Arsenic in Drinking Water – also a Problem in Switzerland?

In Switzerland, areas with elevated arsenic levels are found primarily in the Jura and in the Alps. Weathering and erosion of rocks containing arsenic releases this element into soils, sediments and natural waters. The national limit for drinking water of 50 µg/l arsenic is not exceeded anywhere in Switzerland; however, in localized areas in the Cantons Ticino, Grisons and Valais, arsenic concentrations in the drinking water are above the level of 10 µg/l recommended by the World Health Organization (WHO).

On average, the earth's crust contains 2 mg arsenic per kg. Compared to the abundance of other elements, such as copper, zinc or lead, this concentration is very low; however, arsenic is rather unevenly distributed, i.e., rocks contain either no or very little arsenic (less than 1 mg As per kg of rock), or high concentrations of 50 mg – 500 g per kg. Zones rich in arsenic are usually well defined but can vary in size. Typically they measure between 1 m and several 100 m in diameter (Fig. 1).

Natural arsenic containing formations are either:

- metal ore deposits that contain large volumes of arsenic containing minerals, such as sulfides, arsenates or more rarely iron oxides;
- extended areas of rocks with elevated arsenic concentrations, usually caused by the presence of iron bearing sulfides or oxides, such as pyrite, goethite or hematite.

In addition to these natural sources, arsenic can be detected in landfills and on industrial sites. Most of these contaminated sites are related to urban gas production, the production of special glass, or extensive pesticide use. Since 1970, however, arsenic is no long used in pesticides.

Release of Arsenic into the Environment

When an arsenic containing material comes in contact with moving water, substantial amounts of arsenic can be released into the environment. If the material is present in deeper formations, arsenic can be brought to the surface by thermal springs. When the arsenic bearing formation is near the surface, weathering and erosion release substantial amounts of arsenic into the environment. Arsenic either accumulates in soils and sediments, or is diluted in natural waters. Streams and glaciers can transport arsenic over distances of several 100 kilometers. In soils, sediments, and relatively stagnant, particle rich waters, arsenic typically binds to iron or aluminum oxyhydroxides and to clay minerals. Under certain conditions it can be remobilized, for example, if the pH increases to above 7.5, or when the absence of oxygen leads to iron reducing conditions [1] (see also article by M. Berg, p. 12).

Arsenic may also be released into the environment by atmospheric transport. One study, for example, documented wind transport of arsenic containing fine dust by chemical analyses of mosses [2]. It is not clear at this point, whether volatile arsenic methyl compounds formed by microorganisms are of any importance in Switzerland.

Natural Arsenic Occurrences in Switzerland

Switzerland has three main areas with elevated natural arsenic concentrations (Fig. 2):

- Northeastern Switzerland, where a number of arsenic containing thermal and mineral springs are located;
- the Jura, with its iron containing limestones and clays;
- the Alps, where arsenic bearing ore deposits and crystalline rock formations can be found. In addition, there are other isolated thermal and mineral springs.

Thermal and mineral springs are fed by surface water that has penetrated the rock formations down to depths of several kilometers. The thermal springs of Baden, Zurzach, Schinznach and Bad Saeckingen in northern Switzerland are typical cases and may contain up to 130 µg arsenic per liter at their source [3]. The arsenic in these springs stems from deep lying granites and schists of the Black Forest massif. Due to treatment of the raw water, guests typically receive water containing less than 1 µg arsenic per liter (Fig. 3). The same can be said for the arsenic containing mineral and thermal springs in Saxon, Leukerbad and St. Moritz in the Alps. The cold mineral springs of Val Sinestra in the lower Engadin, with extremely high arsenic concentrations of up to 3 mg/l, are no longer used.

The Jura has three arsenic bearing and iron rich formations: the brown limestones of the Dogger formation and the yellow limestones of the Cretaceous formation contain between 10 and 20 mg arsenic per kilogram of

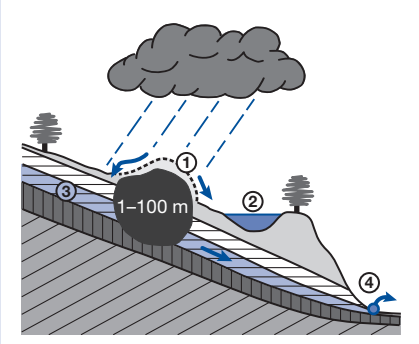

Fig. 1: Weathering of arsenic containing material (silicate rocks, mineral ores, dump sites; black) releases arsenic into (1) soils and sediments, (2) surface waters, (3) ground water, (4) spring water.

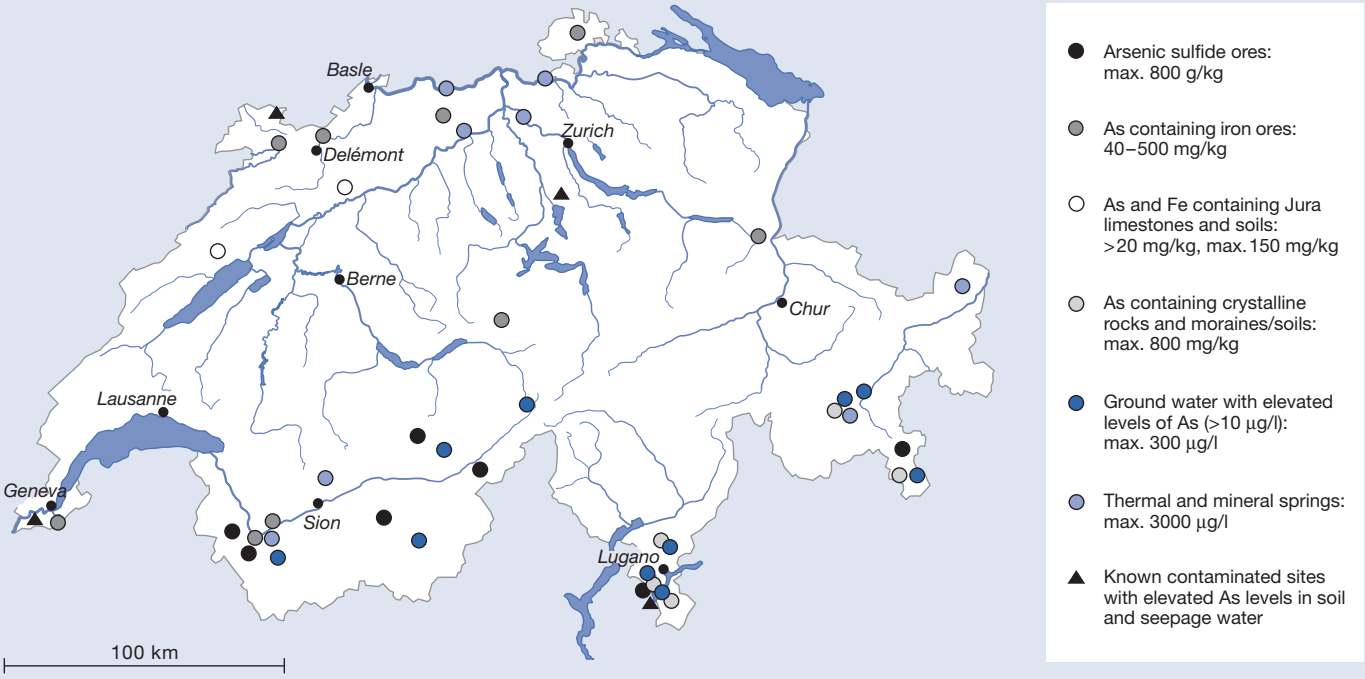

Fig. 2: Areas with elevated levels of arsenic in Switzerland. Elevated arsenic levels in ground water are found primarily in Wallis, Ticino and Grisons.

limestone; however, arsenic is accumulated in the soils during weathering processes and can reach levels of up to 150 mg/kg. These iron rich limestones occur primarily in the Jura mountains of Solothurn, Aargau and Neuenburg. The Bohnerz formation with its iron nodules and red clays is found in restricted areas in the Jura portions of the Cantons Waadt, Jura (Delémont) and Schaffhausen. Bohnerz rocks contain up to 500 mg arsenic per kg of rock. There have not been any investigations as yet on whether arsenic accumulates in the soils of these regions. All of the groundwater and plant samples from Jura analyzed so far have shown very low arsenic concentrations: less than 1 µg arsenic per liter water and no more than 500 µg arsenic per kg dry plant mass. These low values indicate that arsenic is strongly bound to iron phases in the soil.

More heavily impacted areas are in the Swiss Alps, where sulfur and arsenic rich ore deposits or arsenic crystalline silicate rocks are present, such as schists, gneisses and amphibolites. The numerous small ore deposits that were mined in the past, only have a localized impact on the environment. Much more important are situations where arsenic bearing crystalline rocks cover a large surface area, i.e., several 100 km^2. Such areas are found in the Cantons of Wallis, Ticino and Grisons.

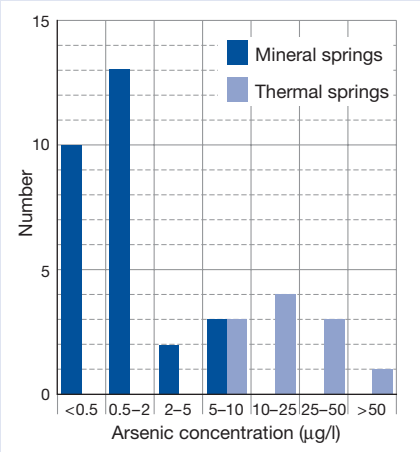

Fig. 3: Arsenic concentrations in utilized thermal and mineral springs [from 3].

Does Drinking Water in Switzerland Contain Arsenic?

In Canton Ticino, environmental impacts of localized arsenic formations have been studied since 1992 [4]. In 1996, all public water supply systems in the Canton were tested for arsenic [5]. The results were rather surprising: water with arsenic concentrations of more than 10 µg/l were found only in the vicinity of Lugano (Sottoceneri), i.e., in Val Isone, in Val Colla, in Malcantone and near Barbengo-Morcote and the adjacent Italian province of Varese. About a dozen communities use drinking water resources that contain between 11 and 50 µg/l arsenic. These values are below the Swiss limit of 50 µg/l arsenic for drinking water, but above the 10 µg/l limit that the WHO recommends. In two cases, however, arsenic concentrations were significantly above both of these limits. Water samples from the Malcantone showed around 80 µg/l, and in neighboring areas in Italy, the concentrations were as high as 300 µg/l. Often the affected spring areas with the contaminated water are at some distance from known ore deposits. This suggests that the arsenic in these areas stems from glacial moraines, river sediments and soils. Weathering and erosion of ore deposits situated further up in the watershed are at the origin of this material, and as a result, arsenic concentrations between 100 and 800 mg/kg can be found. In the area north of Lugano, local pyrite or iron oxide containing gneisses and schists are suspected to be the origin of the arsenic. Impacted areas of the Sottoceneri comprise approximately 500 km^2, affecting about 5000 inhabitants.

Alarmed by the results found in Canton Ticino, the Canton Grisons decided to test all of the 336 public water supplies in 1998. In 312 drinking water samples, arsenic concentrations were below 10 µg/l, while 21 samples had arsenic concentrations between 10 and 50 µg/l. Three samples exceeded the Swiss limit of 50 µg/l. The maximum concentration found was 170 µg/l [6]. Affected are mainly the Val Poschiavo and two individual springs in the upper Engadin. In Val Poschiavo, the occurrence of arsenic is a regional phenomenon, and the situation is similar to the one in Canton Ticino. The number of people affected is not yet known in detail because a large number of private water supplies are also impacted. ETH

Photos: H.-R. Pfeifer, Lausanne

View looking up to the entry of the abandoned arsenic mine of Salanfe in the lower Wallis, and looking down to Lake Ottans, situated below the mine. Between 1904 and 1928, over 700 tons of arsenic were extracted from this mine, and the soils and the water of the surrounding area are heavily contaminated.

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Zurich is currently conducting detailed hydrogeological studies.

Arsenic containing ore deposits and sediments situated in Canton Wallis have been known for some time [7]. Areas most affected are Martigny and vicinity, the Nikolai Valley, the Loetschental, and the Goms. The drinking water in these areas, however, were not tested for arsenic until 1999. Since then, we know that in Canton Wallis approximately 14 000 people live in areas where the drinking water contains between 12 and 50 µg/l arsenic [8].

Risks and Possible Remediation

Although detailed studies are not yet available for all of Switzerland's regions, we can assume that health risks related to arsenic come primarily from the consumption of drinking water with elevated arsenic concentrations. In most cases where the Swiss limit of 50 µg/l is exceeded, communities have responded immediately by abandoning that particular spring or by mixing the contaminated water with arsenic free water. There are several localities, however, where long-term solutions have to be found in order to guarantee an adequate drinking water supply for the next 20 to 30 years that is free of arsenic.

In many cases, there are plans to solve the problem by developing new springs and groundwater sources, which is relatively expensive. In some cases, it would be worthwhile considering the use of arsenic removal technologies, such as membrane filtration or iron and aluminum oxide filters. Which solution will ultimately be the appropriate and most cost-effective one, largely depends on whether or not Switzerland will keep its current limit for arsenic in drinking water of 50 µg/l, or will adopt the 10 µg/l limit which has already been applied in the European Union.

In Switzerland there is currently no legal limit for arsenic concentrations in soils. Outside of the areas impacted by arsenic described here, agricultural soils typically contain less than 10 mg arsenic per kg soil [9]. Even in the industrial sites that have been examined so far, arsenic contaminations are lower than those found in areas impacted by naturally occurring arsenic.

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