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Methods for delineating regions with high baseline concentration of arsenic

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Introduction

The EU Life+ project ASROCKS started in September 2011. The Tampere–Häme region in southern Finland is characterized by elevated natural concentrations of arsenic in the most common soil parent material, glacial till. In some cases, arsenic concentration is elevated also in bedrock, groundwater and even in humus. This region is defined as an arsenic province in the national soil geochemical baseline database TAPIR (www.geo.fi/Tapir). The main objective of the ASROCKS project is to provide guidelines and risk management tools for the exploitation of natural aggregate resources, crushed bedrock, sand and gravel in areas with elevated natural arsenic concentrations in bedrock and soil in the study region. In addition, guidelines will be developed for the use of aggregates in construction areas.

In 1997, Salminen and Tarvainen (1997) demonstrated that geochemical baseline concentrations in Finland change regionally according to the bedrock geology and locally according to the type and genesis of overburden. Reimann and Garrett (2005) concluded that geochemical mapping at an appropriate scale is essential to construct a map showing areas of relatively homogeneous geochemistry. A map of geochemically homogeneous areas with other relevant information can be used to deduct the natural and anthropogenic processes that determine the distribution of elements.

Soil geochemical databases have been used in Finland to delineate regions with naturally high concentration of arsenic or trace metals (Jarva et al. 2010). Four arsenic provinces and seven metal provinces were defined for the national soil geochemical baseline database TAPIR. Soil baseline concentrations of arsenic and selected trace metals (Co, Cr, Cu, Ni, V, Zn) have been calculated for these provinces. In England and Wales a rather similar method has been applied to define the normal background concentrations of contaminants in soil for the most important domains (Ander et al. 2013). The domains are delineated on the basis of the following three factors: soil parent material, urbanization and non-ferrous mineralization and associated mining activities. Thus the delineation of domains in England and Wales takes into account some anthropogenic activities.

Tarvainen and Paukola (1998) showed that regional geochemical maps of till, stream sediments and stream water can be used to delineate areas where concentration of elements derived from bedrock and overburden may exceed the health based risk limits for drinking water. Areas of arsenic contamination in groundwater can be well delineated on the basis of till geochemical data. In contrast, the occurrence of anthropogenic contaminants in ground water could not be predicted from regional geochemical mapping data.

Delineation of the geochemical arsenic province in the ASROCKS project

In the beginning of the ASROCKS project, the area with elevated arsenic concentrations in soil and in bedrock was delineated on the basis of earlier geochemical maps. This arsenic area of Southern Tampere region and Häme region was used to select the 21 preliminary demonstrations sites for the project.

The delineation of the arsenic province for the ASROCKS project was done as follows:

1. The arsenic concentration in the till geochemical data in reconnaissance scale (Koljonen 1992, density 1 sample/300 km^2) was interpolated and smoothed into a regular grid (Fig. 1), where the grid values were determined with the aid of a moving weighted median in a circular window, radius 50 km (Gustavsson et al. 1997). The preliminary delineation was made using ca. 10 mg/kg as a limit value (Fig. 2).

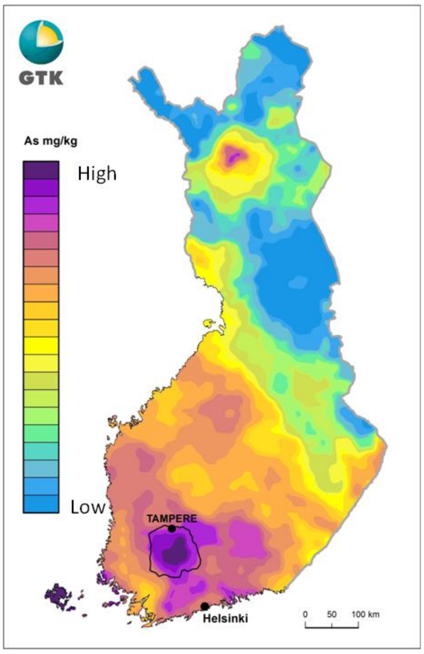

Fig. 1. Distribution of arsenic in till in Finland. Source: Koljonen 1992.

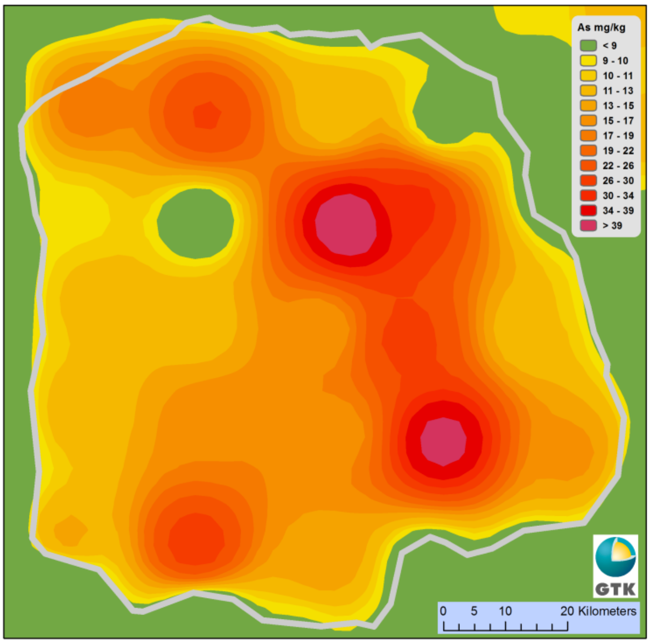

Fig. 2. Delineation of arsenic province of Tampere – Häme region using till geochemical data in reconnaissance scale.

2. The preliminary delineation was tested using an independent data set: the regional soil baseline mapping data (Hatakka et al. 2010). Most of the samples with elevated arsenic concentration in the

latter data set were located within the area delineated in the previous phase. However, in some cases the delineation could be done in more detail with the new data.

3. The arsenic concentrations of the Rock Geochemical Database of Finland were plotted on the delineated arsenic province. Even when the delineation was based on As concentrations in the soil, all the bedrock samples with the highest As concentration in Southwestern Finland were located within the delineated province.

4. Production sites for crushed bedrock, sand and gravel were selected from the delineated arsenic province for the ASROCKS project. The project team collected further information on those production sites and visited the potential demonstration sites during field excursion. 10 production sites for crushed bedrock and 7 sand and gravel pits were selected as preliminary demonstration sites. In addition to that, four construction sites from the delineated arsenic province were selected as preliminary demonstration sites after discussions with regional stake holders.

General guidelines for delineation of regions with elevated concentration of arsenic or other potentially harmful elements

According to the experiences of the ASROCKS project, the ASROCKS project team suggests the following procedures for delineation:

1. Study geological and geochemical literature and figure out the general occurrence of arsenic (or another potentially harmful element) in various rock types in your study area.

2. Collect the geochemical data from your study area to be applied in a GIS program. Prefer data that reflect the concentrations in the bedrock (aggregate production from crushed bedrock) or in sand and gravel (sand and gravel aggregates). In glaciated terrains, arsenic and metal concentrations in till reflect better the composition of the underlying bedrock than other soil parent material.

In the Geochemical Atlas of Europe (Salminen 2005) subsoil sample were taken from residual soil, which generally reflects the underlying lithology. Arsenic distribution in European subsoil show large regional anomalies mostly related to geology (Fig. 3).

3. Add data layers of geology and soil parent material to the GIS program.

4. Use either geochemical point data or interpolated geochemical data to preliminary delineate the arsenic (or other potentially harmful element) province. In some countries the national threshold value for the assessment of soil contamination can be used as a limit value for delineation. In some other countries the national threshold value might be too high compared to natural baseline concentrations and a lower value should be used for delineation of potential hazard regions.

5. Check the occurrence of the most important rock types from geology layer and if necessary redefine the shape of the delineated province.

6. If possible, use an independent geochemical data set to verify the delineation of the province.

7. Add a layer of known aggregate production sites and planned new sites and selected construction sites with planned temporary aggregate production to your GIS data set.

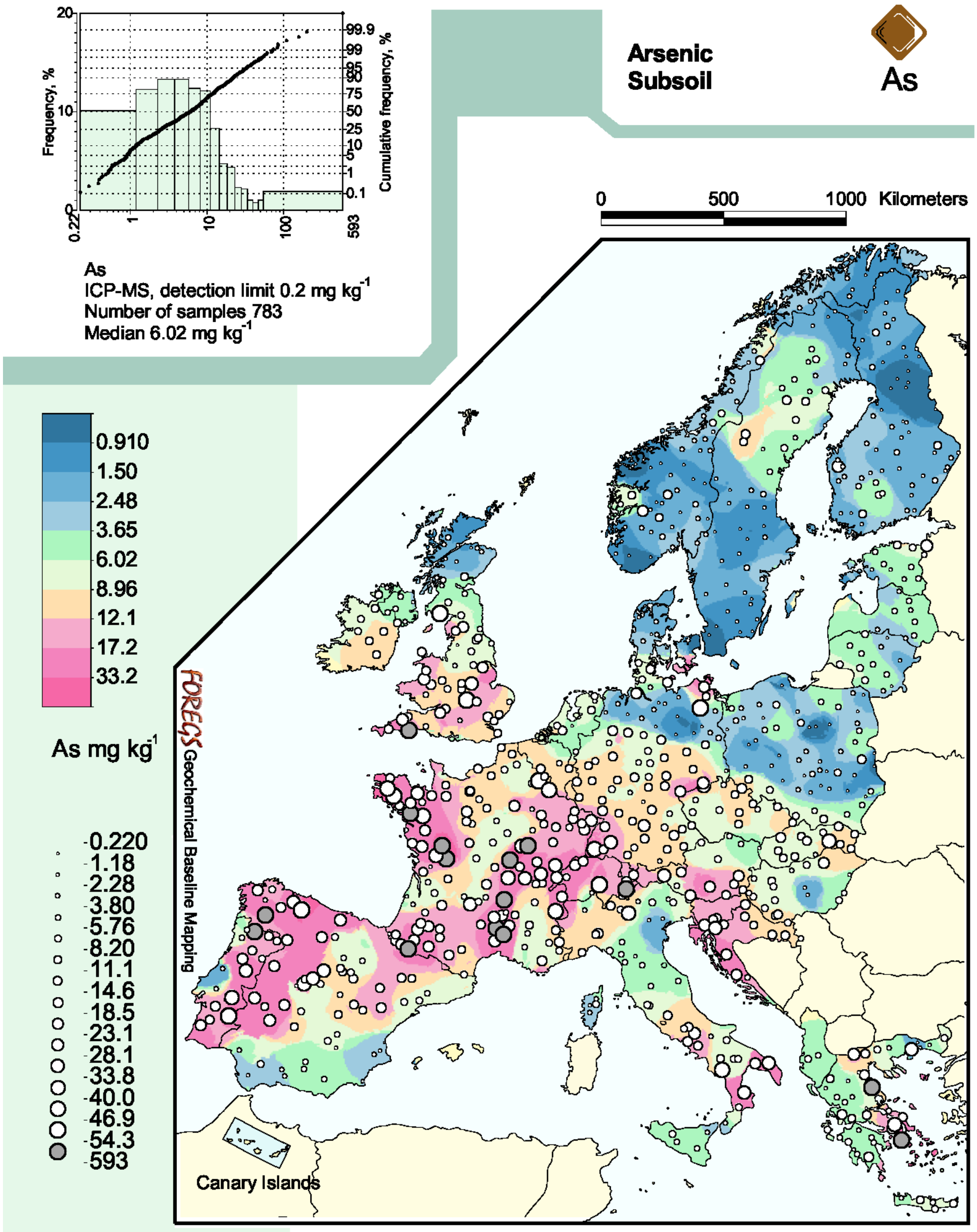

Fig. 3. Distribution of arsenic in European subsoils. Source: Geochemical Atlas of Europe, Part 1 (Salminen 2005).

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