BORAX - Summary of Health Risks Associated with Using Borax in Artisanal and Small-Scale Gold Mining

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EXECUTIVE SUMMARY

Borax is used as a safer alternative to elemental mercury for extracting gold in artisanal and small-scale gold mining (ASGM). Borax is not acutely toxic, although exposure to borax dusts/powders is associated with eye, throat, nose, and skin irritation. Borax is not thought to cause cancer. While no animal or human studies exist on other longer-term health effects of borax itself, studies are available on effects of related compounds (boron, boric acid). Reproductive and developmental toxicity are the main concerns associated with chronic oral/ingestion exposure to boric acid. However, the main exposure pathway of concern for ASGM and other workers is inhalation. Studies of male boron mining/ processing workers to date show no reproductive effects. In ASGM, borax processing/ handling procedures typically do not generate much dust. Similarly, borax's high melting point means that vapor generation in ASGM is likely to be negligible. In sum, it seems unlikely that small-scale gold miners using borax have an increased risk of adverse reproductive or other health risks because of the exposure to borax. Borax should be relatively safe to use in ASGM as long as basic safety precautions are followed, including engineering controls (e.g. spill prevention, process enclosures, ventilation), good workplace hygiene (e.g. frequent hand washing, restrictions on eating/smoking in/near the work area), and the use of personal protective equipment (e.g. eye protection, gloves, protective clothing).

I. BACKGROUND

The use of borax as an alternative processing technology for artisanal gold miners currently using elemental mercury as an amalgamation agent is rapidly gaining acceptance (Appel and Jønsson 2010). Borax acts as a flux, reducing the melting point of gold and allowing it to be released from gold ore concentrate. The gold collected at the bottom of the mixing vessel is typically a higher purity than mercury-extracted sponge gold.

II. DESCRIPTION AND CHEMICAL PROPERTIES

Borax is a salt of the element boron. Chemically it is referred to as disodium tetraborate decahydrate ($Na_2B_40_7 \cdot 10H_2O$, CAS# 1303-96-4) (US Borax 2008). Borax contains 11.34% boron. Boron is always chemically bound to oxygen forming borates (e.g., borax or boric acid). Boron is a naturally occurring element widespread in nature. The average concentration in the earth's crust has been estimated to be 10 ppm and in seawater, 4.6 ppm (Schoderboeck et al. 2011; TOXNET 2006). Borax itself is a white, odorless, alkaline, water soluble powder.

Borates are widely used for industrial purposes (e.g., manufacture of glass, ceramic glazes, fire retardants, laundry additives, fertilizers, insecticides). Borates have been used as a flux in ceramics, metallurgy and mining for over 200 years, although borax's recognition as a possible alternative to mercury in ASGM is more recent. Worldwide, borax is still used as a texturing material in foods, although it has been banned for this use in the United States. The toxicity of borax is based on the natural element boron which may be found in several forms.

III. BORAX EXPOSURE IN ASGM

The use of borax in ASGM takes place in the later stages of processing where concentrated gold ore is added to molten borax, usually in a ceramic bowl. Borax powder is manually added to the bowl and fired until molten, then the gold ore is added and more heat applied. Within a few minutes, the intense heat causes the gold to melt out of the mass. Because gold is heavier that molten borax, the gold collects on the bottom of the vessel and is removed. The following table lists the particular steps in the process and likely borax exposure routes:

ASGM STEP	ACTIVITY	PHYSICAL STATE	EXPOSURE ROUTE	
			Primary	Secondary
Purchase and storage of containers	Receive/store large sealed plastic containers of borax	granular powder	n/a	n/a
Repackaging	Transfer borax to smaller containers	granular powder	Inhalation	Dermal
Addition to bowl	Sprinkle clay bowl with borax	granular powder	Inhalation	Dermal
Melting/burning borax	Apply torch and melt borax	powder/liquid	Inhalation	n/a
Fluxing with gold	Borax lowers melting point of gold and gold melts	liquid	Inhalation	n/a
Cleaning bowl	Scrubbing ceramic bowl to remove residue	solidified borax	Dermal	Inhalation

From this description, it appears that the main risk to ASGM workers using borax likely comes from the manual/hand addition of granular borax to the ceramic reaction vessel. Once the granular borax melts, it no longer poses an airborne dust hazard and, given its boiling point, will not generate vapors or gas. Commercial borax is sold as a granular and not fine powder. This further reduces the likely of airborne release. A comprehensive video describing the complete process is available from the Geological Survey of Denmark and Greenland (GEUS-TUBE 2011).

IV. HEALTH RISK INFORMATION

Acute Toxicity Summary: Borax is not acutely toxic. The lethal dose for humans is estimated to be 0.1-0.5 g/kg, or 7-35 g for an average 70 kg adult although a review of 784 cases of human poisonings with boric acid (10-88 g) reported no fatalities and only 12% of cases with symptoms (TOXNET 2013; ATSDR 2010). Exposure to elevated borax dusts/powders is associated with eye, throat, nose, and skin irritation (ATSDR 2010; Moore 1997).

Chronic Toxicity Summary: Reproductive and developmental toxicity are the main concerns associated with chronic oral/ingestion exposure to boric acid (Moore 1997).

Animal studies in multiple species of the effects of ingested boron have consistently shown that high concentrations of boron are toxic to the developing fetus and the testes (CDC 1988). The U.S. Environmental Protection Agency (EPA) has set a reference dose of 0.2 mg/kg/day (or 14 mg/day for a person weighing 70 kg) to protect against decreased fetal weight, the main outcome observed in animal studies (EPA 2004). The level at which no adverse effect was found for developmental defects in rats was 9.6 mg boron/kg body weight. There are only a few human studies of reproductive effects of ingested boron and they do not show adverse effects (CDC 1988).

There is no similar EPA reference concentration for inhalation exposures, although the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) has published minimal risk levels for inhalation (see following table). Very few animal studies of the reproductive effects following inhalation exposure exist.

Borates are not absorbed across intact skin. They can be absorbed through damaged skin (ATSDR 2010), however there are no studies showing health effects of dermally absorbed borates.

Because of reproductive and developmental toxicity concerns, borax was added to the European Union's (EU) Substance of Very High Concern (SVHC) candidate list in December 2010. The SVHC candidate list is part of the EU Regulations on the Registration, Evaluation, Authorisation and Restriction of Chemicals 2006, and the addition was based on the revised classification of borax as toxic for reproduction category 1B under the Classification, Labeling and Packaging Regulations. Substances and mixtures imported into the EU which contain borax are now required to be labeled with the warnings "May damage fertility" and "May damage the unborn child" (ECHA 2010).

Carcinogenicity: The U.S. EPA and the International Agency for Research on Cancer (IARC) have not yet classified borax (or related substances) with respect to human carcinogenicity (EPA 2004). Borax is not genotoxic in *in vitro* studies (ATSDR 2010). There currently is no human evidence of carcinogenicity and the sparse animal literature shows no effect.

Human occupational exposure studies

In occupational settings, inhalation is the primary route of exposure. The potential target tissues following inhalation exposure are the lungs and the testes, the same as the target tissues identified in oral exposure studies (CDC 1988). In a study from Russia, there was a report of testicular effects in 6 workers exposed to 4-8 times the maximum permissible limit of 10 mg borate/m^3 (CDC 1988). However, the effects were poorly defined and the reporting of data was inadequate to permit proper analysis. In a study of workers in a U.S. borax mining and production plant, the median exposure was 2.23 mg borate/m^3 sodium borate ranging from <0.82 mg/m^3 to 44.8 mg/m^3 (CDC 1988). Several reproductive effects were examined. The authors concluded that exposure to inorganic borates did not appear to adversely affect fertility. Whorton et al. (1994) reviewed several male reproductive effects studies, including a Chinese study examining reproductive outcomes and semen quality of highly exposed workers in a boron mine and boron processing plants. The total daily boron intake (inhalation and ingestion) ranged from 34.4 mg/day to 41.2 mg/day. The study showed no effect on sperm count or motility. In a subgroup of 16 men with an estimated boron intake of 125 mg/day, semen quality was not affected. The authors concluded that, despite the fact that boron has been shown to affect male reproduction in laboratory animals, there is no clear evidence of male reproductive effects attributable to boron in studies of highly exposed workers.

Health risk assessment of borax in ASGM

No studies exist of borax exposure levels or adverse health outcomes in ASGM. However, compared to the above-mentioned studies of workers in boron mines and borax processing plants, boron dust inhalation exposures in ASGM are likely to be lower. The borax in ASGM is not processed or handled in a way so dust is released into the air when it is used. The borax crystalline granules or powder is added to the mineral concentrate and then heated. When heated, the water evaporates and the resultant borax has a high melting point, 742°C. Thus, negligible concentrations of borax are likely to be inhaled as vapor during the process. In summary, it seems unlikely that small-scale gold miners using borax have an increased risk of adverse reproductive or other health risks because of the exposure to borax.

V. HEALTH-BASED STANDARDS AND GUIDELINES

The following table summarizes selected international health-based standards and guidelines concerning borax dust (in air) and boron/boric acid (ingestion exposures).

STANDARD/GUIDELINE	LIMIT	UNITS	SOURCE
WORKER PROTECTION			
Air exposure limits	1	mg/m^3	USA (ACGIH, NIOSH), UK, Mexico, Canada
HUMAN HEALTH PROTECTION			
Minimal risk level - acute inhalation (≤14 days)	0.3	mg/m^3	U.S. ATSDR
Oral ingestion guidelines	0.2	mg/kg/day	U.S. EPA (oral reference dose); U.S. ATSDR (minimal risk level)
Drinking water standard	2.4	mg/L	WHO
Drinking water health advisory	3	mg/L	U.S. EPA (1 and 10 day advisory to protect a 10 kg child)

There is limited information on the ecotoxicity of borax and related compounds. However, borax is used as a household pesticide in many countries, so it is lethal to cockroaches and other insect pests. Borax is currently considered not acutely toxic or slightly toxic to aquatic organisms (crustaceans, fish, molluscs); there is no current data for honeybees or similar terrestrial organisms (Kegley et al. 2010).

There is limited information on borax's potential as a water pollutant. Boron occurs naturally at background levels in both ground and surface waters. Since borax is moderately soluble in water, there is at least the potential for borax (boron, boric acid) to leach from sites of heavy use to nearby waters.

VI. HEALTH AND SAFETY RECOMMENDATIONS FOR BORAX USE IN ASGM

The primary exposure pathway of concern for workers using borax is inhalation. Dermal and oral exposures may also occur but are less of a concern given its low oral toxicity and low dermal absorptivity.

EYE IRRITATION
Borax is an eye irritant. Workers must be careful not to get it in their eyes. If this happens, eyes must be washed with clean running water for at least 15 minutes. Eye goggles are not required unless large amounts are handled and the environment is very dusty.

SKIN IRRITATION
Borax is can be mildly irritating for workers with very sensitive skin or those who have cuts or abrasions on their hands. In general, gloves are not required. In case of skin irritation, wash the area with clean water and mild soap. Gloves should be worn if the skin is severely damaged.

INGESTION
Borax must not be eaten. Workers who handle borax must wash their hands thoroughly before preparing food or eating (especially if they eat with their hands). Containers must be labeled as toxic and kept away from children. Because borax is an odorless white powder, it should not be stored in recycled food containers where it can be mistaken for flour, sugar, salt, powdered milk or other food products. In case of ingestion of large amounts, seek medical attention immediately.

INHALATION
Borax dust must not be inhaled in high concentrations. Workers should use it in the open air, with good ventilation. Borax does not evaporate into the air from open containers (unlike mercury which has a toxic vapor form). Workers who develop irritation inside the nose, cough or difficulty of breathing must be removed from the source and given lots of fresh air. In general, irritation effects occur only at very high dust levels. Under normal use, gas masks or dust masks are not necessary.

Borax should be relatively safe to use in ASGM as long as the safety precautions outlined in the Materials Safety Data Sheet (MSDS) from the vendor are followed. These include engineering controls such as spill prevention, process enclosures, and local exhaust ventilation (if necessary). Additional precautions include use of personal protective equipment such as safety glasses, gloves, protective clothing, and a dust respirator. Also, frequent hand washing, restrictions on eating and smoking in/near the work area, and other good workplace hygiene practices should help minimize ingestion and dermal exposures. The borax MSDS and local regulations should be consulted for handling large spills.

Local regulations should be consulted for proper disposal. After processing, the molten borax mass hardens to a glass-like substance. Given the low toxicity of boron and the low solubility of the vitrified material, special hazardous waste handling procedures are not likely to be necessary.

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