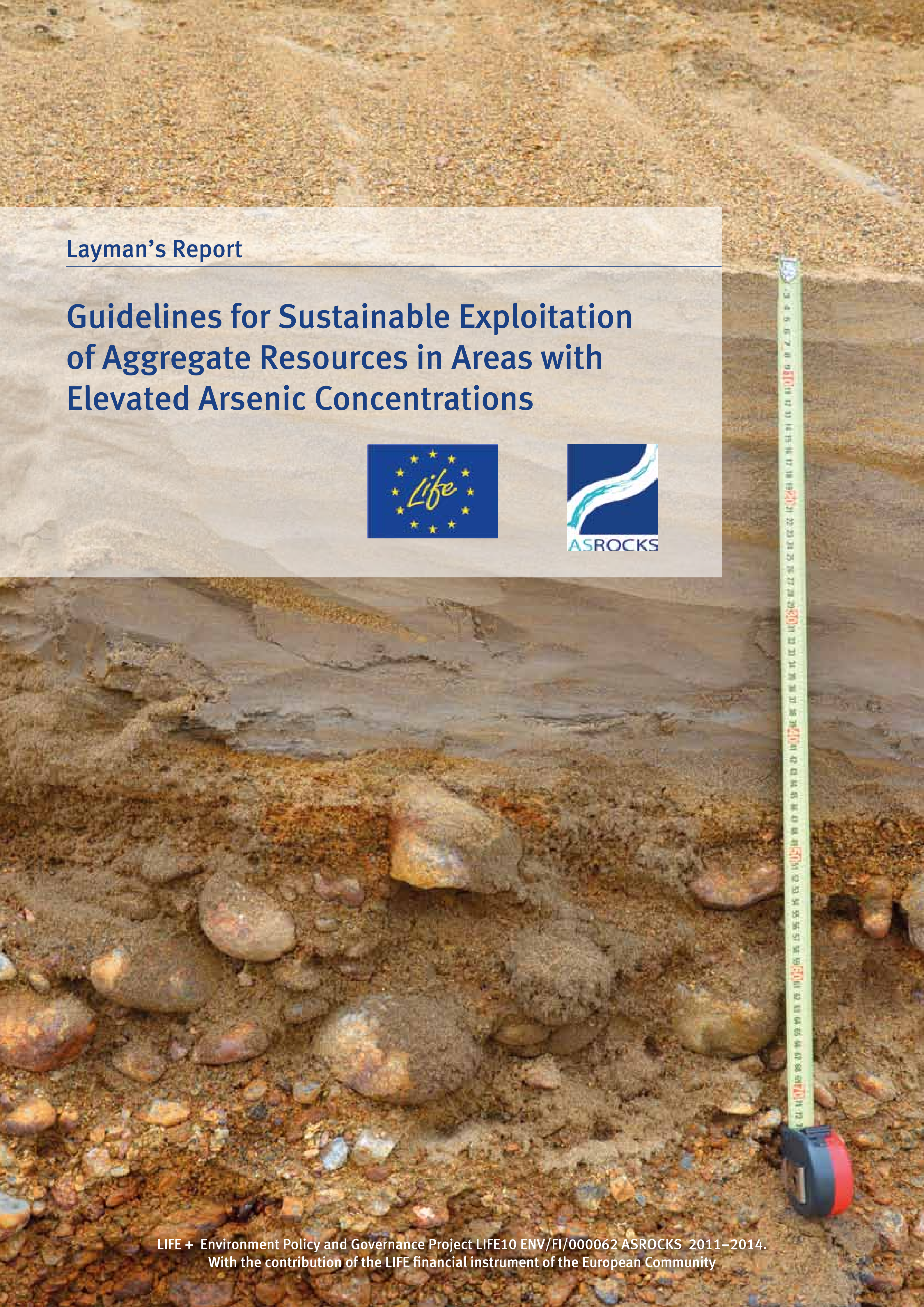

Layman's Report

Guidelines for Sustainable Exploitation of Aggregate Resources in Areas with Elevated Arsenic Concentrations

ASROCKS

LIFE + Environment Policy and Governance Project LIFE10 ENV/FI/000062 ASROCKS 2011–2014.
With the contribution of the LIFE financial instrument of the European Community

Content

The organizations in the ASROCKS project:

Geological Survey of Finland, GTK (Coordinating Beneficiary)
Tampere University of Technology, TTY (Associated Beneficiary)
Finnish Environment Institute, SYKE (Associated Beneficiary)

Pirkkala municipality, Vuores-project (Tampere city), Rudus Oy, Verte Oy, NCC Roads Oy, and Pohjola Rakennus Oy (Pohjola Construction Oy) participated in the project. Ministry of the Environment (Finland) supported the Finnish Environment Institute.

Project start date: 01/09/2011
Project end date: 31/08/2014

Total budget: 1157 302 €
EC contribution: 578 651 €

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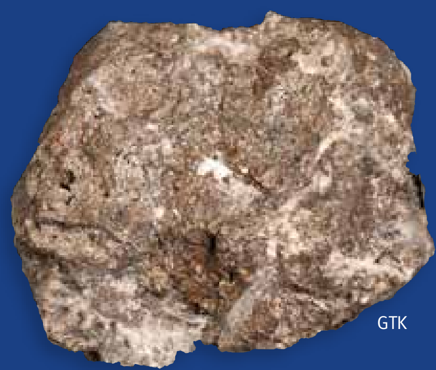
ASROCKS project: http://projects.gtk.fi/ASROCKS_ENG/

Main objectives of the ASROCKS project

The main objective of the ASROCKS project was to provide guidelines and risk management tools for the exploitation of natural aggregate resources (crushed bedrock, sand and gravel) in areas with naturally elevated arsenic concentrations in the bedrock and soil in the Tampere-Häme region in southern Finland. Guidelines were developed as well for construction areas with naturally elevated arsenic concentration in bedrock and soil. The guidelines and tools produced during the project were targeted for the aggregate producers and environment authorities.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Arsenic – a threat causing concern

Arsenic is a toxic and carcinogenic substance with inorganic compounds being more hazardous than the organic ones. Arsenic products were formerly used as colouring agents or as medicine and more recently in pest control and wood preservation. These uses have ceased but arsenic compounds are still used in industry.

Decreasing usage has been followed by less arsenic ending up in the environment. In Finland, arsenic emissions and leaches are small compared to other European countries. Nevertheless, considerable amounts of arsenic can still be found in the soils of former wood preservation plants.

Arsenic occurs naturally in Finnish bedrock. The largest area with higher than average arsenic concentrations is in southern Finland, around Tampere and Hämeenlinna. From soil and rock, arsenic may locally leach into ground water. More than 10 percent of those living in this region and using potable water from drilled bedrock wells are potentially exposed to deleterious amounts of arsenic. The mean exposure of Finnish inhabitants to arsenic is, however, diminutive in international comparison.

In areas with high arsenic concentrations in soil and bedrock, human exposure to arsenic can potentially be locally increased by rock aggregate production as well as by earth moving and excavation activities. Possible routes of exposure include atmospheric dust, exposed earth, and leaching into ground water or surface water. Risk assessment covers all steps of production while it also considers the extent of activity as well as natural conditions and local land-use.

Adverse effects can be prevented by applying good risk management techniques and best available technology. Several acts, such as Environmental Protection Act, Land Extraction Act, Health Protection Act, and Land Use and Building Act, regulate aggregate production and earth moving and excavation. Large schemes are subject to environmental impact assessment.

ASROCKS Research Project studied arsenic risks and their management in aggregate production and earth moving and excavation activities in Tampere–Hämeenlinna region. According to the results, arsenic does not pose any risk to local people, nor to ecosystems in the studied sites.

In Finland and in other Nordic countries, natural environment contains only small average amounts of arsenic compared to many other regions, such as Middle and South Europe. As far as we know, ASROCKS is the first research project in the world which studied and found out how arsenic is leached and transported from aggregate production and earth moving and excavation activities. The results of ASROCKS, and the guidelines that have been drawn from these results, can be applied in other countries where arsenic risks are more severe.

Freiberg, Germany
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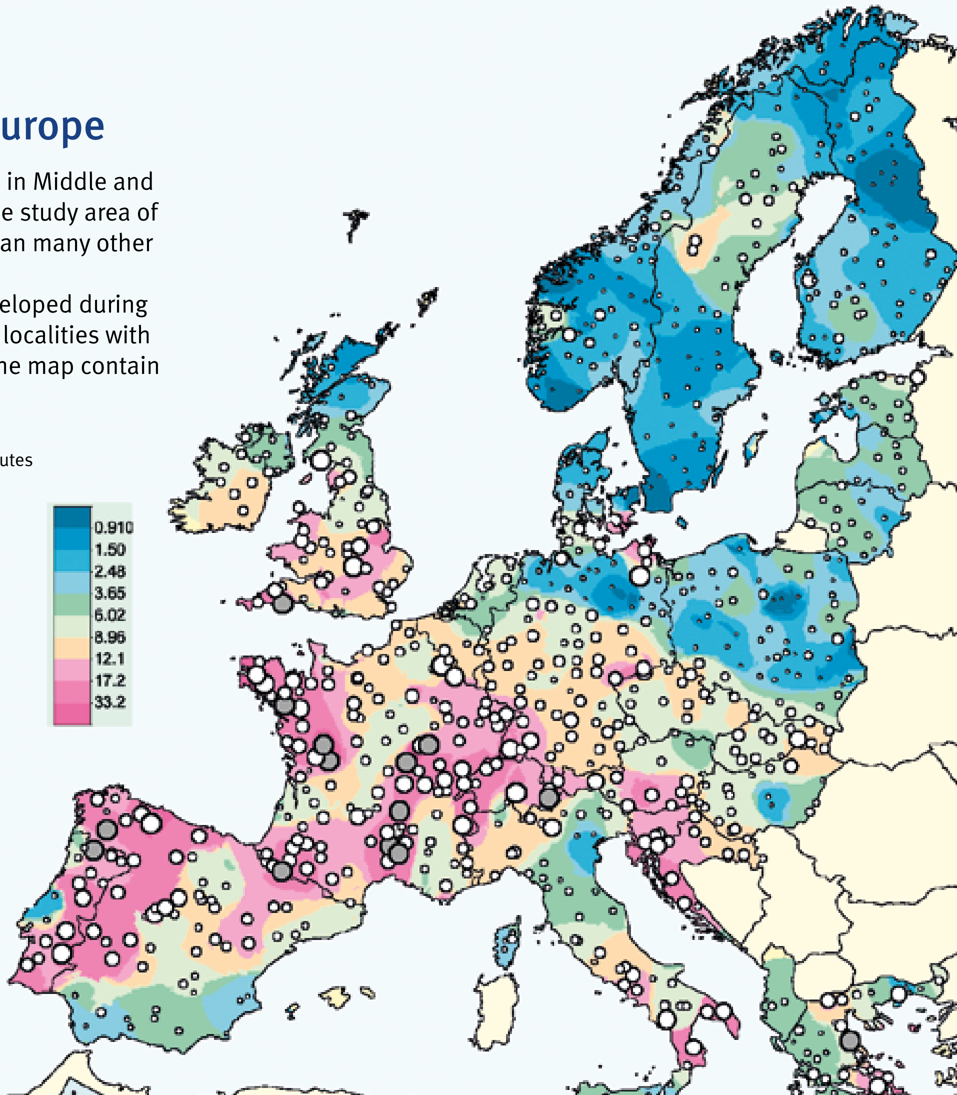
Distribution of arsenic in Europe

The subsoil contains more arsenic in average in Middle and Southern Europe than in Northern Europe. The study area of the ASROCKS project contains less arsenic than many other localities in Europe.

The guidelines and recommendations developed during the ASROCKS project can be applied to other localities with more severe arsenic risks. The red areas on the map contain more arsenic than the blue ones.

The map is based on the results of European geological institutes (www.gtk.fi/publ/foregsatlas).

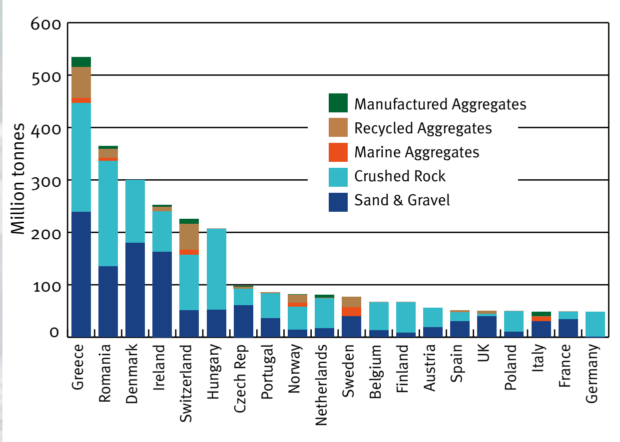


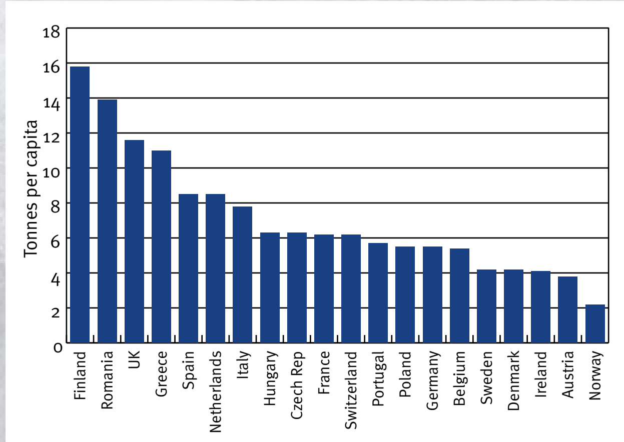
Aggregate production

Aggregate production is one of the most important process industries in the construction sector. The yearly amount of aggregates produced in 27 member countries of the European Union is nearly 3 billion tons according to the statistics published by the European Aggregates Association (UEPG). The amount of crushed rock is on average 50% of the production and the amount of gravel is on average 40%. The number of employed in European aggregate production is over 200 000. The average production amount of aggregates per capita is on average 5 tonnes. Aggregate production is highly regulated in all EU countries which causes a huge effort from over 10 000 production companies on e.g. the evaluation of environmental impacts of the production and product quality control. As aggregates are naturally and geologically variable materials the boundary conditions and environmental impacts of the production are different in over 20 000 European extraction sites.

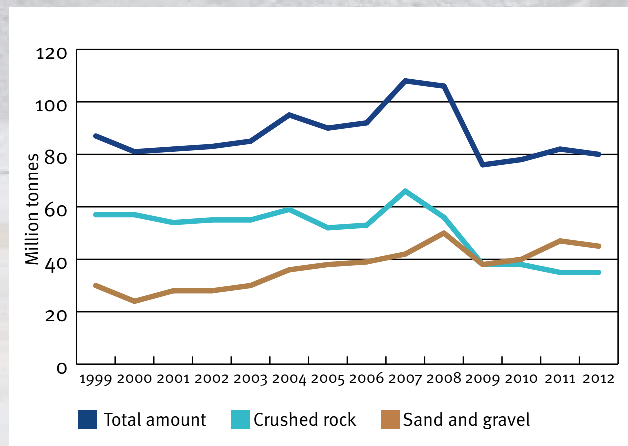
In Finland, some 400 producers operate over 2000 aggregate production sites. In 2010, the total aggregate production of 85 million tonnes consisted of one million tonnes of recycled aggregates, 36 million tonnes of sand and gravel and 48 million tonnes of crushed rock. This corresponds to a production rate of approximately 16 tonnes per capita, which is among the highest in Europe, according to the statistics published by UEPG. During 1998–2008, the volumes permitted for sand and gravel excavation decreased by 20%, while the respective volumes for quarrying for aggregate production increased by 60%. It is estimated that the share of crushed rock aggregates from all aggregates produced will significantly increase in the near future due to the lack of exploitable gravel areas, groundwater conservation policy and new cost-effective quarrying and crushing techniques. Aggregates are mainly used in road and railroad construction, in the foundations of structures and buildings, and in concrete and asphalt production. The annual revenue from aggregate production in Finland totals over 500 million euros. Overall, the activity employs approximately 3000 people.

Aggregate production in Europe





Aggregate production and use in Finland



Delineation of a geochemical arsenic province

In the beginning of the ASROCKS project, the area with higher than average arsenic concentrations in soil and in bedrock was delineated on the basis of geochemical maps.

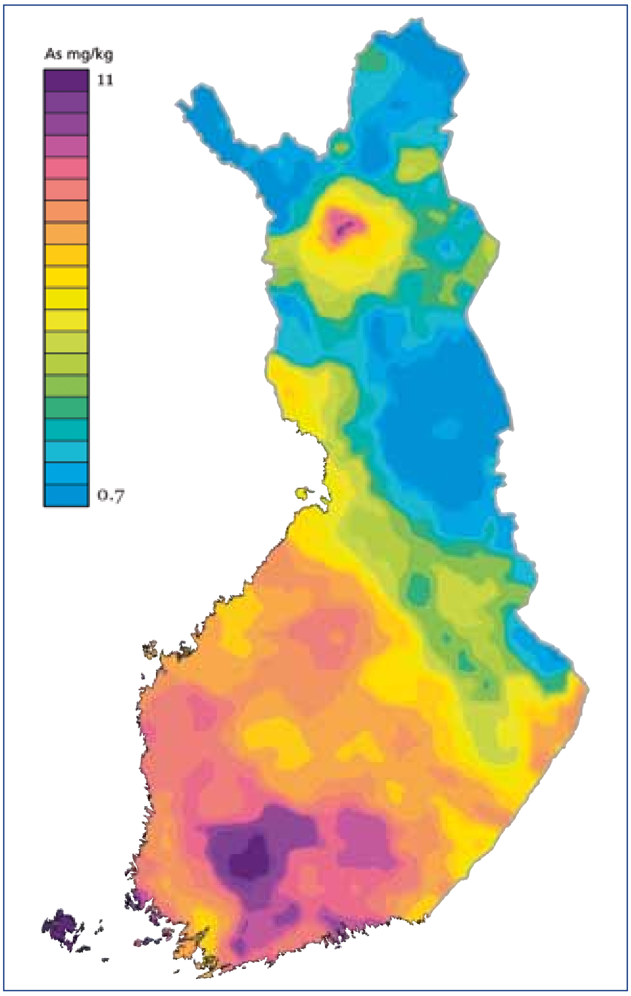
The delineation of the arsenic province for the ASROCKS project was done as follows:

1. The arsenic concentration in the till geochemical data in reconnaissance scale (density 1 sample/300 km2) was interpolated and smoothed into a regular grid. The preliminary delineation was made using ca. 10 mg/kg as a limit value.

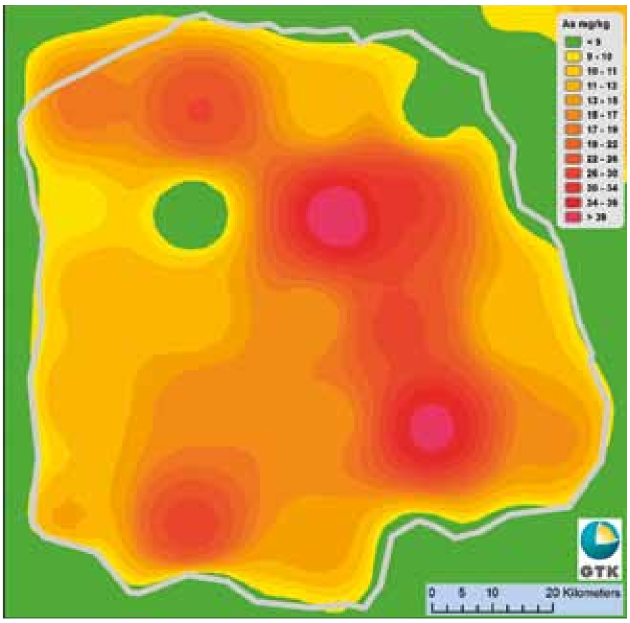
2. The preliminary delineation was tested using an independent data set: the regional soil baseline mapping data. Most of the samples with elevated arsenic concentration in the latter data set were located within the area delineated in the previous phase. However, in some cases the delineation could be carried out 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 arsenic concentrations in the soil, all the bedrock samples with the highest arsenic concentration in South-West Finland were located within the delineated province.

4. Production sites for rock aggregates, sand and gravel were selected from the delineated arsenic province for the ASROCKS project. The project team collected further information on the selected production sites and visited the potential demonstration sites during field excursion. 10 production sites for rock aggregates 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.



Distribution of arsenic in till in Finland. Source: Geochemical Atlas of Finland, Part 2: Till.



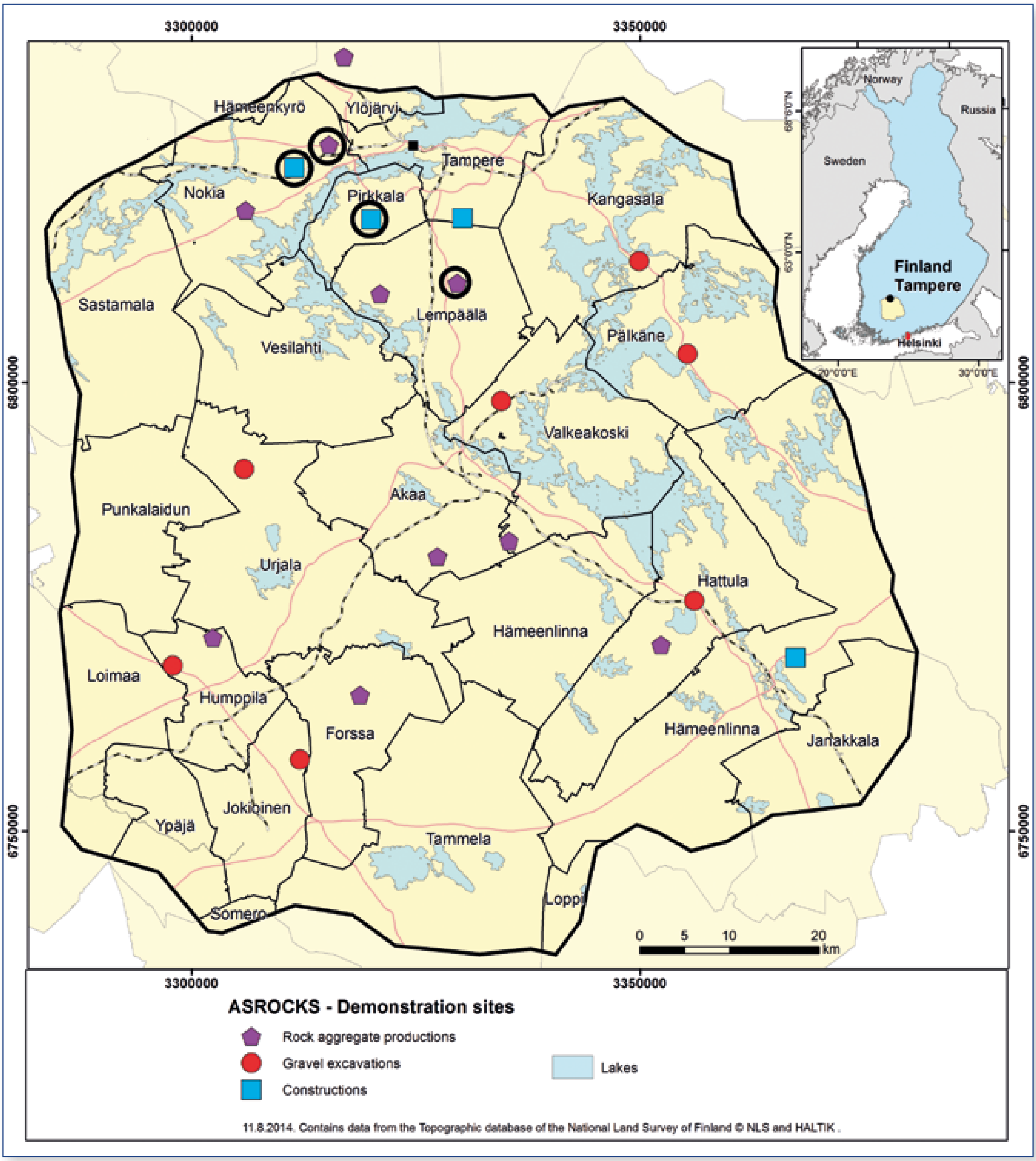
Delineation of arsenic province of Tampere – Häme region using till geochemical data in reconnaissance scale.

Kuva: Eero J. Laamanen / Vastavalo.fi

Studies in the demonstration sites

The demonstration sites of the ASROCKS project were aggregate production and construction sites. From the 21 demonstration sites four sites were selected for more detailed studies. The arsenic concentrations in products and soil samples taken from sand and gravel excavation sites proved to be lower than the local baseline concentrations, while the highest natural arsenic concentrations were found in the bedrock and soil of rock aggregate production sites and construction sites. Thus, two rock aggregate production sites and two construction sites were chosen for a closer look.

The aims of the studies on the ASROCKS demonstration sites were first to find the most important areas with the high natural arsenic concentrations in soil and bedrock and to produce information for risk assessment purposes and for the process of preparing guidelines for the producers, constructors and environmental authorities. The sample media used in this project were bedrock, soil, products, surface water and groundwater, but also some humus, stream sediment and vadose water samples were taken. In one demonstration site three drill holes into bedrock were drilled and in two sites pits through the



ASROCKS demonstration sites. The four demonstrations sites chosen for more detailed studies are circled with black.

quaternary deposits for soil profile sampling purposes were dug with excavator. In addition, bedrock mapping and hydrological mapping were carried out, and different sampling methods were tested and a new sampling method for bedrock samples was developed. Different extractions for arsenic analysis were compared and mineralogical studies of some samples were done. The arsenic concentrations in samples were measured with portable XRF and the results were compared with the laboratory measurements. Various leaching tests and a dust study were carried out.

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Bedrock drill core from a demonstration site.

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Soil profile sampling in a pit.

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Rock powder sampling using a drill-hammer.

The arsenic determinations from bedrock and soil samples show if there are harmful amounts of arsenic in the planned aggregate production site or in a construction site. Water is the main conduit for arsenic in nature. Therefore, the arsenic concentrations in surface water and groundwater could reflect the arsenic concentrations in bedrock and soil. Arsenic is necessarily not in an easily leachable form, thus the analysis of bedrock or soil samples are recommended. The arsenic concentrations in dust, humus and stream sediment tells about the drift of arsenic in the environment. The leaching tests show how easily and how much of the arsenic is leaching as well as in which kind of conditions the leaching is most or less probable.

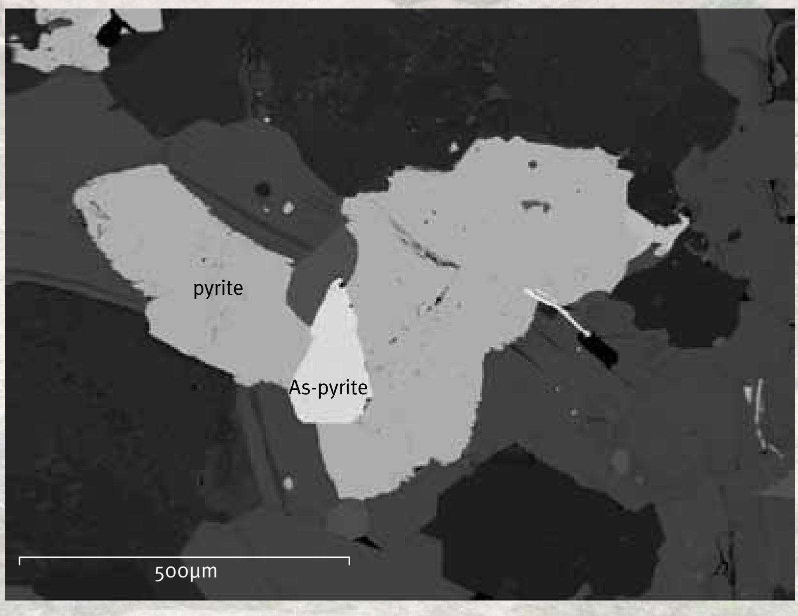
Results

Arsenic content varies widely in different rock types. Arsenic-rich sulphides may occur in shear and contact zones of the bedrock and in some rock types evenly disseminated. The highest arsenic concentrations were measured from gabbro rocks.

In soils of the study area, arsenic was found mostly as dust coating on mineral surfaces. The arsenic concentrations in the ASROCKS sand and gravel demonstration sites were mostly at the same level as the local baseline arsenic concentration. The highest arsenic concentrations in till are close to the bedrock surface. In ASROCKS project also some soil samples were taken from the fine-grained sediment of dried puddles in some production areas. Often, the arsenic concentrations were much higher in these sediments than in those of soil or bedrock.

In aggregate products, the highest arsenic concentrations were often found in the fine-grained aggregates. The sampling method does not play a very important role in coarse-grained products (graded samples). The composite samples based on 30–50 subsamples present best the average arsenic concentrations in the product piles. However, the adequate amount of single samples present better the total deviation of the composition, thus the minimum and maximum values can be found.

While the most important pathway of arsenic to the environment is water, representative water samples were important for the risk assessment. Both total and dissolved arsenic concentrations were determined from water samples.



The brightest mineral in the image is arsenic-bearing. It occurs with ordinary pyrite (the second brightest mineral). The darker minerals are silicates. Backscattered electron image on a polished thin section. Jeol JSM-9500LV scanning electron microscope.

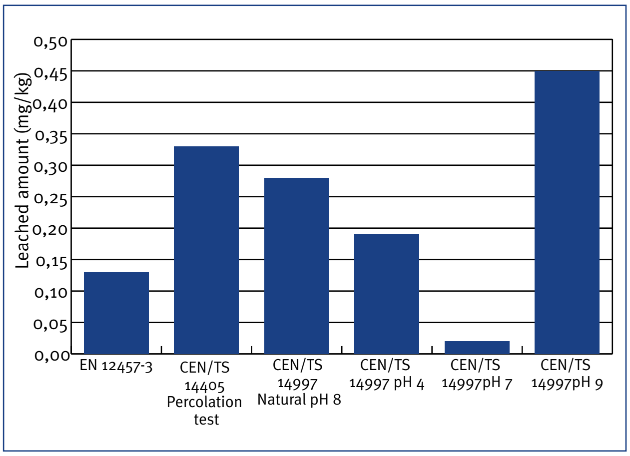
Kuva: Eero J. Laamanen / Vastavalo.fi

Results of the leaching tests

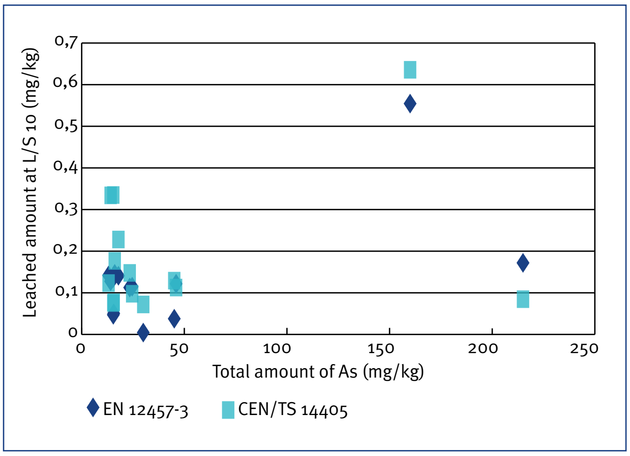
The leaching of arsenic was measured with four different test methods. All the test methods are European standards or technical specifications in order. Also total arsenic and aqua regia soluble arsenic concentrations were measured. The aim of the analyses was to assess the amount of easily leachable arsenic and the leaching behavior of arsenic in varied conditions, for example in different pH values. Soil and rock aggregate products of different grain sizes e.g. 0/4 mm, 4/8 mm and 0/16 mm., were collected for leaching tests. The leaching tests applied were EN12457-3, CEN/TS 14405, CEN/TS 14997 and EN 1744-3.

The aqua regia soluble arsenic concentrations of the aggregate products were 14–215 mg/kg. With the four leaching tests utilized, the leaching of arsenic from rock aggregates and soil samples was mainly less than 0.5 mg/kg. No correlation between the leaching and the total amount of arsenic was found. In the leaching tests that are most common in Finland, EN 12457-3 and CEN/TS 14405, the amount of arsenic leached was <1–2%. The leaching of arsenic from fine rock aggregate products depended on the pH: the amount leached was higher in pH values 4 and 9 than in neutral pH 7. According to the results the recommended test method for evaluation of leaching properties in the long run is the percolation test from a fine aggregate product (0/4 mm).

An example of the results of the different leaching tests with a 0/4 mm sample.



Comparison of the total amount of arsenic to leaching test results



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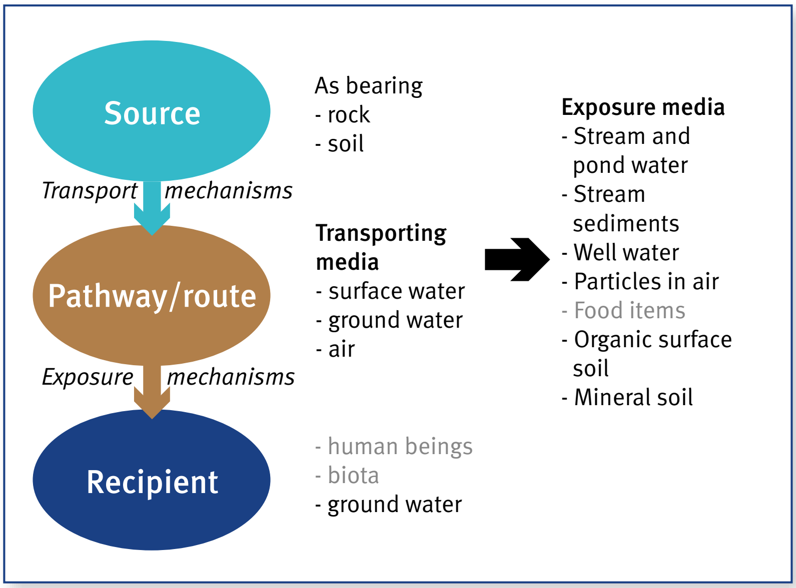
Risk assessment and risk management



How did we conduct risk assessments in ASROCKS

In ASROCKS the concept of arsenic risk was restricted to cover risks to biota, to groundwater quality and risks to human health outside of the assessed production or construction sites (no occupational health).

First we identified the most significant transport pathways and potential recipients at four selected study sites. The data consisted of GIS-data, land use plans and observations from the field trips. Then we constructed a conceptual model for primary sources of arsenic, transport pathways, exposure routes and recipients. All these elements are required in order to define an existent risk. Erosion, leaching, dusting and surface water runoff were the studied potential transport mechanisms of arsenic bearing material.

1. **Concentrations of arsenic in different environmental media/transport pathways were defined.** Concentration measurements of arsenic were available from most of the potential transporting and exposure media at the ASROCKS demo sites, except for biota and human food sources.

2. **Demonstration calculation of the arsenic load discharges with solids to the receiving water body was conducted.** Exceptionally diverse data was available from an EIA process of this aggregation production site, which is located in a catchment of a stream selected to the NATURA2000 network.

3. **Concentrations of arsenic were compared against various benchmarks such as ecological benchmarks background values and soil guideline values.**

4. **Human exposure was calculated at a case of a construction site.**

Results of risk assessment

The overall conclusion of the risk assessment is that there are no significant toxicological risks at the studied four ASROCKS sites.

At the rock aggregate production sites the ecological risks in the final receiving water body are insignificant. Also the risks to human health are insignificant. The dusting, for example, appears not to be as significant route of arsenic exposure at the aggregate production site conditions in ASROCKS study area, as the general expectations have been. The calculation of the risks to humans at a construction site showed that use of As-bearing material in topsoil could pose a minor risk.

Risks to groundwater quality remained unsure, because there is no clear evidence of the transport mechanisms in fractured bedrock at these sites.

Outlooks of arsenic risk management

Case-specific permits and their specific terms provide the steering mechanisms for the practical risk management actions for aggregate production. For earthworks city plans and local construction norms serve as important tools. Recently the use of these instruments has become slower and more complicated in the study area, because of the increased concern of arsenic risks. If unreasonable risk management actions are to be avoided; good risk communication plays a major role.

Information on the current practices was compiled from single local permits and the national database for the national environmental authorities' registered documents, documents related to EIA-procedures, and city plans in the Tampere-Häme region. A full day large workshop and two minor ones were organized during the ASROCKS project. The workshop used the open café method where a group of experts gathered around tables with a specific theme to discuss: city planning, permits, supervision and monitoring and the acceptability of soil and rock aggregate products. Also a supplementary e-mail questionnaire was carried out among the municipal authorities at the ASROCKS study area.

The planning phase of a new quarry or construction area was identified as most crucial in risk management. ASROCKS recommendations call for better quality of site investigations and larger target group of their application, such as preparation of regional land use plans, master plans and detailed city plans.

During action arsenic risks will be in the future monitored more often, especially in the vicinity of some bigger aggregation production sites in ASROCKS study area. The media to be investigated is increasingly surface water and potentially also the aggregate products. The need for bedrock groundwater monitoring should be carefully considered and nearby wells are recommended to be used when possible. It is very demanding to get reliable results with reasonable costs. Humus sampling could be a feasible monitoring method at sites, where the content of arsenic is exceptionally high or where the original source of arsenic is not clear. Humus layer receives the arsenic load, which is transported in particles via air.

The need for practical risk management actions arise usually from a wide range of potential load to environment, but can be successfully used also for mitigating arsenic risks. Commonly required risk management actions at quarries (BAT) and large construction sites include, for instance dust binding and increasingly also sedimentation basins or other storm water management technologies. Protective surface structures are common at constructed sites (e.g. paving), which hinder the rain water from leaching the arsenic from the underlying ground. Surface cover also prevents erosion and dusting.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Water is used for dust binding; the aggregate load is sprinkled.

Arsenic removal technologies are very rarely used in Finland outside mine areas or other industrial sites. Some households clean their well water with a suitable arsenic removal technology to get potable water. No significant increase is expected in the use of these removal technologies, at least by reason of ASROCKS results.


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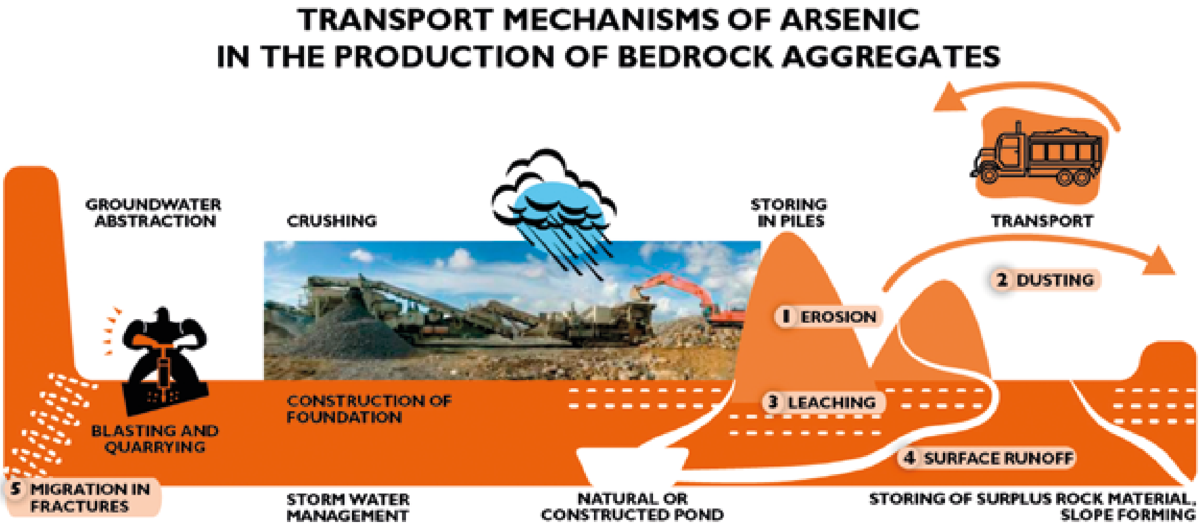
A full day large workshop and two minor ones were organized during the ASROCKS project with companies and authorities.



Published guidelines

The guidelines how to take arsenic into account in aggregate production and construction in area with elevated arsenic concentrations in bedrock and soil were published in various forms. The guidelines were compiled together with the stakeholders operating in ASROCKS study area in order to ensure their commitment and get practical advice from different expertize; aggregation and construction branches, local and regional authorities and planning consultants.

The general Finnish guidelines are found in print and in ASROCKS web pages (http://projects.gtk.fi/ASROCKS/ohjeistus/) where the ASROCKS main results and recommendations are distinguished and highlighted. A complementing report on guidelines for sampling procedures in aggregate production sites and sampling plans is also published by ASROCKS.

Guideline contents

1. Naturally occurring arsenic and anthropogenic emissions
2. Environmental and health effects
3. City planning and permitting
4. ASROCKS recommendations on investigations
5. Environmental impact assessment and risk assessment
6. Guideline values and interpretation of monitoring
7. Technical risks management

These guidelines are not a mandatory regulation for authorities, but serve in supporting a broad set of existing guidance. Information is provided on the characteristics and occurrence of arsenic, as well as the health and environmental effects. The obligations and present practices of aggregate producers and earthwork contractors are described. Recommendations are also given on how to interpret the results of environmental investigations. Finally, some technical means for reducing the arsenic load are presented.

The generic guidelines to be applied in other European countries (http://projects.gtk.fi/ASROCKS_ENG/guidelines/) summarize the suitable methods for arsenic pathway recognition, sampling and the choice of analytical methods and selection of risk management tools.

Recommended site investigations in planning and action phases

According to the results of the ASROCKS demonstration sites, the most important questions to address when a new aggregate production site or construction site is being set up are as follows:

- Is the new site located within an arsenic province, i.e. in the geological region with naturally elevated arsenic concentrations?
- What are the rock types at the site?
- Is there any information on elevated arsenic concentrations at the site or in its surroundings?
- What is the direction of surface water runoff from the site?
- Are there any private household wells or important groundwater aquifers nearby (within 300–500 m)?
- Are there any valuable natural resources or protected ecosystems or species in the surroundings?
- What is the planned land use and would this involve playgrounds or residential areas?

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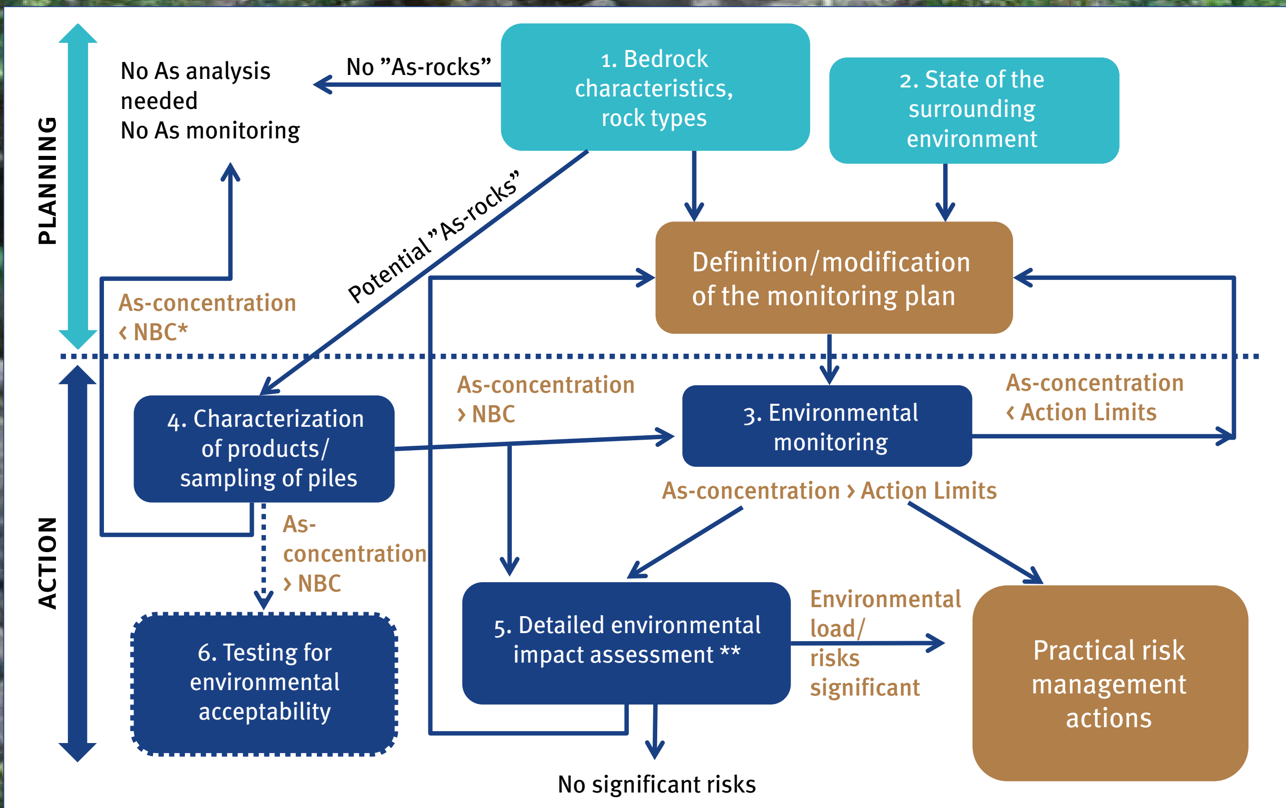
Notice board nearby a demonstration site.

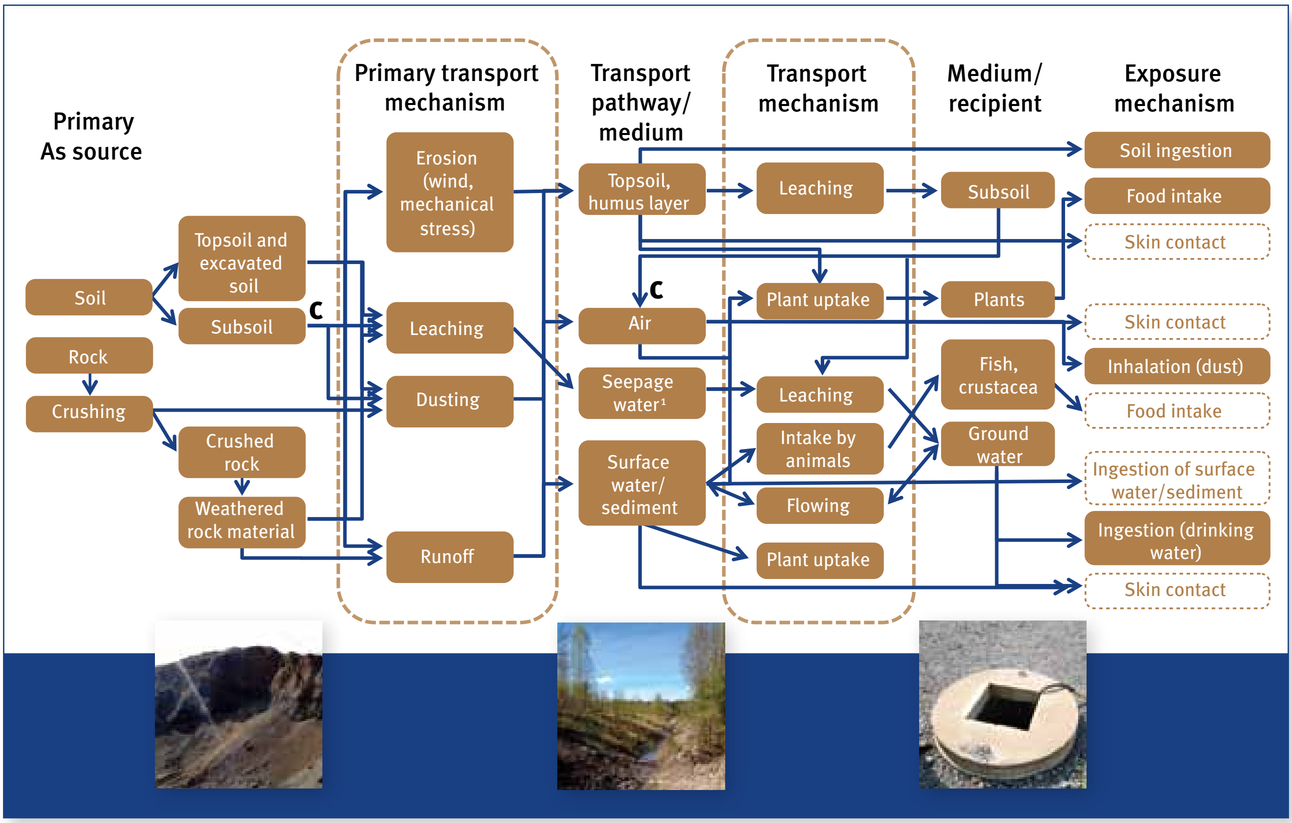
Flow chart



* NBC = normal background concentration, ** resampling, more detailed assessment etc.

Kuva: Jari Väätäinen, GTK

Formation of health risks - conceptual site model



Simple risk assessment methods and reference values

ASROCKS project constructed general conceptual models for the arsenic risks at aggregate production and earth work sites to be used as decision tools for defining the needs and targets of the site investigations. A preliminary risk assessment can in most cases be conducted with quite simple tools, such as comparing data from the site investigations with "the national list of inert rock types" and available reference values. Detailed route and exposure assessment is rarely needed in ASROCKS study area, because high arsenic concentrations found not to be so common.

The current custom of using human health based benchmarks for arsenic contents in stream water is not appropriate in Finland, because these small streams are very rarely used for household purposes. In mining areas reference values taken from the international literature have occasionally been used, but we are still missing suitable ecologically based reference values for fresh water ecosystems in Finland.

ASROCKS defined normal background concentrations for stream water and stream sediment in different regions of Finland, which can be used as reference values. Newly introduced reference values for contaminated sites (discharge) can be used in Finland, with tight restrictions in mind given in the guidelines by Ministry of the Environment.

Leaching tests for the CE marking of aggregates

In the European Economic Area, CE marking will be required for aggregate products. The harmonized test methods for virgin and recycled aggregates, especially those concerning dangerous substances, are under preparation in CEN (European Committee of Standardization). It is possible to include the information about the amount of any dangerous substance in a CE mark as soon as the national requirements are available.

The results from the different leaching tests applied in the ASROCKS project can be used in Finland when setting the national requirement for arsenic. They can also be useful for selecting suitable leaching test methods in other parts of Europe.

Dissemination and networking

Dissemination

The ASROCKS project has made a significant impact on the sustainable exploitation of rock aggregates in a region where environmental issues and fears for arsenic pollution have complicated the situation for years. Therefore, a lot of effort and resources were allocated to dissemination activities during the project. Local people, local and regional land-use authorities, environmental authorities and industrial parties as well as the Ministry of the Environment and scientific and technical community were the main target groups. Dissemination was required both in Finnish and in English languages. A lot of effort was put to the Layman's report, which was published both in English and in Finnish.

During the project it appeared that ASROCKS is the first project in the world which developed guidelines for rock aggregate production and construction activities in an area with arsenic in soil or bedrock. Even in Europe many countries have areas with greater arsenic concentrations in average compared to Finnish levels. Therefore, dissemination of the results to other European countries was seen to be most urgent and several meetings were organized in other European countries. A Road Show was arranged in 2014. The ASROCKS results, guidelines and recommendations were presented to local experts and/or environmental authorities in Uppsala, Sweden; Bratislava, Slovakia and Freiberg, Germany.

Examples of dissemination activities include:

- Presentations for general public: the kick-off meeting in Tampere in 2011 and two final seminars in Hämeenlinna and Tampere in 2014.
- Presentations for key stakeholder groups (rock aggregate producers, local and regional authorities and land owners) in the workshop in Tampere in 2013.
- Presentation at the Environment and Infrastructure Fair (Ympäristö ja Yhdyskunta 2012 -messut) in October 2012 in Helsinki.
- Presentations at the national annual seminars for environmental administration on contaminated soil (Helsinki February 2013) and on aggregate production (Helsinki May 2014).
- Presentations for scientific community in the 30th Nordic Geological Winter Meeting in Reykjavík in January 2012; in the seminar "Geochemistry and ore deposit models" at the University of Oulu on 17-18 October 2012; in the meetings of the Finnish Society for Soil Investigation and Remediation (Mutku ry) in Tampere on March 2013 and April 2014; in the Aquaconsoil conference in Barcelona 16-18 April 2013; in the 11th Finnish Conference of Environmental Sciences (FCES) in Tampere, 2-3 May 2013; in the 29th International conference for the Society for Environmental Geochemistry and Health (SEGH) in Toulouse, France on 8-12 July 2013; The 12th SGA Biennial Meeting 2013 (Society for Geology Applied to Mineral deposits) in Uppsala, Sweden on 11-15 August 2013; and EuroMining-fair in Tampere on 11-12 September 2013.

Networking

The project had active networking with many projects, for example:

- ABSOILS (LIFE09ENV/FI/000575) "Sustainable Methods and Processes to Convert Abandoned Low-Quality Soils into Construction Materials" demonstrates conversion of abandoned and low-quality soils - such like soft clays - into construction materials. Both ASROCKS and ABSOILS projects deal with natural constructions materials and both projects have demonstration sites in Finland. Experts from both projects met at the Geological Survey of Finland on 27 March 2013 and presented the preliminary results.
- ARSENAL, "Solutions for Arsenic Control in Mining Processes and Extractive Industry" has many links to ASROCKS since it was also coordinated by GTK. ARSENAL was co-funded by Finnish Funding Agency for Innovation (www.tekes.fi).
- South-East Finland - Russia ENPI CBC Programme project 2007-2013: "Efficient use of natural stone in the Leningrad region and South-East Finland" also have links to rock aggregate production like ASROCKS and was coordinated by the Geological Survey of Finland.

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Key persons and representatives of stakeholders after the final seminar of the ASROCKS project in Tampere 19th August 2014.

Summary

The volume of aggregate production is close to three billion tons in the European Union with the number of employed exceeding 200 000 persons. Aggregates are used in road and railroad construction and in the foundations of infrastructure and buildings. They form the basis for concrete and asphalt production. In Finland, the annual revenue from aggregate production exceeds 500 M€.

The main objective of the ASROCKS project was to develop guidelines for the exploitation of natural aggregate resources, crushed bedrock, sand and gravel, in areas with higher than average arsenic concentrations in bedrock and soil. Arsenic is a toxic and carcinogenic substance. People living in an arsenic-rich area can be exposed to arsenic, for example, using potable water from drilled bedrock wells occurring close to the production and construction sites.

During the project it appeared that ASROCKS is the first in the world to develop guidelines for aggregate production in arsenic-rich areas even though severe arsenic problems have been reported from localities in Europe, Asia and America.

The ASROCKS project found no actual problems in the studied aggregate production and construction sites in Finland. The guidelines and sampling and analytical procedures developed in the ASROCKS project can be applied in other countries since arsenic-rich areas occur in most European countries and the average levels seem to be higher in Middle and Southern Europe than in Northern Europe.

Because of the international importance and the pioneering nature of the findings, the ASROCKS project allocated a lot of resources to dissemination activities during the last year of the project.

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Main deliverables and publications of the ASROCKS project

Deliverables

1. Map of areas with elevated natural concentrations of arsenic in bedrock and soil in the Tampere-Häme region. 30.11.2011 (Action 1) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
2. Launch of the project's web-site. 30.11.2011 (Action 8)
3. Brochure of the project and its objective. 31.1.2012 (Action 8)
4. Map showing locations of 21preliminary demonstration sites and the list of aggregate production sites, major earthworks and selected potential construction sites in Tampere-Häme region. 31.1.2012 (Action 1) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
5. Dissemination plan. 28.2.2012 (Action 8)
6. Sampling plan for selected 21 demonstration sites. 31.3.2012 (Action 1) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
7. List of selected detailed demonstration sites for Action 2. 31.8.2012 (Action 1) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
8. Questionnaire to major stakeholders. 31.10.2012 (Action 8) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
9. Evaluation of dissemination 31.3.2013 (Action 8) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
10. Description of selected 21 demonstration sites, 31.5.2013 (Action 1) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html http://tupa.gtk.fi/raportti/arkisto/3_2013.pdf
11. General Guidelines for Sampling Procedures in Aggregate Production Sites and Sampling Plans, 31.5.2013 (Action 2) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
12. Results of leaching experiments of selected aggregates 30.9.2013 (Action 2) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
13. General and site-specific conceptual models for qualitative risk assessment 31.10.2013 (Action 2) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
14. Decision support model of sustainable exploitation for environmental authorities. 30.4.2013 (Action 3) http://projects.gtk.fi/ASROCKS/ohjeistus/
15. Guidelines for the sustainable exploitation of aggregate resources in areas with naturally elevated concentrations of arsenic in soil and/or bedrock. 30.4.2014 (Action 4) http://projects.gtk.fi/ASROCKS_ENG/guidelines/
16. Operation manual for authorities at municipal and regional levels. 30.4.2014 (Action 4) http://projects.gtk.fi/ASROCKS/ohjeistus/
17. Risk management tools for sustainable exploitation of aggregate resources in areas with elevated arsenic concentrations. 30.6.2014 (Action 3) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
18. Booklet: Guidelines for environmental management of aggregate resources. 31.8.2014 (Action 8) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
19. Layman's report. 31.8.2014 (Action 8) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html
20. After-LIFE Communication Plan. 31.8.2014 (Action 7) http://projects.gtk.fi/ASROCKS_ENG/project/deliverables.html

Reports

Tarvainen, T., Kuula-Väisänen, P. & Härmä, P. 2013. ASROCKS- hankkeen Action 1 vaiheen tutkimuskohteet.45 s. Geologian tutkimuskeskus, Arkistoraportti 3/2103. 45 s. (in Finnish). Description of demonstration sites for Action 1 in the ASROCKS project.

Hatakka, T., Backman, B., Härmä, P., Kuula-Väisänen, P., Reinikainen, J., Tarvainen, T. & Vuokko, J. 2013. Näytteiden otto geokemiallisia analyysejä ja liukoisuustestejä varten kalliokiviainesten sekä soran ja hiekan tuotantoalueilla ja rakennuskohteissa luontaisesti korkeiden arseenipitoisuuksien alueilla. Geologian tutkimuskeskus, Arkistoraportti 141/2013. 26 s. (in Finnish). Description of sampling procedure for geochemical analyses and leaching tests in the ASROCKS demonstration sites.

Ketola, T. & Kuula, P. 2013. ASROCKS-hankkeen Action 2 –vaiheen liukoisuustestien tulokset. Tampereen teknillinen yliopisto. Rakennustekniikan laitos. Maa- ja pohjarakenteet. Tutkimusraportti. 30 s. (in Finnish). Results of leaching tests for Action 2 in the ASROCKS project.

Elminen, T. & Wennerström, M. Kallioperän heikkousvyöhykkeistä Nokian, Harjuniityn, Koiviston ja Marjamäen kohdealueilla. Geologian tutkimuskeskus, Arkistoraportti 53/2014. 10 s. (in Finnish). Bedrock structures and shear zones in the ASROCKS demonstration sites at Nokia, Harjuniitty, Koivisto and Marjamäki.

Hannukainen, L. 2013. The impact of mineralogy on the leaching of arsenic. Unpublished B.Sc. thesis, Tampere University of Technology. (in Finnish)

Main Publications

Lehtinen, H. (ed.), Härmä, P., Tarvainen, T., Backman, B., Hatakka, T., Ketola, T., Kuula, P., Luoma, S., Pyy, O., Sorvari, J. & Loukola-Ruskeeniemi, K. 2014. Kiviainesten otto arseenialueilla: Opas kiviainesten tuottajille, maarakentajille ja viranomaisille. (in Finnish. Summary in English: Exploitation of aggregates in areas with naturally elevated concentrations of arsenic in bedrock and soil. Guidelines for producers, earthwork contractors and authorities.) Geological Survey of Finland, Guide 59. 68 pages, 39 figures, 17 tables and an appendix. http://tupa.gtk.fi/julkaisu/opas/op_059.pdf

Hallanaro, E.-L. and Loukola-Ruskeeniemi, K. 2014. Arseenia kalliossa! ja mitä siitä sitten seuraa… (in Finnish. Summary in English: Arsenic in Bedrock! - and Then What Happens...) Geological Survey of Finland, Special Publications, 107 pages. (The Laymans report of the Asrocks project in Finnish, targeted to general public.) http://tupa.gtk.fi/julkaisu/erikoisjulkaisu/

Lehtinen, H. & Sorvari, J., 2013. Yli 20 vuotta arseeniriskien hallintaa Pirkanmaalla. Ympäristö ja terveys 7/2013, 50-54. (in Finnish). Over 20 years of arsenic risk management in the Pirkanmaa area, Finland.

Conference presentations

30th Nordic Geological Winter Meeting in Reykjavik, Iceland, 9.-12.1.2012, Jussi Mattila and Paavo Härmä, abstract and oral presentation.

“Geochemistry and ore deposit models”-seminar, 17.-18.10.2012, Oulu, Finland, Paavo Härmä, abstract and poster presentation.

12th International UFZ-Deltares Conference on Groundwater-Soil-Systems and Water Resource Management, “Aquaconsoil”, 16–19 April 2013, Barcelona, Spain. Jaana Sorvari, abstract and poster presentation.

The 11th Finnish Conference of Environmental Sciences (FCES), 2.-3.5.2013, Tampere, Terhi Ketola, abstract and poster presentation.

The 29th International conference for the Society for Environmental Geochemistry and Health (SEGH) in Toulouse, France on 8-12 July 2013. Timo Tarvainen and Paavo Härmä, abstract and oral presentation.

The 12th SGA Biennial Meeting 2013 (Society for Geology Applied to Mineral deposits) in Uppsala, Sweden on 11-15 August 2013. Paavo Härmä and Kirsti Loukola-Ruskeeniemi, abstract and poster presentation.

EuroMining-fair, 11-12 September 2013, Tampere.
Terhi Ketola, poster presentation.

“31st Nordic Geological Winter Meeting” 8-10 January, 2014 in Lund, Sweden, Birgitta Backman and Tarja Hatakka. Abstracts and oral presentations.

PANK menetelmäpäivä (PANK Method Meeting) in Helsinki on 23 January 2014. Terhi Ketola. Oral presentation.

11th Finnish Geochemical Meeting in Espoo, Finland on 5-6- February 2014. Paavo Härmä, Tarja Hatakka and Birgitta Backman. Abstracts and oral presentations.

Kiviaines- ja murskauspäivät (Seminar of Aggregates and crushing) in Vantaa, Finland, on 13-14 February 2014. Pirjo Kuula. Oral presentation.

Kannenkuvat: GTK

After LIFE

In the future, the following activities will be carried out:

1. Website. The website of the project will be available at least until 2019 (http://projects.gtk.fi/ASROCKS). Deliverables of the project will be available for industry, environment authorities and for general public free of charge. “Guidelines” subpages will be updated on a regular basis. The website of the ASROCKS project is linked to the website of the Coordinating beneficiary. Therefore, the web pages will be taken care of by the web page administrator of Geological Survey of Finland.
2. The guidelines developed during the ASROCKS project may be implemented into regulations of environment authorities in Finland and the European Union.
3. The results of the ASROCKS project will be presented in near future in numerous conferences and workshops, including
   - NORDROCS, 5th Joint Nordic Meeting on Remediation of Contaminated Sites in Stockholm, Sweden, 15-18th September 2014,
   - Environment and Underground research seminar in Espoo, Finland, 5th October 2014
   - IAEG, International Association for Engineering Geology XII Congress in Torino, Italy, 15-20th September 2014.
   - the results of ASROCKS project will be presented to the European Aggregates Association (UEPG) in Brussels 9th October 2014.
4. The results of the ASROCKS project will be applied in the regional plan of the Tampere region in determining areas appropriable for exploitation of crushed rock aggregates.
5. The beneficiaries of the ASROCKS project are eager to continue investigations and demonstration activities with arsenic-rich aggregate products. Therefore, there will be ideas for new cooperative projects in near future. Cooperation with other European countries having challenges with high arsenic concentrations in bedrock and subsoil will continue.

Kuva: Kaj Skön / Vastavalo.fi

Highlights

ASROCKS project developed the guidelines for sustainable aggregate production and construction in arsenic-rich areas.

The guidelines can be applied in other countries with problems with arsenic.

Arsenic is a carcinogenic substance especially in drinking water.

ASROCKS was the first project in the world to investigate and develop risk management tools for arsenic in crushed rock aggregate and construction industry.

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TAMPEREEN TEKNILLINEN YLIOPISTO

SYKE

LIFE + Environment Policy and Governance Project LIFE10 ENV/FI/000062 ASROCKS 2011–2014.
With the contribution of the LIFE financial instrument of the European Community