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TAPIR — Finnish national geochemical baseline database

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ABSTRACT

In Finland, a Government Decree on the Assessment of Soil Contamination and Remediation Needs has generated a need for reliable and readily accessible data on geochemical baseline concentrations in Finnish soils. According to the Decree, baseline concentrations, referring both to the natural geological background concentrations and the diffuse anthropogenic input of substances, shall be taken into account in the soil contamination assessment process. This baseline information is provided in a national geochemical baseline database, TAPIR, that is publicly available via the Internet.

Geochemical provinces with elevated baseline concentrations were delineated to provide regional geochemical baseline values. The nationwide geochemical datasets were used to divide Finland into geochemical provinces. Several metals (Co, Cr, Cu, Ni, V, and Zn) showed anomalous concentrations in seven regions that were defined as metal provinces. Arsenic did not follow a similar distribution to any other elements, and four arsenic provinces were separately determined. Nationwide geochemical datasets were not available for some other important elements such as Cd and Pb. Although these elements are included in the TAPIR system, their distribution does not necessarily follow the ones pre-defined for metal and arsenic provinces.

Regional geochemical baseline values, presented as upper limit of geochemical variation within the region, can be used as trigger values to assess potential soil contamination. Baseline values have also been used to determine upper and lower guideline values that must be taken into account as a tool in basic risk assessment. If regional geochemical baseline values are available, the national guideline values prescribed in the Decree based on ecological risks can be modified accordingly.

The national geochemical baseline database provides scientifically sound, easily accessible and generally accepted information on the baseline values, and it can be used in various environmental applications.

1. Introduction

In Finland, a new Government Decree on the Assessment of Soil Contamination and Remediation Needs (214/2007) came into force in June 2007. According to the Decree, baseline concentrations, referring both to the natural geological background concentrations and the diffuse anthropogenic input of substances, shall be taken into account in the assessment process. If the regional geochemical baseline of an element exceeds the threshold value given in the Decree, the regional geochemical baseline is to be used as the trigger value for the assessment of soil contamination. The new Decree has therefore generated a need for reliable and readily accessible data on geochemical baseline concentrations in Finnish soils. This information is provided in a national geochemical baseline database, TAPIR. The database was developed in co-operation between the Geological Survey of Finland (GTK) and the Finnish Environment Institute (SYKE). In addition to GTK and SYKE, several Finnish consulting companies will both provide and use the required information on the geochemical baseline concentrations. MTT Agrifood Research Finland has also provided baseline information on agricultural soils for the database.

The terms “background” and “baseline” are often used as synonymous (e.g. Galuszka, 2007). The term “natural background” is widely used to infer background levels reflecting natural processes uninfluenced by human activities (Reimann and Garrett, 2005). Lee and Helsel (2005) define baseline as “summary of existing conditions over some time frame for some environmental system, or material of interest that typically do include influence of human activities”. Baseline represents a measure of a given sample in a specific location and time (e.g. Galuszka, 2007). Reimann and Garrett (2005) do not support the use of the term “baseline”. They have introduced the term “ambient background” that describes “the unmeasurably perturbed and no longer pristine natural background”. However, Reimann and Garrett (2005) also argue that “many slightly elevated levels in soils and sediments reflect ambient background and are no longer natural

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since natural background no longer exists". Thus, the term "natural background" could be used as long as natural processes can still be noticed. The TAPIR system presented in this article uses the term "baseline" to refer both to the natural geological background concentrations and the diffuse anthropogenic input of substances at regional scale. The chosen terminology follows the one used in the FOREGS geochemical baseline mapping programme (Salminen et al., 2005; De Vos and Tarvainen, 2006).

The TAPIR system consists of two separate databases: a relational database for geochemical baseline analysis from individual sampling points and another database for regional statistical summary data. Access to the point-wise database is restricted to the data providers and to the managing authority, GTK. Each data provider, such as a research institute, a university or a private consulting company, can enter field observations and analytical data from geochemical baseline sampling sites to the point-wise database using a web-based interface. Information on geochemical baseline concentrations from different soil parent materials and sampling depths is entered separately. The managing authority can then accept or reject the suggested baseline observations. The accepted analytical results are used to calculate statistics for pre-described geographical regions, referred to as geochemical provinces that were originally delineated by Eklund (2008).

The latter part of the database system holds the statistical summary information from the pre-defined geochemical provinces. Statistics are regularly calculated separately for each soil parent material type and for each geochemical province. These summary data are publicly available through a web-based geographical user interface (http://www.gtk.fi/tapir).

2. Materials and methods

A wide variety of observational data can be saved in the point-wise database of the TAPIR system. Information is collected via datasheets by logging into the web-based interface. Contact information is first entered on the organization responsible for sampling. This information is required in order to continue data input. The general information datasheet collects information on the sampling procedure including name of the person who has taken the samples and the sampling date. The general information datasheet also compiles information on the sampling site as well as the sample itself. The data provider can enter the name and coordinates of the sampling site, the sampling depth, a description of the sampling site (pre-defined list of sites), the sample material (pre-defined list of possible sampling types: till, sand, clay, man-made ground, and humus), sample type (single sample or composite sample), groundwater level (if known) and possible source of diffuse contamination that can easily be observed at the sampling site (pre-defined list of possible contamination sources). Information on coordinates of the sampling site and on sample material is mandatory, other information is entered if it is available.

The inorganic substances datasheet collects information on analysis results. The database only accepts analysis results from the <2 mm grain size fraction. The leaching method has to be selected as either aqua regia extraction or concentrated nitric acid leach. The Finnish Environmental Administration Guidelines relating to the Decree (214/2007) describe the recommended analytical methods when investigating possible soil contamination (Ministry of the Environment, 2007). Either aqua regia extraction (ISO 11466, 1995) or a concentrated nitric acid leach method (USEPA 3051A, 1998) is suggested. The determined concentrations for selected trace elements can be entered for one or several elements. In addition to the trace elements As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, V and Zn indicated in the Decree (214/2007), some other relevant and potentially harmful elements (Tl, Ba, B, Mo, Se and Sn) are included in the database.

Since the baseline concentration refers to both the natural geological background concentrations and the diffuse anthropogenic input of elements, it is also possible to provide information on analytical results for some organic compounds to the database, although these compounds are not usually natural in origin. PAH as well as PCB datasheets collect information on such samples. The concentrations can be reported as total concentrations of PAH compounds or PCB congeners based on the Decree (214/2007), or as concentrations of a single compound or congener. The name of the laboratory and analysis method used can also be noted.

The TAPIR system has determined acceptable concentration levels for each element to be considered as a baseline concentration. The lower guideline value is set as a maximum acceptable concentration for those trace elements and organic compounds that are indicated in the Decree (214/2007). For the other elements the limits are based on other existing risk-based reference values. However, GTK as a managing authority is able to decide if higher concentrations are also eligible to be included in the TAPIR system e.g. due to specific geological conditions of an area.

In the detailed assessments of soil contamination and especially in risk assessment procedures more parameters such as pH, total carbon content and cation exchange capacity are often needed. This information is not collected to the TAPIR system thus it has originally been generated to provide information on regional baseline concentrations to be used in the first phase of tiered based risk assessment.

Though neither grain size distribution nor clay or organic carbon contents are documented from the samples in the TAPIR system, the information on soil parent material is mandatory. The TAPIR system distinguishes the used sample material in nine classes based on variation in grain size and organic carbon content: (1) glacial till, (2) clay and other fine-grained sediments, (3) sand and other coarse-grained sorted sediments, (4) humus or other natural biogenic topsoil, (5) peat, (6) man-made soil dominated by biogenic material, (7) coarse-grained man-made soil, (8) fine-grained man-made soil, and (9) man-made soil with variable texture. Statistics (e.g. median, mean, 25th and 75th percentiles) are always calculated to each sample material separately.

The scheme of the TAPIR system is illustrated in Fig. 1.

In 1997, Salminen and Tarvainen (1997) demonstrated that geochemical background concentrations in Finland change regionally according to the bedrock geology and locally according to the type and genesis of overburden. Salminen and Gregorauskiene (2000) compared geochemical baseline concentrations in two very different geological environments in Finland and in Lithuania. Geochemical baseline concentrations are dependent on bedrock geology, the provenance of the sample material collected, the sample medium (e.g. topsoil, stream sediment), its grain size and the extraction method. In the TAPIR system, all the metal analysis results are based on aqua regia extraction or concentrated nitric acid leach, the analysed grain size is <2 mm, and statistics are calculated for different soil parent material types. However, even within Finland the chemical composition of soil parent material varies between geological units. Thus, it will not be possible to define a single baseline value for each soil parent material type that is valid throughout the country. This is why geochemical provinces are introduced in the TAPIR system and statistics are presented for each soil parent material within each geochemical province separately.

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.

GTK carried out nationwide geochemical mapping of till in Finland on a reconnaissance scale (1 sample/300 km^2) in 1983 (Koljonen, 1992) and on a regional scale (1 sample/4 km^2) during 1984–1992 (Salminen, 1995). These surveys provided information on the natural elemental