. High temperature smelting of ores containing elevated concentrations of antimony result in the production of volatile forms of antimony that are very noxious, and irritating to eyes, nose, throat and respiratory system (Cooper and Harrison, 2009). However, these forms of antimony are not present in soils, nor would they be present in ores that are not subjected to high temperatures (Cooper and Harrison, 2009). Antimony in its natural state in soils is has low availability and low absorption into the body, and has not been associated with adverse health effects (Cooper and Harrison, 2009).
Arsenic (As)	High toxic potential - elevated exposures have been associated with cancers and is an acute poison affecting the central nervous system (Bhadauria and Flora, 2007; Chen *et al.*, 2009; Halatek *et al.*, 2009; Singh *et al.*, 2010; Smith and Steinmaus, 2009)
Boron (B)	Low toxic potential - high exposures can have potential adverse effects on the nervous system and reproduction (Degen and Hengstler, 2008; Nielsen, 2008; Robbins *et al.*, 2009)
Barium (Ba)	Low toxic potential - no systemic adverse effects have been reported even with large exposures (*e.g.,* barium enemas used in medical diagnostic radiography) ; however, barium is one of the metal constituents in particulate materials that are associated with decreased lung function (Gerlofs-Nijland *et al.*, 2007), indicating there may be health concerns from inhalation exposure compared to oral ingestion.
Bismuth (Bi)	Low toxic potential - many beneficial uses in medicine. Bismuth “slices” provide shields to reduce the amount of radiation received by non-target organs in medical tomography (Catuzzo *et al.*, 2009). Bismuth is combined with antibiotics and other agents in the treatment of Helicobacter pylori infection (Luther *et al.*, 2010; Malfertheiner *et al.*, 2009) and chronic diarrhea in people with HIV/AIDS (Nwachukwu and Okebe, 2008). Bismuth reduces the use of antibiotics in treatment of bacterial infections in cattle (Berge *et al.*, 2009). Bismuth is one of the agents used in common antacids where reversible adverse effects (blackening of the mouth and tongue) have been reported (Cohen, 2009).
Calcium (Ca)	Low toxic potential - an essential mineral for healthy bones and joints, extreme exposures may be associated with calcium “stones” and deposits in the biliary system, kidneys and joints.
Cadmium (Cd)	High toxic potential - moderate exposures are associated with adverse effects associated with kidney, bone metabolism, lung function and lung cancer (Arora *et al.*, 2008; Bernard, 2008; Huff *et al.*, 2007; Kim *et al.*, 2008; Kobayashi *et al.*, 2008; Satarug *et al.*, 2010; Thompson and Bannigan, 2008).
Cobalt (Co)	Medium toxic potential - with large exposures adverse effects, in association with other metals (*e.g.*, cadmium, uranium) have been linked to oxidative stress and a range of effects arising from oxidative stress including neuromuscular effects and fatigue (Busch *et al.*, 2010; Lang *et al.*, 2009)
Chromium (Cr)	Occurs in several valences (*e.g.*, Cr[III], Cr[VI]), with markedly different toxic potentials for different valences. Cr[VI] produced in some industrial processes and exposure is associated with increased cancers. Most natural sources (*e.g.*, ores) contain Cr[III] which has low toxic potency (Aelion *et al.*, 2009; Baccarelli and Bollati, 2009; Bruske-Hohlfeld, 2009; d'Errico *et al.*, 2009; Smith and Steinmaus, 2009). Speciation of chromium in the mining ore is required.
Copper (Cu)	Low toxic potential - an essential mineral for maintaining health and well-being, extreme levels of exposure can cause blood disorders, cardiovascular effects and impaired liver function. Very high exposures can result in liver dysfunction, metallothionine complex formation, crystalline deposits in the liver and kidney, abnormal kidney function (Krewski *et al.*, 2010; Meek *et al.*, 2010; Stern, 2010)
Gold (Au)	Low toxic potential - direct contact with metallic gold can be associated with skin rashes and sensitization to skin rashes in individuals with specific gold sensitivity

Table 1 Naturally Occurring Chemical Elements in Marlin Mine Ore	
Chemical	***Hazard Characteristics***
Iron (Fe)	Low toxic potential - an essential nutrient for red blood cell production, adverse effects associated with extreme exposures. Adverse effect can be associated with metabolic diseases and correlate with several types of cancer, particularly of the digestive tract (Grant, 2008; Haynes *et al*., 2009; Satarug *et al*., 2010)
Lead (Pb)	High toxic potential - low levels of exposure are associated with adverse effects on the development of the central nervous system and brain in children, and higher exposures affect the nervous system and kidney in adults (Degen and Hengstler, 2008; Knol *et al*., 2009; Mohammad *et al*., 2008; Schmid *et al*., 2009; Telisman *et al*., 2007)
Mercury (Hg)	High toxic potential - low levels of exposure to organic mercury are associated with adverse effects in the central nervous system, including progressive brain dysfunction. Inorganic or metallic mercury have much lower toxicity than the organic forms. Mercury in ore would be inorganic (Holmes *et al*., 2009; Prasher, 2009; Tan *et al*., 2009)
Magnesium (Mg)	Medium toxic potential - Mg is an essential nutrient as co-factor in cellular metabolism (Ohira *et al*., 2009; Puliyel *et al*., 2009; Tucker, 2009).
Manganese (Mn)	Medium toxic potential - high exposures can result in adverse neurological effects (Burton and Guilarte, 2009; Haynes *et al*., 2009; Moreno *et al*., 2009) and elevated exposures to Mn as part of a mixture of other metallic elements have been associated with some cancers (Chakraborty and Mukherjee, 2009; Spangler and Reid, 2010). Mn is an essential nutrient as co-factor in cellular metabolism and normal cell function (Haynes *et al*., 2009)
Molybdenum (Mo)	Low toxic potential - elevated exposures are associated with endocrine effects, particularly on the thyroid and thyroid stimulating hormone (Meeker *et al*., 2009)
Nickel (Ni)	Medium toxic potential - excess inhalation exposure during high temperature smelting processes involving nickel and other metals has been associated with sino-nasal cancers. Hypersentivity allergic reactions and skin rashes have also been reported in certain predisposed individuals exposed to metallic nickel (Alam *et al*., 2008; Bruske-Hohlfeld, 2009; d'Errico *et al*., 2009; Das *et al*., 2008; Jacob *et al*., 2009; Ogami *et al*., 2009)
Potassium (K)	Low toxic potential - an essential nutrient for body electrolyte composition, nervous system, kidney and cardiovascular function. Extreme exposures can cause heart failure (Dawwas *et al*., 2009; Guglin, 2009; Sandhiya and Dkhar, 2009; Tabrizchi, 2010)
Sodium (Na)	Low toxic potential - an essential nutrient for body electrolyte composition, nervous system, kidney and cardiovascular function, extreme exposures are associated with high blood pressure, cardiovascular disease and kidney disease (Brown *et al*., 2009; He and MacGregor, 2009; Kagiyama *et al*., 2009; Kshatriya *et al*., 2010; Meland and Aamland, 2009; Mohan and Campbell, 2009; Sanders, 2009; Xu *et al*., 2009; Yang, 2009)
Selenium (Se)	Medium toxic potential - essential nutrient for bone/cartilage metabolism and liver function; extreme exposures associated with cancers. Organic selenium is more toxic than inorganic forms (Chapman, 2009; Macfarquhar *et al*., 2010; Mozaffarian, 2009; Russell, 2009). Selenium in the mine ore would be in an inorganic form.
Silver (Ag)	Low toxic potential - direct contact with metallic silver can cause potential skin rashes and sensitization to skin rashes in individuals with specific silver sensitivity
Strontium (Sr)	Medium toxic potential - elevated, prolonged exposures are associated with interference with calcium metabolism and bone/cartilage development and homeostasis (Neuprez and Reginster, 2008; Suzuki *et al*., 2008; Thuy *et al*., 2008)
Titanium (Ti)	Low toxic potential - direct contact with titanium containing metals has been associated with skin rashes (Yanagisawa *et al*., 2009), and nanoparticles containing titanium have been associated with decreased lung function and lung cancer (Pan *et al*., 2009; Warheit *et al*., 2009) and oxidative stress (Muller *et al*., 2010)

Table 1 Naturally Occurring Chemical Elements in Marlin Mine Ore

Chemical	***Hazard Characteristics***
Thallium (Tl)	High toxic potential - high, long-term exposures associated with tobacco smoke and lung cancer (Pappas *et al.*, 2007). No adverse effects occur from natural background levels of Tl (Peter and Viraraghavan, 2005). Elevated exposures result in general systemic toxicity, particularly effects on the nervous system and muscle function (*e.g.*, heart) believed interference with various body functions related to sulphydryl groups of enzyme systems (Peter and Viraraghavan, 2005). Tl is soluble in water and readily mobilizes from natural sources (*e.g.*, mining ores) resulting in elevated concentrations and concerns about environmental effects from mine effluents(Peter and Viraraghavan, 2005). Thallium (Tl201) has been used for some time in cardiovascular diagnostic procedures; however, recent studies show evidence of short-term genetic damage (Yildirim *et al.*, 2005) and of increased cancers, particularly in young patients where thallium was used as a diagnostic agent (Kaste *et al.*, 2010).
Vanadium (V)	Low toxic potential - high exposures associated with decreased lung function (Cohen *et al.*, 2007; Duvall *et al.*, 2008; Makkonen *et al.*, 2010; Worle-Knirsch *et al.*, 2007)
Zinc (Zn)	Medium toxic potential - an essential mineral required to maintain health and well-being of bone, blood systems, liver and body metabolism, extreme levels of exposure are associated with disorders of the urogenital system (Johnson *et al.*, 2007), and zinc is one of the metal constituents in fine particulate material that is associated with decreased lung function (Gerlofs-Nijland *et al.*, 2007)

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ATTACHMENT A DOCUMENTATION PROVIDED BY MONTANA EXPLORADORA DE GUATEMALA, S.A.

1. Hazardous Materials Management Guidelines, International Finance Corporation, Environmental Health and Safety Guidelines
2. World Bank Environmental Health and Safety Guidelines, Mining and Milling - Open Pit
3. World Bank Environmental Health and Safety Guidelines, Mining and Milling - Underground
4. World Bank Environmental Health and Safety Guidelines for Waste Management Facilities
5. International Cyanide Management Institute, International Cyanide Management Code for the Manufacture, Transport and Use of Cyanide in the Production of Gold
6. Copies of two internal reports: Report on Evaluation and Monitoring of Industrial Health and Safety at the Marlin Mine, SAFECO Consultants, July- Sept. 2007 & April – June 2008.
7. Detailed breakdown of ore composition