Global impacts of geogenic arsenic – A medical geology perspective


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Arsenic contamination through natural (geogenic) and anthropogenic sources is a serious threat to humans all over the world. Natural sources of arsenic exposure may include contaminated groundwater, volcanic sediments, coal, and springs sourced by thermal waters. The number of people affected by arsenic is staggering, the problems life threatening, the scope global, and the potential for medical geology interventions – enormous. Medical geology has the objectives of identifying harmful geologic agents, determining exposures related to deteriorating health conditions, and developing sound principles, strategies, programs and approaches to eliminate or minimize health risks, from the naturally occurring physical and chemical agents in the environment [Selinus *et al.* (2005)]. In this paper, we explore the global health impacts from chronic arsenic exposure and provide examples where geogenic (natural) exposures to arsenic have impacted the health of millions of people worldwide.

Geogenic sources of arsenic exposure

Arsenic is the most extensively studied of the metals and metalloids found in drinking water worldwide. Arsenic is released into the environment from both natural and anthropogenic sources. Global natural emissions of arsenic and arsenic compounds have been estimated to be 8,000 tons each year, whereas anthropogenic emissions are about three times higher [NRC (2000)]. Environmental natural exposure to arsenic is generally in the form of either arsenite (As^{3+}) or arsenate (As^{5+}). The former is the predominant form in drinking water from deep (anaerobic) wells, while the latter predominates under aerobic conditions.

Arsenic contamination of drinking water is a public health issue worldwide. The catastrophic health problems caused by arsenic in the well waters of Bangladesh and West Bengal, India, have been front page stories in mass-media and in scientific journals. Although estimates as to how many people are at risk vary, some as high as 100 million, there is no question that arsenic poisoning may affect tens of millions in Bangladesh alone, and in West Bengal it is suspected that about 6 million people are exposed to arsenic-contaminated drinking water above the 50 µg/L As level. This situation has been called the "*greatest mass poisoning in history*". What is not often reported is that the tens of millions of people exposed to arsenic in Bangladesh represent only a portion of the people who are at risk worldwide. Elevated levels of arsenic have been reported in water supplies of communities in Argentina, Austria, Brazil, Canada, China, Ghana, Greece, Hungary, Iceland, India, Japan, Korea, Malaysia, Region Lagunera (Torreon, Mexico), Inner Mongolia, Nepal, Romania, Taiwan, Vietnam, Zimbabwe, and the U.S.
In addition, arsenic mobilized by coal combustion has caused severe health problems in China and Slovakia. In China alone several hundred million people commonly burn raw coal in unvented stoves that permeate their homes with high levels of toxic metals and organic compounds (see *Photo 1*). At least 3,000 people in Guizhou Province in southwest China are suffering from severe arsenic poisoning. The primary source of the arsenic appears to be consumption of arsenic-tainted chili peppers dried over fires fueled with high-arsenic coal [Zheng *et al.* (1996)].

Health effects induced by chronic arsenic exposure

The future is bleak for many of the people exposed to high levels of arsenic from inhalation of arsenic-rich dust, ingestion of tainted food or groundwater. Inorganic arsenic has been recognized as a human poison since ancient times, and large doses can cause death. Lower levels of inorganic arsenic ingested may cause stomach and intestine irritation, with symptoms such as stomach ache, nausea, vomiting and diarrhea. Other effects may include respiratory conditions (e.g. bronchitis, rhinitis, shorthness of breath, nasal congestion, etc), cardiovascular manifestations (e.g. hypotension, congestive heart failure, and cardiac arrhythmias), neurological (e.g. peripheral neuropathy, polyneuropathy), and gastrointestinal manifestations (e.g. diarrhea, hemorrhagic gastroenteritis, hepatocellular necrosis), hematological effects (e.g. anemia, leucopenia), developmental and reproductive effects (e.g. spontaneous abortions, stillbirths, low birth weights, congenital malfunctions, neonatal deaths), immunological effects, and a higher risk for diabetes mellitus. But perhaps the single most characteristic effect of long-term chronic oral exposure to inorganic arsenic is a pattern of skin changes. These include a darkening of the skin (e.g. hyperpigmentation and hypopigmenta-

Photo 2: These photographs show severe skin lesions from chronic arsenic poisoning. (a) The palms show multifocal hyperkeratotic lesions. (b) Non-healing ulcer near the groin from a suspected case of arsenic poisoning in Torreon, Mexico.
photo courtesy of Dr. Elizabeth Meza, Torreon, Mexico. No biopsies were done to confirm these lesions.

Photo 2 : Lésions de la peau dues à un empoisonnement chronique à l'arsenic. (a) Les paumes de la main montrent des lésions hyperkératotiques multifocales. (b) Ulcère non traité près de l'aine (suspicion d'empoisonnement à l'arsenic à Torreon, Mexico).

Photo reproduite avec l'aimable autorisation du Dr. Elizabeth Meza, Torreon, Mexique. Aucune biopsie n'a été réalisée pour confirmer ces lésions.

Photo 1: Domestic coal-burning in Guizhou Province, China, demonstrating the practice of drying chili peppers over unvented ovens.

Photo courtesy of Prof. Dr. Baoshan Zheng, Institute of Geochemistry, Guiyang, Guizhou Province, P.R. China.

Photo 1 : Dans la province de Guizhou, Chine, le séchage des piments est réalisé au-dessus de fours démunis de conduit d'évacuation et fonctionnant au charbon.

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tion) and the appearance of small lesions of the palms, soles, and torso (see *Photo 2*) [Centeno *et al.* (2000)]. Epidemiological evidence shows an association between inorganic arsenic in drinking water and increased risk of skin, lung, bladder, and kidney cancers [Smith *et al.* (1992)].

The future – A medical geology opportunity

Biomedical scientists and public health officials are working with geoscientists to better characterize those natural sources of arsenic in the environment, so solutions to many of the health problems induced by chronic exposure to arsenic could be developed. For example, by studying the geological and hydrological environment, geoscientists are trying to determine the source rocks from which arsenic being leached into the ground water. They are also trying to determine the conditions under which the arsenic is being mobilized. For example, is the arsenic being desorbed and dissolved from iron oxide minerals by anaerobic (oxygen-deficient) groundwater or is the arsenic derived from the dissolution of arsenic-bearing sulfide minerals such as pyrite by oxygenated waters? The answers to these questions will allow the public health communities around the world identify aquifers with similar characteristics and more accurately determine which populations may be at risk from arsenic exposure.

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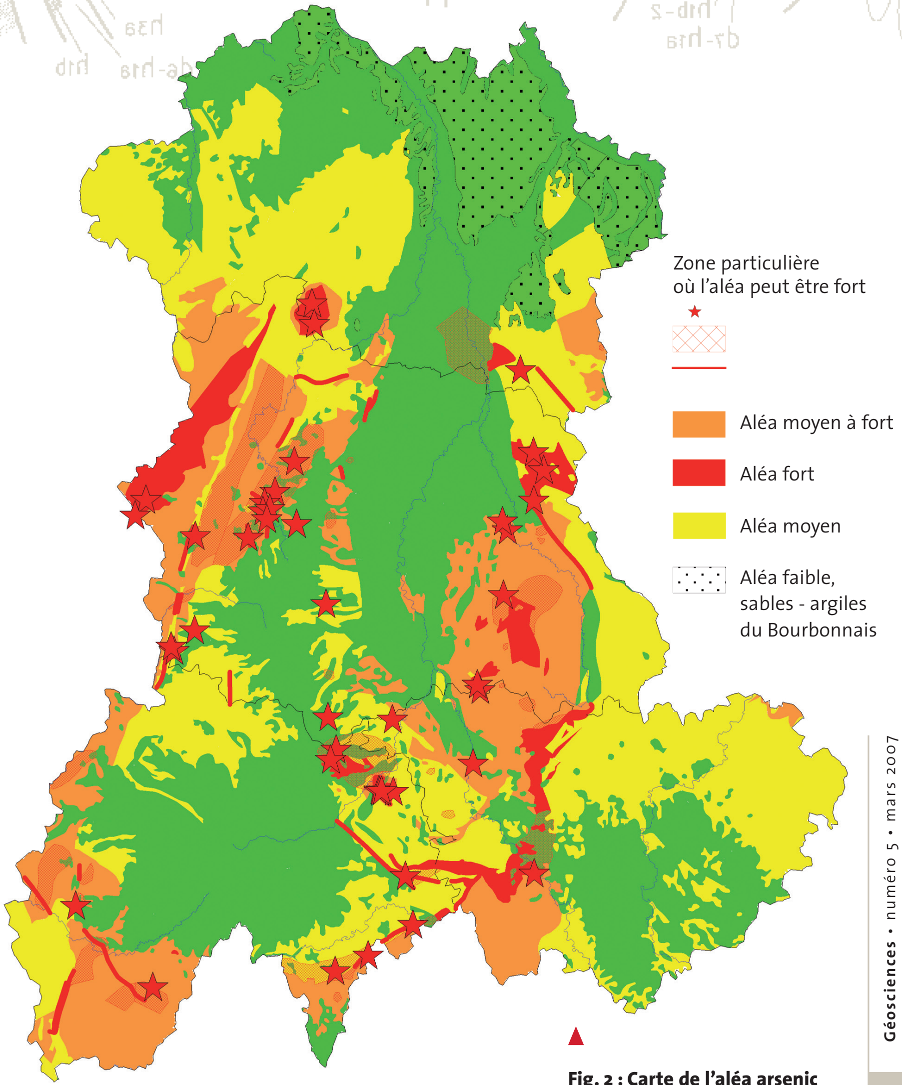

Fig. 2 : Carte de l'aléa arsenic (> 10 µg/L) dans les eaux souterraines de la région Auvergne.

Fig. 2: Map of arsenic hazard (> 10 µg/L) in groundwater in the Auvergne region.

Source : Bertin *et al.*, 2006.

du milieu géologique. Ce niveau d'application est utile pour cibler les actions à mettre en œuvre pour protéger les systèmes exploités pour l'eau potable ;

► **une application prospective :** fournir des recommandations pour mieux gérer l'implantation de nouveaux captages. Puisque certains systèmes offrent naturellement une eau non conforme aux normes de qualité pour la production d'eau potable, il apparaît essentiel pour l'implantation de nouveaux captages d'identifier les zones susceptibles de présenter un fond géochimique élevé.

Dans la perspective de cette dernière application, différents travaux ont été menés en France à l'échelle régionale ou nationale pour délimiter les zones à risque de fond géochimique élevé en éléments traces. En Auvergne où de nombreux captages présentent des concentrations en arsenic supérieures à la norme de 10 µg/L, une cartographie de l'aléa arsenic (concentration supérieure à 10 µg/L dans les eaux souterraines) a été réalisée [Bertin *et al.* (2006)] (*fig. 2*).

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