Risk Assessment and Risk Management Procedure for Arsenic in the Tampere Region

Risk Management of Environmental Arsenic in Finnish Conditions - case Pirkanmaa region

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Abstract

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Risk management related to environmental contaminants such as arsenic (As), can be based on policy instruments, informational mechanisms and technical methods. For example, emissions and human exposure can be restricted by issuing regulations, orders and guidelines (policy instruments). Different registers and databases can be used to support risk management (informational mechanisms) and different technical remediation and cleaning methods can be used to reduce the environmental concentrations of arsenic or to transform it to a less harmful form. Such actions can be subsidized by state or municipalities (economic policy instruments). Land use planning is also one of the methods to control risks. In the first phase of the task 'Risk management' belonging to the RAMAS -project all existing methods used in the management of As-related risks were surveyed. In the next phase, the study was focused specifically on the risk management procedures adopted in the study region Pirkanmaa and on the identification of possible development needs. The work was based on the data produced in other RAMAS tasks. Relevant data included the information about the occurrence of arsenic and possible sources and risks to human health and biota originating from these.

In the identification of the existing risk management actions we used different literature sources and administrative documents such as environmental permits and regulations. In addition we interviewed several experts. To identify the regional-level risk management needs we also produced risk maps using the ArcGIS9.2 tool.

Our survey showed that in Finland, the anthropogenic sources of arsenic are well-known and that several mechanisms are in use for the management of the risks. According to the risk assessment carried out within RAMAS the major source of human health risks in Pirkanmaa is the arsenic in drinking water originating particularly from drilled groundwater wells. These risks have been restricted e.g., by expanding the water supply network, such activities have also been subsidized by state. It is important that the expansions are continued in the future. In some cases residential activities may result in significant additional exposure at former wood impregnation plants. These risks can be reduced by remedial measures which are regulated pursuant to the Environmental Protection Act and former waste legislation. Data on the contaminated sites which might contain arsenic e.g., mine sites and wood impregnation plants, have been collected and are maintained in the national register. So far, remediation measures have been carried out at eight of the existing 14 wood treatment plants located in Pirkanmaa. At present only few remediation methods are available of which soil excavation and treatment off site has been the most common. No notable remediation activities have been realized at mine sites.

From the viewpoint of environmental risks, old mine sites in particular are relevant owing to their large spatial scale. In Pirkanmaa, valuable nature reserves are located at least in the vicinity of the mine sites of Haveri and Kutemajärvi. However, the factual spatial dimensions of the environmental effects are unknown. We recommend restricting human activities particularly at the tailings areas of mine sites in order to eliminate the distribution of arsenic via air and surface runoff. This can also be accomplished by active remediation measures. The impact areas may also extend to future residential areas. Therefore, it is necessary to ascertain the range of the environmental effects of mine sites when new areas area reserved in the local and master plans on land use. The wetlands between mine sites and larger water systems effectively bind arsenic and hence hinder its migration further in the water system. The functioning of such natural 'purification units' should be maintained. At the Ylöjärvi mine site, it could be worthwhile to establish different zones on which the risk management actions would be focused. At the core zone contamination could be acceptable and the land use could be heavily restricted in order to eliminate exposure. At former wood impregnation plants, the most contaminated hot spots could be marked in order to avoid human exposure. Some of the former impregnation plants are located on important groundwater areas (class I). At such areas it is important to consider possible risks to groundwater quality.

When deciding on the risk management actions it is finally necessary to give up the 'zero risk' target since there are several factor involved in decision-making. Such factors include among others, resource needs, valuation aspects (what we want to protect), and the feasibility of risk management affected e.g., by the availability of different methods.

Keywords (GeoRef, Thesaurus): environmental geology, arsenic, ground waters, soils, pollution, risk assessment, risk management, remediation, Pirkanmaa, Finland

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Tiivistelmä

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Ympäristön haitta-aineista kuten arseenista aiheutuvia riskejä voidaan hallita oikeudellis-hallinnollisin, tiedollisin, teknisin ja taloudellisin keinoin. Erilaisilla säädöksillä, määräyksillä ja ohjeilla (oikeudellis-hallinnolliset keinot) rajoitetaan esimerkiksi päästöjä tai ihmisten altistumista. Riskien hallinnassa käytetään apuna myös erilaisia rekistereitä ja tietokantoja. Kunnostus- ja puhdistustoimilla voidaan pienentää arseenin pitoisuuksia ympäristössä tai esimerkiksi saattaa arseeni haitattomampaan muotoon. Näitä toimia voidaan tukea taloudellisesti. Riskit voidaan lisäksi ottaa huomioon maankäytön suunnittelussa. RAMAS -hankkeen 'Riskinhallinta' -osaprojektin ensimmäisessä vaiheessa selvitettiin laajalti olemassa olevia arseenista aiheutuvien riskien hallintakeinoja. Seuraavassa vaiheessa keskityttiin erityisesti Pirkanmaan alueella toteutettujen riskinhallintamenettelyjen ja näiden kehitystarpeiden tunnistamiseen. Työssä hyödynnettiin RAMAS -hankkeen muissa osaprojekteissa tuotettua tietoa arseenin alueellisesta esiintymisestä ja mahdollisista päästölähteistä sekä näistä aiheutuvista riskeistä ihmiselle ja eliöstölle.

Riskinhallintamenettelyjen tunnistamisessa käytettiin aineistona erilaisia kirjallisuuslähteitä ja hallinnollisia dokumentteja kuten lupapäätöksiä ja säädöksiä sekä kohdennettuja asiantuntijahaastatteluja. Alueellisten riskinhallintatarpeiden tunnistamista varten tuotettiin kartta-aineistoja käyttäen ArcGIS9.2 työkalua.

Selvitys osoitti, että Suomessa arseenilähteet on tunnettu jo pitkään ja niistä aiheutuvia riskejä on pyritty hallitsemaan usein eri keinoin. RAMAS –hankkeessa toteutetussa riskinarvioinnissa terveysriskien kannalta olennaisimmaksi tekijäksi tunnistettiin pohjavedestä peräisin olevan juomaveden sisältämä arseeni. Ongelma liittyy erityisesti porakaivoihin. Pirkanmaan alueella näitä riskejä on pyritty rajoittamaan vesijohtoverkostoa laajentamalla. Näitä toimia on valtio tukenut myös taloudellisesti. Verkoston laajentamista on syytä jatkaa edelleen. Asumiseen liittyvä altistuminen etenkin entisillä kyllästämöalueilla voi joissain tapauksissa muodostaa merkittävän lisäriskin. Näitä riskejä pyritään vähentämään kunnostustoimin, joita säädellään ympäristönsuojelulain ja aiemman jätelainsäädännön perusteella. Arseenia mahdollisesti sisältävät pilaantuneet alueet kuten kaivokset ja kyllästämöt on kartoitettu ja niitä sisältävät tiedot on koottu kansalliseen Matti-rekisteriin, jossa niitä myös ylläpidetään. Kahdeksalla Pirkanmaan alueen 14 kyllästämöstä on myös toteutettu joitain kunnostustoimia. Käytettävissä on toistaiseksi vain muutamia kunnostusmenetelmiä, joista maa-ainesten poisto ja käsittely muualla on ollut yleisin. Kaivosalueilla sen sijaan aktiivisiin kunnostustoimiin ei ole ryhdytty.

Ympäristöriskien kannalta etenkin vanhat kaivosalueet ovat merkittävä riskitekijä johtuen lähinnä vaikutusalueen laajuudesta. Ainakin Haverin ja Kutemajärven kaivosten läheisyydessä on arvokkaita luontokohteita. Vaikutusalueen todellista laajuutta ei kuitenkaan tunneta. Toimintojen rajoittaminen etenkin kaivosten rikastushiekka-alueilla siten, että arseenin leviäminen esimerkiksi ilman kautta estyy, olisikin siksi suotavaa. Vaihtoehtona ovat myös aktiiviset kunnostustoimet. Kaivosten vaikutusalueella voi myös olla kaavoituksen piirissä olevia toimintoja, lähinnä asutusta. Kaavojen tarkistamisen ja uusien kaavojen laatimisen yhteydessä onkin tarpeen selvittää kaivosten ympäristövaikutusten alueellinen ulottuvuus. Kaivosalueiden ja vesistöjen välillä olevien kosteikkoalueiden todettiin sitovan tehokkaasti arseenia ja estävän sen leviämistä laajalti vesistöön. Tällaisten luontaisten "puhdistamoiden" toimintaa on syytä ylläpitää. Laajalti pilaantuneella Ylöjärven kaivosalueella voitaisiin myös muodostaa vyöhykkeitä, joihin riskinhallintatoimet kohdennetaan. Ydinvyöhykkeellä hyväksyttäisiin pilaantuminen ja alueen käyttöä rajoitettaisiin voimakkaasti altistuksen välttämiseksi. Entisillä kyllästämökiinteistöillä voimakkaimmin pilaantuneet alueet voitaisiin merkitä maastoon ihmisten altistumisen vähentämiseksi. Osa Pirkanmaan toimintansa lopettaneista CCA-kyllästämöistä sijaitsee tärkeillä (luokka I) pohjavesialueella, joilla on tarpeen ottaa huomioon myös mahdolliset riskit pohjaveden laadulle.

Viime kädessä riskinhallintatoimista päätettäessä joudutaan tinkimään "nollariskitason" tavoitteesta, sillä riskinhallintatoimiin ja niiden laajuuteen vaikuttavat riskien lisäksi lukuisat muut tekijät. Näitä ovat mm. riskinhallinnan vaatimat resurssit, arvotukseen liittyvät kysymykset (esim. mitä halutaan suojella), ja mm. menetelmien saatavuudesta riippuva riskinhallinnan toteuttamiskelpoisuus.

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PREFACE

RAMAS is a three-year project (2004 - 2007) funded by the participating organizations and the LIFE ENVIRONMENT –programme, by the beneficiary, Geological Survey of Finland (GTK), and by the following partners: Helsinki University of Technology (TKK), Pirkanmaa Regional Environment Centre (PIR), Finnish Environment Institute (SYKE), Agrifood Research Finland (MTT), Esko Rossi Oy (ER) and Kemira Kemwater (Kemira).

The acronym RAMAS comes from the project title "Risk Assessment and risk Management procedure for Arsenic in the Tampere region". Spatially, the project covers the whole Province of Pirkanmaa (also called the Tampere region) comprising 33 municipalities (in 2005), and 455 000 inhabitants within its area. The number of municipalities decreased to 28 in January 2007 while the number of inhabitants reached 469 000. Tampere, Finland's third largest city is the economic and cultural centre of the region.

The project aims to identify various sources of arsenic in Pirkanmaa, to produce an environmental risk assessment (covering human health risk assessment and ecological risk assessment) for the region and to present recommendations for the management of risks. This project is the first in Finland to create an overall, large-scale risk management strategy for a region that has natural and anthropogenic contamination sources.

The project is divided into logically proceeding tasks having responsible Task Leaders who coordinate the work within their tasks:

1. Natural arsenic sources (GTK) Birgitta Backman
2. Anthropogenic arsenic sources (PIR), Kati Vaajasaari until 30.4.2006; Ämer Bilaletdin since 1.5.2006
3. Risk assessment (SYKE), Eija Schultz
4. Risk management (SYKE), Jaana Sorvari
5. Dissemination of results (TKK), Kirsti Loukola-Ruskeeniemi
6. Project management (GTK), Timo Ruskeeniemi

The project produces a number of Technical Reports, which are published in a special report series by GTK. Each report will be an independent presentation of the topic in concern. The more comprehensive conclusions will be drawn in the Final Report of the RAMAS project which summarizes the project results. Most reports will be published in English with summaries in Finnish. A cumulative list of the reports published so far is presented in the back cover of each report. All documents are also downloadable in the project's home page: www.gtk.fi/projects/ramas.

1 Introduction

It is generally known that exposure to arsenic (As) or its compounds can induce a variety of adverse ecological or health effects, human genotoxicity and carcinogenicity being among these. Therefore, suitable measures are needed to manage risks resulting from arsenic contamination. The regional-level risk management (RM) needs and options to control the Arsenic-related risks to human health and biota were investigated within the RAMAS project. Several areas with an As-anomaly have been identified in Finland, the southern parts of Pirkanmaa (Tampere region) being one of these. Pirkanmaa also has a long industrial history and therefore, anthropogenic arsenic is expected to pose additional risks.

This study is a continuation of the earlier survey on existing and potential RM actions (Lehtinen & Sorvari 2006). Some data presented in the report of this survey are also updated. The identification of RM needs was based on the results of the health risk assessment and ecological risk assessment conducted in a separate task (documented in Sorvari *et al.* 2007). However, risks to humans and biota constitute only one element in the decision making on RM actions and primarily a part of the identification of RM needs. Other elements to consider include e.g., regulatory control, technical availability and feasibility of the planned actions, benefits of RM measures, pressures in land use or other regional or even global politics, financial and human resources and social or cultural aspects. Since study on these other factors was out of the scope of RAMAS project, the focus in this report is on the risk aspects. However, the possible contributions of these other elements are briefly discussed.

2 Definitions

The RAMAS terminology for the regional risk management of environmental arsenic has developed during the project. The concepts of risk and risk management were first defined very widely. According to the generic definition, ‘risk’ is the combination of the probability of an event and its consequence, generally used only when there is at least the possibility of negative consequences. In the socio-economic discourse, risk can be defined as the chance of adverse effect on the socio-economic system, like unemployment, unwillingness to invest, high costs of remediation, psychological effects, etc. (see IMS[1]). However, the risk assessment procedures carried out in RAMAS covered only the toxicological risks and risks to the quality of the environment, i.e., risks to human health, risks to biota and risks to groundwater quality. Hence, the concept of risk was restricted to cover only these factors. In the environmental discourse, this definition of risk is probably the most common**.** Moreover, for the RAMAS project, very little information was readily available of the adverse effects of arsenic pollution on the sosio-economic system.

The ISO Technical Management Board on risk management terminology has prepared a generic vocabulary (ISO/IEC guide 73:2002). This terminology does not particularly refer to the management of environmental and health risks. In this guide the term `risk management´ is defined as a set of coordinating activities, including the risk assessment procedure. In RAMAS project the procedure and the detailed results of risk assessment are described in a separate report. The term ’risk management‘ in RAMAS reports refers mainly to the terms ’risk treatment‘ and ’risk communica-

[1] IMS = Integrated management strategy for prevention and reduction of pollution of waterbodies at contaminated industrial megasites. http://www.euwelcome.nl/kims/strategies/?index=7, 12.4.2007.

tion‘ defined in the ISO terminology. The relevant stakeholders from the viewpoint of the RAMAS project are discussed in section 3.2.

Risk management
- Coordinated activities to direct and control an organization with regard to risk

Risk treatment
- Process of selection and implementation of measures to modify risk. Risk treatment embraces the terms risk avoidance, risk optimization, risk transfer and risk retention.

Risk communication
- Exchange or sharing of information about risk between the decision-maker and other stakeholders

Stakeholder
- Any individual, group or organization that can affect, be affected by, or perceive itself to be affected by, a risk. (Source: ISO/IEC guide 73:2002)

3 Study materials and methods

3.1 Working phases

The identification of the development needs in the risk management of arsenic in the study area, Pirkanmaa, was based on two working phases (Fig. 1). Phase 1 comprised a survey on the available RM measures with a focus on national level and on policy instruments. In addition to those measures focused specifically and explicitly on arsenic, also mechanisms addressing a broader array of agents were included. Some of these instruments prioritize other elements instead of arsenic. Many of the regulations still pending during the realization of Phase 1 have since been enacted.

In Phase 1, a survey on technical means to restrict or eliminate arsenic risks was also carried out in parallel with the study on policy instruments. This survey covered all environmental media and releases, except air emissions which were excluded on the basis of the results from the preliminary studies on the potential sources of arsenic in Pirkanmaa. Moreover, the survey was focused on the full-scale methods with proven feasibility. The survey on the technical methods is reported separately, together with the policy study (Lehtinen & Sorvari 2006).

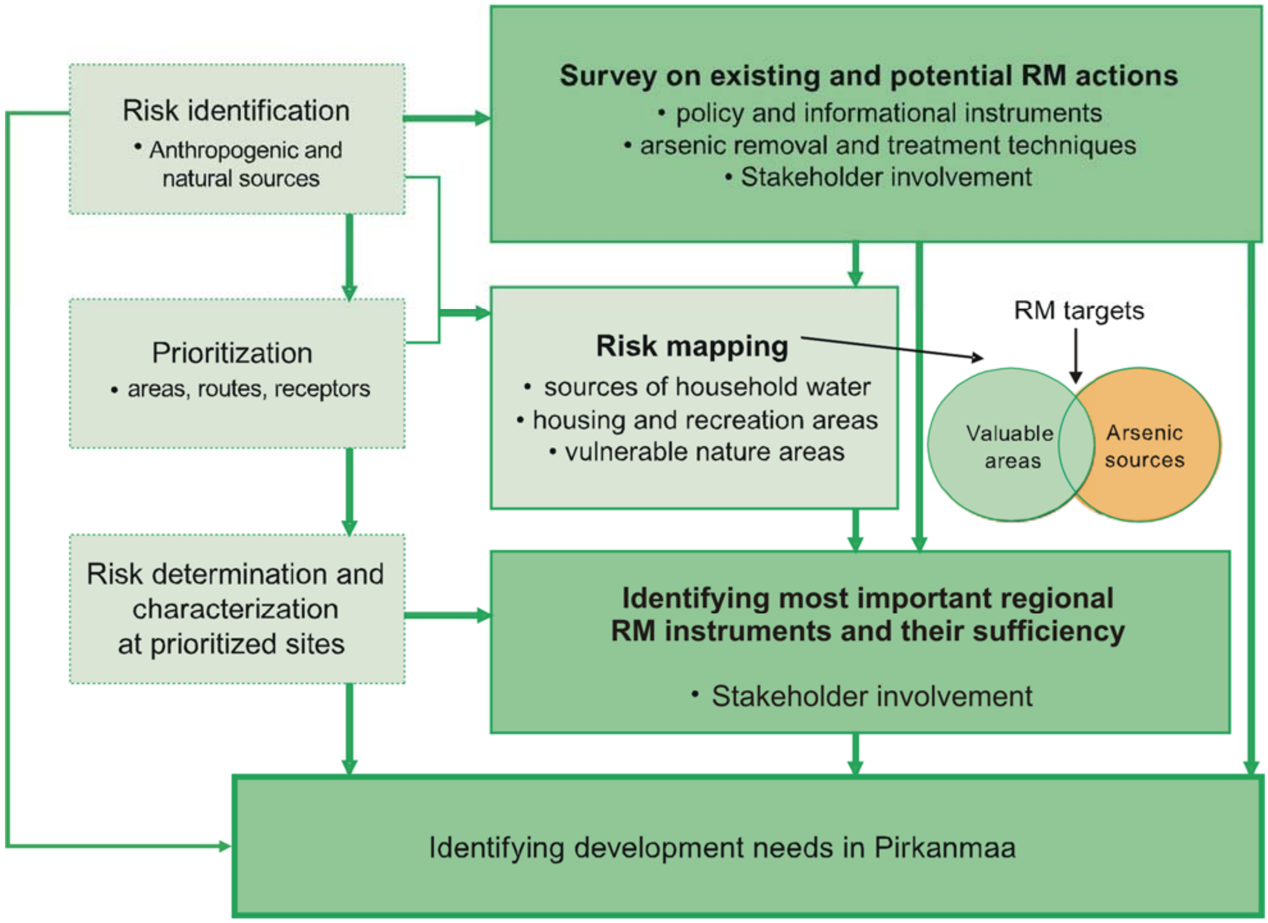


Figure 1. Working phases for the identification of development needs in the management of arsenic-related risks in Pirkanmaa and their connection to the risk assessment procedure.

In Phase 2, our study was more focused on Pirkanmaa. Moreover, additional data produced within RAMAS project were included in the study. We produced a set of regional risk maps pointing out the most important targets of RM actions. The geographic data on potential arsenic sources and areas with high environmental concentrations of arsenic was integrated with the valued regional resources such as valuable nature areas and residential or recreational areas. Here we used the ArcGIS9.2 software. The information gathered for risk mapping included e.g., data on

- The coverage of the public water supply network at regional scale: densely populated areas covered by the network and network of water pipelines at more sparsely populated areas
- Future development plans of the water supply network at regional scale
- Water sources: bigger lakes, classified shallow groundwater areas and points of groundwater intake
- Distribution of the population and identification of population centres, villages and areas with scattered settlements
- Future trends in the movement of population at regional scale
- Future trends in land use according to the official regional land use plan
- Protected and other highly valued nature areas.

In addition to these data, the information on the possible sources of arsenic gathered in other RAMAS tasks were verified and complemented. We also considered the results of some additional targeted environmental studies such as concentrations of arsenic in the vicinity of quarries and landfills.

In Phase 2 the survey data from Phase 1 were analysed from the viewpoint of the study area, Pirkanmaa. Hence, we emphasized the regional scale of risk management instruments. Furthermore, some additional stakeholder involvement was organized in order to highlight the most important instruments these stakeholders are using in the management of As-related risks at their work as experts or decision makers. Because the stakeholders are numerous and the identified RM targets vary considerably in size and character, the proposals for regional RM actions had to be kept in quite a generic level.

3.2 Stakeholder involvement and data sources

In risk management, the consideration of stakeholders, i.e., parties who might affect or be affected by the possible RM actions, is essential. Therefore it was necessary to ensure stakeholder involvement also in our study. Communication on the studies and stakeholder involvement actually had an important role in the whole RAMAS project. Therefore, numerous presentations were given to audiences comprising people from research institutes, municipalities, consulting companies and regulatory organizations. A press conference was held both in the beginning and at the end of the RAMAS project. Several journalists from the local and regional newspapers and two TV channels attended these occasions. Short interviews were broadcasted in the national or regional news (TV, radio) during the following evening and numerous newspapers wrote about the arsenic issue.

To communicate particularly with the local stakeholders, a stakeholder seminar and a meeting with regional water- and environmental authorities representing the Pirkanmaa regional environmental authority (PREC) were carried out in Tampere city in the beginning of the Phase 2 of the RM task. Some 40 people attended the seminar. The preliminary risk area maps, i.e., maps based on the geographical data on the natural occurrence of arsenic in Pirkanmaa, were published at this seminar. Discussion after the presentations was lively. Since the Pirkanmaa Regional Environment Centre (PREC) was one of the RAMAS partners and the party responsible for producing data for the RA and RM, the knowledge transfer between the project and the regional environmental authorities in PREC was quaranteed. A wide group of the PREC personnel (total 119, year 2006) comprising mainly experts and authorities were contacted by e-mail or by phone during the project. Here, the experts on water management and the permitting authorities were the key stakeholders. In addition, contacts with the experts involved in the development the regional prioritization model for contaminated sites (SMP model) and in the registration of the sites in the national database proved to be very helpful.

Altogether, we contacted over 20 experts dealing with policy instruments somehow related to the risk management of environmental arsenic. These experts represented several different national institutions, such as environmental administration, Finnish Environment Institute, Finnish Forest Research Institute, Finnish Food Safety Authority and Finnish Geological Survey. Some of the national authorities, for instance persons from the Department of Environmental Protection in the Ministry of the Environment, the Ministry of Agriculture and Forestry, and the Ministry of Social Affairs and Health who are actively involved in the issues concerning environmental legislation at national and EU level, were also informed about RAMAS project. These institutions also delivered us some necessary data.

The identification of the existing RM methods and the need for additional RM instruments and tools was based not only on the use of expert interviews, but also on the use of various other data sources such as, literature, regulations, law-drafting reports, guidelines and other administrative documents, registers and databases (see Table 1).

Table 1. The primary data sources and the field of expertise they represent.

Stakeholder	Expertise used in RAMAS project
Ministry of the Social Affairs and Health (STM)	Control over household water quality
The State Provincial Office of Western Finland (POW)	Control over household water quality
Finnish Institute of Occupational Health (FIOH)	Occupational exposure to arsenic, reference for non-exposed persons
The National Product Control Agency's (STTV)	KETU–register for the information on chemical import and production
Finnish Food Safety Authority (EVIRA)	Pesticides and restrictions for their usage Quality control of the fertilizing products Quality control of the feed and feed additives Registered veterinary medicines Harmful substances in foodstuff
National Agency for Medicines	Registered human pharmaceuticals
University of Turku, zoological museum	Arsenic in conservation chemicals
University of Art and Design Helsinki	Arsenic in glass and ceramics industry
Environmental Administration	
The Regional Environment Centers	The experts who are in charge for the issues related to water supply, contaminated sites, protection of valuable natural resources and the authorities granting environmental permits for industrial activities and waste treatment.
Finnish Environment institute (SYKE)	SYKE/Chemicals division: risk management of biocides and detergents (e.g., application of the Arsenic Directive) SYKE/Research Department: previous studies on the techniques for arsenic removal
HERTTA –database	The status and quality of surface waters (PIVET -register): arsenic concentrations in the Pirkanmaa study area Urban/community structure (MOST register = YKR): division of population in population centers, villages and in the areas with scattered settlement Coverage of the local master plans in Pirkanmaa
VAHTI –database	Emission and monitoring data related to environmental permits (e.g. all permits concerning mining activities) VELVET[2] : the connections to waterworks Available technical means to restrict arsenic risks
Database for soil status	Potentially contaminated areas and actions executed on them (studies, remediation measures)
Databases on geographic information concerning valuable nature areas	Protected nature areas, areas included in conservation programmes, NATURA 2000 areas
The Council of the Tampere Region	The regional land use plan
Chosen private actors (power plants)	Concentration of arsenic in ashes

No data was readily available for the analysis of whether arsenic could be found in the emissions or solid wastes generated by a certain activity in Pirkanmaa. The preparatory material produced for the

[2] VELVET = Data system for registered waterworks

permit procedure is only partly saved to a public database (VAHTI). Thus, an expert analysis was conducted among Pirkanmaa environmental authorities and RAMAS project whether there are still active industrial sources of arsenic in Pirkanmaa. Some generators of waste relevant as arsenic sources were also considered as stakeholders and their representatives were briefly interviewed (e.g., energy power plants, municipal landfills).

The RAMAS study area covers the area governed by the Council of the Tampere Region. The regional councils are statutory bodies representing federations of local authorities and they are responsible for regional development. As an opening for the stakeholder involvement, we asked the Council of the Tampere Region for the official regional plan as a geographic dataset. The latest regional land use plan for the next 10 – 15 years in Pirkanmaa was recently approved (29.3.2007) by the Ministry of the Environment.

Due to the variety of the potentially contaminated media, it was not possible to collect exhaustive data on the technical RM means to restrict environmental concentrations and emissions of arsenic. To gather the information on the methods available in Finland, we interviewed representatives of 10 companies dealing with arsenic removal or soil remediation and contacted a group of regional environmental officers that had showed interest towards RAMAS project during their national meeting. VAHTI –database was used in order to track cases in which some technical measures to eliminate risks caused by arsenic had already been required for. All environmental permits concerning mining activities, including the waste management, were surveyed because according to a separate RAMAS study, the old mining sites were among the most important potential arsenic sources (Parviainen *et al*. 2006). Other potential activities releasing arsenic to the environment were surveyed more randomly due to the limited resources. The results from Phase 1 were supplemented with, e.g., material from the international conference held in Montpellier (Difpolmine 12.-14.12.2006) and the Swedish research seminar held in Örebro (Renare Mark 20-21.3.2007).

4 Main sources of environmental arsenic in Pirkanmaa

4.1 Natural arsenic anomalies

In Finland, the elevated concentrations of natural arsenic are derived from the arsenic bearing minerals which are locally, as in parts of Pirkanmaa area, enriched in the bedrock (Arsenic anomaly). Due to the action of geological and geochemical processes, arsenic has migrated from bedrock to groundwater and soils. In the Pirkanmaa region, clearly elevated concentrations of arsenic have been detected in bedrock, in the deeper layers of glacial till formations and in water from wells drilled deep into bedrock. In the nationwide survey, the median arsenic concentrations in the samples taken from the upper part of till (0.5 - 2 m) were also relatively high. To complement this data, some soil samples were taken from forested land on silts or sands. No anomalous concentrations of arsenic were found in these samples (Backman *et al.* 2006). Despite the elevated arsenic concentrations in the surrounding tills, the arable soils studied contained only low amounts of arsenic (Mäkelä-Kurtto *et al.* 2006).

Originally, in RAMAS project the spatial description of the As–anomaly areas was based on the division of the study region into three separate geological zones (see Fig 3): the Central Finland Granitoid Complex (CFGC) in the northern parts of Pirkanmaa, the Tampere Schist Belt (TB) and the Pirkanmaa Belt (PB). The high concentrations of natural arsenic in bedrock are clearly focused on the southern belts TB (average concentration 10.41 mg As/kg, median 2.22 mg As/kg) and PB (average concentration 4.50 mg As/kg, median 1.90 mg As/kg). The maximum concentration, 377 mg As/kg was found in Tampere Belt. The concentrations of arsenic in the most northern geological zone, CFGC, do not differ much from those in other parts of Finland (average concentration in CFGC 1.73 mg As/kg and in whole Finland 2,69 mg As/kg, median in CFGC 1.00 mg As/kg and in whole Finland 0,9 mg As/kg).

In Pirkanmaa, about 38 % of the land surface is covered by glacial till deposits the area being broader in the north compared with the southern parts of the study region. The average thickness of these till deposits is 3 – 4 meters, but in the northern parts of Pirkanmaa the bedrock is relatively well exposed. The vertical structure of arsenic concentrations is clearly illustrated in ore prospecting till data. Part of the ore prospecting samples of till has been taken from the deeper parts of till deposits, right on the bedrock surface while the maximum concentrations of arsenic in these deep layers reach 7860 and 9280 mgAs/kg in the PB and in the TB area. The samples taken from the upper parts of till deposits showed the maximums of 1050 mg/kg and 596 mg/kg, respectively. It is noteworthy, that in the deeper till layers some 10 % of the samples (n = 9392) contained arsenic more than 50 mg/kg and 5% contained more than 100 mg As/kg. The corresponding percentages in the upper tills (n = 1431) were 4% and 1%, respectively (Backman *et al*. 2007b). It was also observed that the subsoils contain significant amounts of unweathered sulphides.

The arsenic concentrations in Pirkanmaa peat deposits have to be considered since some power plants use peat as a fuel. In 2005 there were four power plants using peat originating from both Pirkanmaa and other parts of the country. These were controlled by the regional environmental permit authorities. The interviews targeted to the permitting authorities revealed no exceptionally high concentrations of arsenic in peat deposits used in energy production. Peat deposits can be found all over Pirkanmaa, but the most frequently exploited deposits are situated in the CFGC zone. The peat deposits were not studied during RAMAS project.

The RAMAS project aimed at, among other things, to generate a spatially more detailed illustration of the natural arsenic anomaly compared with the one based mainly on geological zones. This task proved to be challenging. At the end of the project, we produced an aggregated preliminary ‘risk map’ in which three geochemical datasets corresponding bedrock, fine fraction of till and drilled well water were connected within 250m x 250m grids. The classification of areas to different ‘risk classes’ was based on the national quality standard for arsenic in drinking water (10 µg/l) and the national guidelines of arsenic (50 mg/kg or 100 mg/kg on less vulnerable areas) used for the identification of contaminated soil. The classification procedure is reported in Sorvari *et al.* 2007.

4.2 Anthropogenic sources

At present, As-containing materials are hardly handled or used in Finnish agriculture. We do not expect that the some 5000 farms in Pirkanmaa make any exception in this. The study on 13 farms conducted by MTT Agrifood Research Finland as part of RAMAS project, verified this assumption. This study included sampling of arable soils and crops in the selected dairy and crop farms within 100 kilometers from Tampere city. (Lehtinen & Sorvari 2006, Mäkelä-Kurtto *et al.* 2006).

Pirkanmaa has a long industrial history and therefore, anthropogenic arsenic was expected to pose additional risks to human health and biota. The proportion of the Pirkanmaa population occupied in the industry is still higher compared with the whole country. For the RAMAS project the regional environmental authorities listed 193 industrial or other potentially polluting activities liable for environmental permit within their area. No major operating industrial plant in Pirkanmaa has reported the use of significant amounts of As-bearing materials or thereof, to emit any significant amounts of arsenic into the environment. Some of the power plants use peat as a fuel. Peat contains arsenic as an impurity. Arsenic originating from the burning of peat mostly ends up in the ash. The ashes have lately been disposed off in the municipal landfills.

The additional sampling carried out in RAMAS and the survey on the PREC's laboratory database (LIMS) indicated that the remaining relevant anthropogenic arsenic sources include the closed sulfide ore mines and their tailings, closed sawmills and wood impregnation sites and older landfills. Wood impregnation with CCA chemical has ceased in Pirkanmaa as it should have been ceased in all EU member countries in accordance with the Arsenic Directive[3] and its amendments. Some evidence of environmental contamination by arsenic associated with quarrying activities was also shown by the sampling of surface waters.

Soil at old shotgun shooting ranges may contain arsenic because the lead shots have contained up to 0.5 % of arsenic. However, the main pollutant at the ranges is the lead. A regional survey on the contamination of Pirkanmaa shooting ranges has been published recently (Mustajoki 2004). The preliminary sampling at six ranges showed relatively low concentrations of arsenic varying between 1.1 and 5.8 mg/kg in topsoil, 1.1 and 28 mg/kg in peat and 1.2 and 4.1 µg/l in surface water. Arsenic has been found in former demolition plants of car batteries in Finland owing to the fact that lead accumulators have contained some arsenic. However, there was hardly any monitoring data available from such sites at the Pirkanmaa region.

The survey on the effluents of 36 municipal waste water plants revealed only one sample with concentration reaching 6 µg As/l, usually the concentrations have stayed below 3 µg As/l. We can assume that arsenic concentrations would be effectively diluted in the receiving water systems, and consequently, would not cause significant environmental risks. (Parviainen *et al.* 2006).

The LIMS database contained only results from two analyses of arsenic in municipal sludge and from 18 analyses of forestry sludge, these representing the data available within the whole study region. The concentration of arsenic varied between 3.1 and 12 mg/kg (Parviainen *et al*. 2006). The concentrations are low compared to the regulatory limit value of 25 mg As/kg recently set for fertilizing compounds[4]. In Finland, the sludges are mainly used in the green areas and landscaping (80 %) and only in minor extent in cultivation (12 %) or landfill constructions (6 %). Unprocessed sludge is usually unsuitable for these purposes. Therefore, sludges are normally handled and mixed with other organics and sand leaving only about ¼ of the original mass in the final product. (Rantanen *et al.* 2006).

[3] Commission Directive 2003/2/EC of 6 January 2003 relating to restrictions on the marketing and use of arsenic, tenth adaptation to technical progress to Council Directive 76/769/EEC.
[4] Decree of the Ministry of Agriculture and Forestry, 12/2007

Table 2. Summary of the anthropogenic arsenic sources and their preliminary, qualitative risk assessment.

Source	Ramas sampling	Other data	Description of risks	Uncertainties, comments
Risks identified, A				
Wood impregnation (CCA)	X	X	High arsenic concentrations detected in soil, also relatively high solubility and ecotoxicity	Just one demonstration site selected for RAMAS sampling, site was situated on a highly classified groundwater area
Mining and tailings	X	X	High As concentrations detected in soil, water and sediment, ecological risks evident	Recipient area at Ylöjärvi mine site broader and more diversified compared to Viljakkala mine site, further investigations needed
Closed landfills	X	X	Concentrations exceeding the quality standard for drinking water detected	Source remained unclear, landfill or natural occurrence?
Energy production, ashes		X	Ashes with moderate concentrations of arsenic, have been delivered to operating landfills	Solubility of arsenic may hinder recycling or even disposal in landfills for non-hazardous waste
Rock engineering (quarrying)	X		Concentrations exceeding the quality standard for drinking water detected in a couple of surface water samples (ponds)	Limited number of samples and sites studied, further investigations needed
Minor risks, B				
	Ramas sampling	**Other data**	**Risks**	**Uncertainties, comments**
Functioning municipal landfills	X	X	Leachates and runoffs are collected and treated in a municipal waste water treatment plant	No monitoring data from the environment available, only data from the leachates. Risk management relies on the water collection system
Industry		X		No detailed survey on all sites, numerous sites with varying activities
Municipal waste water and sludge	X	X	The concentration of arsenic in waste water mainly below 3 µg/l	
Industrial waste water + sludge		X		No detailed survey on all sites, only sampling data from forestry sludge available
Landfills for surplus soil (inert waste) and composts		X		No monitoring data available
Scrap yards (12 accumulator or car demolition plants)		X	One monitored scrap yard in which no arsenic has been detected	Arsenic is not included in the obligatory monitoring
Handling of contaminated soil		X	No major leaching of As detected	Risk assessment based on expert judgment
Closed shooting ranges		X	Maximum content of 28 mg As/kg soil detected, risks mainly from the lead	Due high mobility (compared with lead), arsenic may pose a risk to groundwater quality

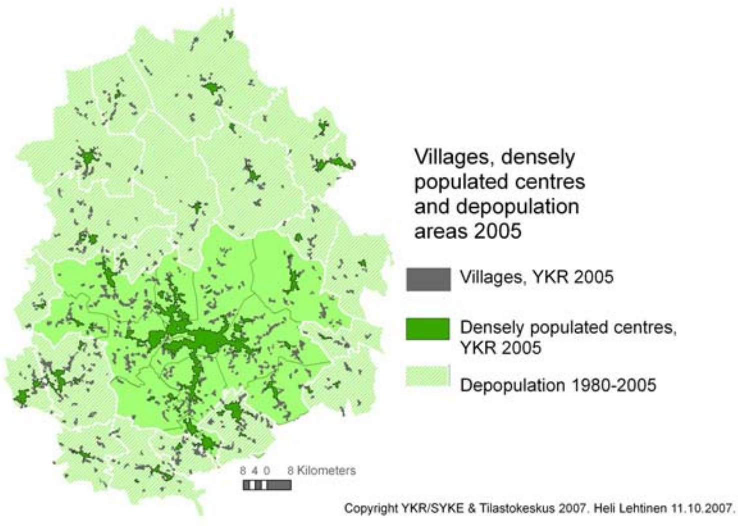
5 Arsenic risks in Pirkanmaa

5.1 Receptors

5.1.1 Inhabitants

The size of the Pirkanmaa area is equivalent to half of Belgium. The total number of inhabitants within this region was 468 990 in 2005 (MOST[5], 2007) and the population is expected to reach the number of 500 000 inhabitants by the year 2020 (PREC 2006). The households are quite small, including 2.1 inhabitants on the average. There are more households with aged people than households with children. The average disposable yearly income in Pirkanmaa has been at similar level as in the whole country, ranging from about 13 600 (sub region Upper Pirkanmaa) to 15 000 (Tampere Central Region) €/inhabitant. (Council of Tampere Region 2007).

The majority of the population lives in the vicinity of the Tampere city, right on the well-known natural arsenic anomaly. The spatial structure of population changes gradually. For years, the migration has been directed toward the Tampere city and its neighbouring municipalities, also from other provinces (see Fig. 2). The sub region called Tampere Central Region comprises 320 280 inhabitants. Some of the six sub regions are clearly losing inhabitants, e.g., regions in the northern, north-western, and south-eastern parts of Pirkanmaa. Still, approximately 15 % of the inhabitants live at sparsely populated rural areas or in small villages. (Council of Tampere Region 2007).



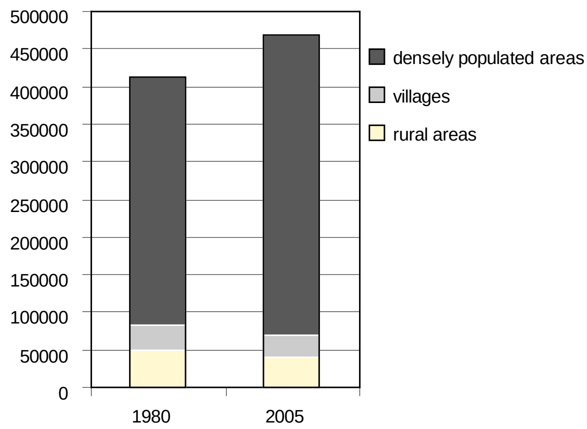


Figure 2. Map: Densely populated areas and areas which have been loosing inhabitants in Pirkanmaa (depopulation area 1980-2005) GIS analysis based on MOST. Diagram: Total population in 1980 and 2005 in the three areas with different population structures: densely populated areas, villages and rural areas. (Source: Finnish Environment Institute/ Statistics Finland 2007).

In 2002 it was estimated that 89 % of Pirkanmaa inhabitants were served by registered waterworks (PREC 2006). The densely populated areas within the city of Tampere and its neighbouring municipalities are served by public water supply system with few exceptions. In this area, the water supply system is mainly based on surface water: in 2002 surface water comprised 67 % of the total

[5] MOST = Monitoring system of spatial urban structure, Finnish Environment Institute & Statistics Finland. (MOST= YKR in Finnish, yhdyskuntarakenteen tietojärjestelmä)

volume corresponding to the water use of 33352 m^3/d. The share of the total water use in Tampere city is around half of the water use in whole Pirkanmaa region. Outside Tampere city the registered waterworks supply mainly water from some 100 existing sites for shallow groundwater discharge. (VELVET 2007, PREC 2006).

It was difficult to estimate the actual number of people using their own private wells for drinking water supply on a very detailed regional scale. Moreover, the type of wells, i.e., dugwell versus well drilled into bedrock, is not registered in any public database. Therefore, the current situation was estimated by using two different approaches based on public registers and GIS analysis (see Appendix I). The two separate calculation methods show that the number of people using their own private wells for drinking water supply is somewhere between 45 000 – 65 000 inhabitants in the whole Pirkanmaa region. The municipal differences in the number of people that are without organized water supply are illustrated in Figure 3 and Table 3.

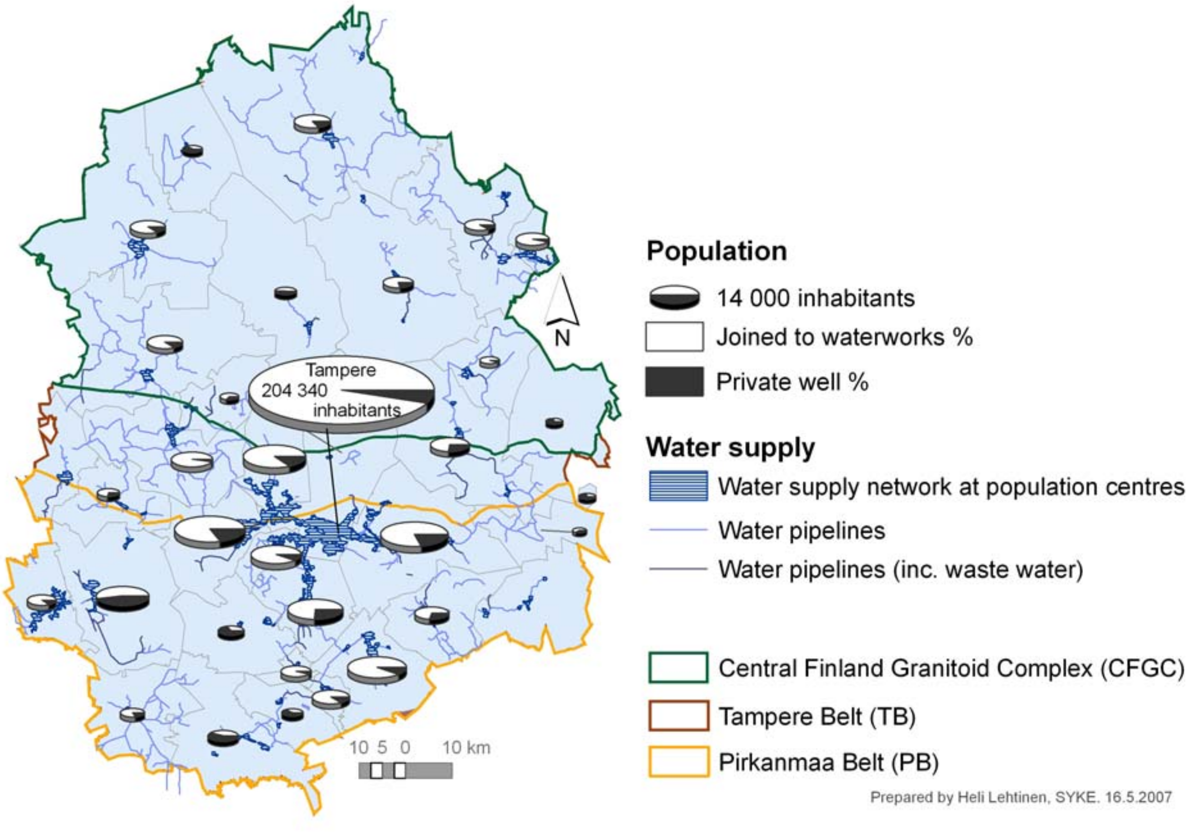


Figure 3. Estimated number of the inhabitants in the Pirkanmaa municipalities using their own well water as drinking water. The total number of inhabitants in the Tampere municipality was 204 340 in 2005. Data sources: MOST 2007, VELVET 2007, PREC 2006 report and PREC corrections 2007.

Table 3. Summary of results based on the use of two different approaches to estimate the number of inhabitants without organized water supply in year 2005.

Municipality	Village population/ Number of identified villages without water supply network (GIS analysis)	Rural population (GIS, MOST 2005)	Village and rural population using their own wells for water supply (based on GIS analysis)	Total population using their own wells for water supply (VELVET-register with some corrections)
Akaa (Toijala + Viiala)	214 /5	436	650	1410
Hämeenkyrö	86 /2	1829	1915	350
Ikaalinen	54 /2	1877	1931	1030
Juupajoki	36 /1	554	590	170
Kangasala	1175 /23	1625	2800	5410
Kihniö	105 /3	997	1102	1450
Kuhmalahti	61 /1	390	451	420
Kuru	247 /7	1179	1426	1410
Kylmäkoski	130 /3	657	787	1610
Lempäälä	450 /9	1030	1480	4750
Längelmäki	176 /6	*	176	1190
Mouhijärvi	31 /1	820	851	810
Mänttä	33 /1	131	164	340
Nokia	396 /6	1287	1683	5300
Orivesi	160 /5	1864*	2024	2410
Parkano	199 /7	1551	1750	1010
Pirkkala	0 /0	279	279	1240
Punkalaidun	83 /2	1314	1397	670
Pälkäne + Luopioinen	320 /7	1567	1887	1960
Ruovesi	157 /4	1860	2017	1200
Tampere	1157 /13	1727	2884	9050
Urjala	260 /9	1886	2146	3130
Valkeakoski	922 /11	1152	2074	1800
Vammala + Suodenniemi	1033 /14	2889	3922	1800
Vesilahti	565 /11	1221	1786	2550
Vilppula	80 /3	1282	1362	660
Virrat	0 /0	2504	2504	1360
Ylöjärvi + Viljakkala	365 /9	1791	2156	3910
Äetsä	156 /6	684	840	690
Total	**8651 /171**	**34519**	**(9,6 %) 45034**	**(12,6 %) 59090**

* Since 1.1.2007 The Längelmäki municipality has been divided by the municipalities of Orivesi and Jämsä.

5.1.2 Vulnerable environments

The Pirkanmaa area contains valuable forests, marshes, wetlands and eskers. The nature conservation areas are small and fragmented and the use of land outside the areas is so effective that the populations and habitats of rare species are constantly decreasing. Almost 2.5 % of the total Pirkanmaa area is designated as protected nature areas.

Eskers are long, narrow, steep-sided, sinuous ridges of poorly stratified sand and gravel deposited by a sub-glacial or englacial stream. The two nationally significant glaciofluvial sand and gravel formations, The Central Finland End Moraine and Pälkäne - Tampere - Hämeenkyrö esker district, are important for shallow groundwater recharge and also for sand and gravel extraction. Together with minor sand and gravel deposits these districts cover about 5.4 % of the surface area in Pirkanmaa. Important aquifers for household water are found even in smaller esker areas. Out of the 184 classified groundwater areas 91 have been identified as important for groundwater supply (illustrated in Fig. 12 as shallow groundwater areas). Their yield has been estimated to reach 146 000 m^3/d. Water is typically clean rich in oxygen, and often also easily extractable in the glaciofluvial deposits.

In Pirkanmaa, there are more than 2 500 lakes exceeding the size of one hectare. The dominating landscape is mosaic comprising forest land and waters. The population has historically spread along the shores of the numerous rivers and bigger lakes. The surface waters have a significant recreational value as fishing and bathing sites. The surface waters are also used for making potable water. Tampere, Valkeakoski and Vammala produce potable water from surface water originating from lakes and rivers of the Kokemäenjoki river basin. The surface water is also increasingly used for maintaining artificial groundwater reservoirs. Almost the whole Pirkanmaa region lies inside Kokemäenjoki river basin. The quality of water differs regionally. The southern parts of Pirkanmaa are partly covered by fine-grained sediments, clays and silts. These areas have been taken for agriculture.

Land and Water in Pirkanmaa

- **Total area** 14 658 km^2
- **Land area** 12 613 km^2
- **Forestry land** nearly 10 000 km^2
- **Arable and horticultural land** 13 % of the land area
- **Waterways** 2 045 km^2, 2679 lakes (area ≥1 hectare)
-

Source : Council of Tampere Region 1.1.2007

5.2 Routes of human exposure

According to the health risk assessment carried out in RAMAS, exposure through drinking water containing arsenic is the main source of arsenic-related risk in Pirkanmaa. The human exposure scenarios studied included exposure to water from drilled wells and dug wells, exposure in a residential area built on a former CCA-plant site and occupational exposure to air dust in the Ylöjärvi mine site. (Sorvari *et al.* 2007).

The average total daily dose of arsenic varied between 0.16 – 55 µg/kg/d the mean value being 0.68 µg/kg/d (median 0.27 µg/kg/d). The acceptable daily intake values used in this study varied between 0.3 and 1.0 µg/kg/d resulting in the maximum of 180-fold exceeding of the acceptable level. The biomonitoring study confirmed the exposure to arsenic in well water. Furthermore, the regional-scale epidemiological study showed elevated incidences of liver cancer on geochemical arsenic anomaly areas compared with the reference area. In addition, it seemed that there is a higher incidence of bladder, skin and kidney cancers, however only part of the risk ratios determined were statistically significant. (Sorvari *et al.* 2007).

Health risks associated with drinking water depend on the type of water source since the concentrations of arsenic are very different in the water originating from a drilled well, dug well and public waterworks. In the case of dug wells, only a few people were expected to be subject to adverse health effects arising from arsenic but in the regional scale the risk needs to be considered.

5.2.1 Household water from different sources

In 2004, there were altogether 14 larger waterworks out of the 122 registered waterworks in Pirkanmaa, which were liable for reporting to the EU commission on the quality of drinking water. In seven of these waterworks the production of drinking water was based on groundwater, in four plants on surface water and in three plants, the raw water was a mixture of groundwater and surface water. The concentration of arsenic in these waters were analysed 24 times in 12 waterworks during 2004. In 20 out of the 24 samples, the concentration was clearly below 1 µg As/l, and in 4 samples the concentration was 1 µg As/l (Zacheus 2005).

The data on the drinking water quality produced in the 108 smaller waterworks is scattered in the 33 municipalities. The national register, in which this data would be compiled, is still under preparation. Only the recent regulations include the obligation of wider water quality monitoring in the smallest waterworks. During RAMAS, no information on arsenic monitoring was readily available.

During the RAMAS project, The State Provincial Office of Western Finland (POW) carried out a small inquiry targeted to the municipalities in order to have a better understanding of the analysing practices of arsenic and measured arsenic concentrations in the drinking water served by small waterworks. Although only 22 out of the 33 municipalities replied to the inquiry, we could draw some tentative conclusions based on the responses. We also contacted three experts from the local health authorities in the connection with the biomonitoring study carried out along with the health risk assessment. These experts reported the maximum concentration of 3 µg As/l in household water. Overall, the arsenic concentrations in the water distributed by smaller waterworks or pipeline networks have mainly been near to the detection limit. The few exceptional concentrations have been measured from single wells, which are used by a couple of households. These wells were located in Lempäälä and Nokia. It is noteworthy that the results from chemical analyses run in 1980´s are not comparable with those conducted after 1992 when the more sensitive and accurate ICP-MS technique was adopted.

These above presented data show that people using water supplied by registered waterworks are not exposed to significant arsenic doses from drinking water. However, the exposure may be higher in the case of drinking water supplied by the smallest waterworks which only have minor obligations to monitor water quality. The smallest waterworks are usually run by a local co-operative or consortium.

During the RAMAS project, an extensive GIS-database was build for the needs of health risk assessment related to arsenic in well water. The database included data corresponding 1 272 drilled wells and 283 shallow dug wells. Some additional sampling was also conducted. The data on arsenic in well water was not equally available from the 33 municipalities of the Pirkanmaa region. The municipalities of Orivesi and Tampere offered the most comprehensive data. Sampling activities have generally been focused on areas with known geological arsenic anomaly (see Table 4).

Concentrations exceeding the Finnish quality standard for drinking water (10 µg As/l) have been detected in every fourth of the drilled well water samples taken from the southern geological zone comprising both TB and PB. The data available in RAMAS clearly suggests that the three geological belts differ from each other in terms of arsenic concentrations in well water. The median value (5.5 µg/l) in drilled wells in the TB area is higher compared with the other two areas (Backman *et al.*, 2006). According to the risk calculations, health risks associated with naturally occurring arsenic at the CFGC zone are very low (Sorvari *et al.*, 2007). The population of the two southern geological belts correspond 78 % while Tampere city alone comprises 44 % of the total population in Pirkanmaa. (Table 4).

The probabilistic quantitative health risk assessment showed that 5.9 – 46 % of people using drilled well water as a source of drinking water would experience arsenic doses above the acceptable daily intake values (ADIs). The variation in the estimate originates from the variability and uncertainty of the input values used in calculations but also from the variability of acceptable daily doses issued by different organizations (Sorvari *et al.* 2007). From these estimates it follows that if all the people residing outside the organized water supply network in Pirkanmaa were using untreated water originating from the wells drilled into bedrock, altogether 20 700 – 30 000 inhabitants would be exposed to arsenic level above the safe level. This estimate is based on the use of the most conservative, i.e., the lowest, acceptable daily intake value. A less conservative ADI would result in an estimate of 2700 – 3800 inhabitants, respectively. Fortunately not only drilled wells but also dug wells and springs are used for drinking water supply, particularly on areas with suitable soil type. Hence, the conservative estimate is expected to overestimate the factual population-level health risks. Furthermore, at least dozens of household-specific equipment designed for arsenic removal have been adopted in Pirkanmaa.

The majority of people using well water as a source of drinking water reside in the municipalities of Tampere, Kangasala, Nokia and Lempäälä. We can also conclude that the majority of the people that may be exposed to arsenic through drinking water inhabit the municipalities of Tampere and Lempäälä.

The highest median contents of arsenic in drilled well water were found in the municipalities of Orivesi, Lempäälä and Tampere. Here, only the datasets comprising more than 10 samples were considered. The few samples with elevated arsenic concentrations in the dugwells were taken in the municipalities of Lempäälä, Orivesi and Kangasala.

Table 4. The number of potential recipients exposed to arsenic through well water in different municipalities and geological zones (CFGC = Central Finland Granitoid Complex, TB = Tampere Belt and PB= Pirkanmaa Belt).

Municipality	**Population without organized water supply (two approaches)**	**Total population**	**As µg/l in drilled wells, median (max) blue = springs and dug wells**	**Number of arsenic samples ≥ 10 µg/l /total number of samples**
Ikaalinen	1030 – 1931	7550	0,13 (0,20)	0 / 3
Juupajoki	170 – 590	2220	1,00 (1,00)	0 / 2
Kihniö	1102 – 1450	2350	0,73 (2,72)	0 / 4
Kuru	1410 – 1426	2760	0,26 (6,58)	0 / 8
Längelmäki	*	240	0,46 (1,00)	0 / 9
Mänttä	164 – 340	6520		no samples
Orivesi	2024 – 2410	4590	1,00 (2,00)	0 / 7
Parkano	1010 – 1750	7340	0,14 (1,91)	0 / 9
Ruovesi	1200 – 2017	5400	0,79 (1,17)	0 / 2
Tampere	*	1360	0,88 (10,0)	3 / 79
Viljakkala	680 (joined to Ylöjärvi)	1180	0,80 (1,1)	0 / 6
Vilppula	660 – 1362	5460	0,46 (1,38)	0 / 4
Virrat	1360 – 2504	7850	0,38 (1,38)	0 / 7
Ylöjärvi	*	1000	0,93 (0,93)	0 / 1
Northern Pirkanmaa (CFGC)	11720 – 14870	55820	0,46 – 0,61 (6,58)	3 / 143 (2 %)
Akaa (Toijala ja Viiala)	650		see Toijala and Viiala	
Hämeenkyrö	350 – 1915	10190	1,13 (175)	5 / 49
Kangasala	2800 – 5410	26810	0,42 (44,2) **(19,2)**	5 / 71
Kuhmalahti	420 – 451	1120	0,72 (43,0)	3 / 21
Kylmäkoski	787 –1610	2630	0,42 (11,2)	1 / 8
Lempäälä	1480 – 4750	18250	7,74 (1560) **(26,6)**	47 / 101
Längelmäki	176 – 1190	1430	8,30 (16,0)	1 / 2
Mouhijärvi	810 – 851	3010	2,86 (87,0)	1 / 5
Nokia	1683 – 5300	29150	3,01 (235)	21 / 101
Orivesi	*	4340	10,00 (2230) **(45,0)**	38 / 73
Pirkkala	279 – 1240	14870	1,21 (22,6)	7 / 64
Punkalaidun	670 – 1397	3450		no samples
Pälkäne + Luopioinen	1887 – 1960	6860	0,98 (50,8)	5 / 64
Tampere	2884 – 9050	202980	5,50 (900)	124 / 380
Toijala (Akaa)	1060	8350		no samples
Urjala	2146 – 3130	5560	0,49 (8,92)	0 / 17
Valkeakoski	1800 – 2074	20410	1,72 (48,2)	6 / 54
Vammala + Suodenniemi	1800 – 3922	16590	0,37 (4,51)	0 / 12
Vesilahti	1786 – 2550	3830	1,27 (80)	2 / 22
Viiala (Akaa)	350	5440	0,58 (0,93)	0 / 3
Viljakkala	*	900	0,30 (4,05)	0 / 4
Ylöjärvi	2156 – 3230	22040	2,37 (822)	5 / 34
Äetsä	690 – 840	4960	5,37 (5,48)	0 / 2
Southern risk area (TB and PB)	30164 – 47370	413 170	TB 4,05 – 5,5 (2230) PB 1,50–1,60 (1560)	271 / 1087(25 %)
Pirkanmaa total	**45034 – 59090** **9.6 % - 12.6 %**	**468 990**	**1,56 – 2,50 (2230)**	**274 / 1230(22 %)**

* = not known for different geological belts, only by a town. Inhabitants of Luopioinen (2405) added to Pälkäne and inhabitants of Suodenniemi (1359) added to Vammala, because of the changes in village borders.

5.2.2 Ambient air

The preliminary assessment of some contaminants such as arsenic in air and in atmospheric deposits has been conducted recently by the Finnish Meteorological Institute (Alaviippola *et. al* 2007). Annual average concentrations of arsenic (ng/m^3) in ambient air have exceeded the lower assessment threshold of 2.4 ng/m^3 set in the EU directive (2004/107/EC) only at some cities with metal industry. No such sites are found in Pirkanmaa area. In the very northern Finland, the annual average background concentrations have varied between 0.2 and 0.3 ng As/m^3 since 1996 while the concentration in the southern capital area has been around 1 ng As/m^3 (refers to measurement executed in 2000-2004). Background concentrations in Pirkanmaa would probably settle in between these monitoring areas.

The annual wet deposition of arsenic has been calculated from the rainwater analysis taken since 1990´s at 8 background monitoring stations located in different parts of Finland. The deposition of arsenic has diminished from the maximum of 180–200 µg/m^2 (1995–1996, south-eastern Finland) to some 26–73 µg/m^2 at all background monitoring stations (year 2003). Similar trend has been observed in the biomonitoring of mosses. No definite point sources of arsenic can be identified on the basis of these monitoring data in Pirkanmaa region, but the concentrations of arsenic in mosses appear to be slightly higher in the vicinity of southern, big cities compared to those in rural areas. This finding also applies to Tampere city and the surrounding rural areas (Fig. 4). We can assume that the annual arsenic deposition in Pirkanmaa is equivalent to the concentration levels measured in the three southern background monitoring stations, Kotinen being the closest one of them.

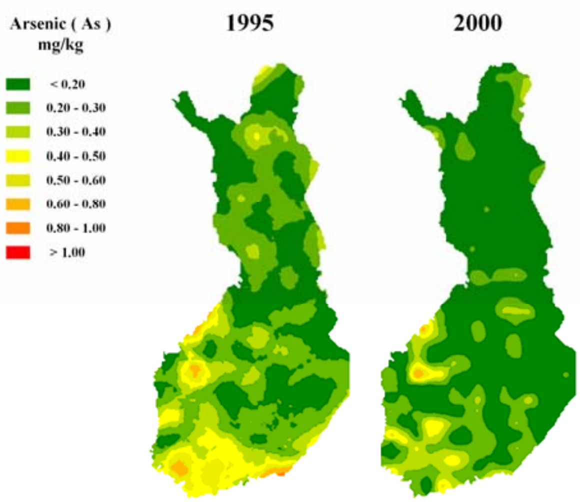


Figure 4. Arsenic concentration in mosses 1995 and 2000 (Poikolainen and Piispanen 2004).

In the RAMAS -project, arsenic concentration in ambient air was measured at the Ylöjärvi mine site where wide open tailings area is susceptible to wind erosion. Moreover, tailings area is currently used for testing of explosives, which often causes high dust emissions. The sampling was focused on those days when the explosion tests were ongoing. All samples were taken right in the vicinity of the site, during a period of 24 hours.

The measurements revealed that even the maximum arsenic concentrations in air dust remain below the highest acceptable concentration (10 µg As/m^3) issued for working environment in Finland. However, during a dry day the As-bearing dust does have some effect on the ambient air quality and the dust may spread to the adjacent areas. The concentrations at tailings site varied from 0.6 ng As/m^3 in air (rainy day) to 272 ng As/m^3 (during the explosion tests). The median concentration before explosions 2.3 ng As/m^3. After the tests, the average concentration reached a value of 6.1 ng As/m^3. (Backman *et al.* 2007b).

The sampling period - 11 days - was very short compared the period needed for the comparison with reference values of arsenic in ambient air. The health risk assessment carried out in task 3 (belonging to RAMAS) included the derivation of estimates of a lifetime excess cancer risk associated with the airborne arsenic originating from the Ylöjärvi mine site. The calculations showed only minor risks of cancer owing to the fact that the area is only in occupational use and hence, exposure occurs only during the working hours (Sorvari *et al.* 2007).

Table 5. Summary of the preliminary risk assessment of exposure to airborne arsenic.

Ambient air and deposition				
Source	**Ramas sampling**	**Other**	**Risks**	**Uncertainties, comments**
Respirable particles, background		x	No significant human health risk	No monitoring sites in Pirkanmaa
Respirable particles, tailings site	x		Long term human exposure improbable at the area used by the Defense Forces. Arsenic concentrations in air at the same level than at some monitoring sites of known industrial arsenic sources in Finland. No significant human health risk, if the exposure time is limited.	Sampling only during 11 summer days (24 h), 5 rainy days. Measurement results underestimate the arsenic concentrations during dry season. No data from winter season.
Wet deposition		x	So far, no significant effect on the total human exposure to arsenic	The annual net balance of arsenic in cultivated soils of southern Finland slightly positive (0.138 g/ha) contrary to northern soils, possibly due to the differences in atmospheric deposition.

5.2.3 Soil and other media

The separate biomonitoring study conducted in RAMAS showed that in addition to well water, other sources of human exposure to arsenic were also present in some farmer families (reported in Sorvari *et al.,* 2007). This appeared as elevated concentrations of inorganic arsenic in the urine samples in the reference study group. This study group included only families using drinking water of very low arsenic concentrations (< 1 µg As/l). Furthermore, the highest concentrations of arsenic in urine were almost without exception detected in the persons who stay most of the time at their own property. However, additional studies on crops and arable land at thirteen farms showed only low arsenic concentrations not deviating notably from the level in southern Finland, atmospheric deposition being the main continuous source of arsenic (Mäkelä-Kurtto *et al.,* 2006). Hence, the reason for the few anomalous urinary arsenic concentrations remained unclear.

Although the studies on exposure routes were versatile, some important routes may have been ignored. For example, the courtyards of the study farms were not investigated despite the fact that vegetables for household consumption are often grown on them. Moreover, the residential buildings are usually built on different landscape than the crop fields and hence, the samples taken on crop fields do not represent the soil in courtyards. The significance of exported food items and beverages as source of inorganic arsenic in Finland also remained somewhat unclear. Inferring from the literature, the most interesting food item to be studied further is rice.

Investigations of forest soil, forest berries and mushrooms or sap from birches in an arsenic anomaly area showed only low concentrations of arsenic (Backman *et al*. 2007b). Therefore, we could conclude that excluding the drinking water route, human background exposure to arsenic would generally be at the same level than elsewhere in the country.

At heavily contaminated CCA-plant sites exposure to arsenic in soil may significantly add to the total health risk particularly in the case of small children (age 1–6). High concentrations of arsenic have also been detected in Lake Parosjärvi adjacent to the Cu-W-As mine site. The long-term median concentrations in surface water vary between 68 and 130 µg As/l. In summertime, this lake is occasionally used for the purpose of a swimming school for children. However, taking into account the temporal dimensions of swimming, such activities were not expected to result in any significant exposure of arsenic. Additional observations of high arsenic concentrations in surface water were found along the route running from the Lake Parosjärvi down to Lake Näsijärvi. This stream-lake-stream route has not drawn any notable human activities.

Table 6. Summary of the preliminary risk assessment related to human exposure to arsenic through surface water at the water system receiving effluents from the Ylöjärvi mine site. (Sources: Bilaletdin et al. 2007, Keskitalo 2006.)

Source	RAMAS sampling	Human health risks	Uncertainties, comments
Background concentrations		No significant human health risk	
Stream flowing from the former mine site Lake Parosjärvi	x	The water is not suitable for long-term human consumption or washing of food production facilities due to high arsenic content. No significant human exposure routes were identified.	The water quality has been classified as satisfactory for recreation, hygienic quality being good. A swimming school for children run during summer season, entry by car is restricted (gate). The surrounding houses (owned by the Technical Research Centre of the Finnish Defense Forces) receive the tap water from the municipal water supply network.
Parosjärvi-Näsijärvi-route: before lake Vähä-Vahantajärvi	x	As concentrations exceed the health-based reference values. Human exposure is expected to be low.	No significant activities in the vicinity of the small streams. Some grazing sheep. For recreational use the water in Lake Vähä-Vahantajärvi is classified as 'passable' due to other reasons than arsenic content.
Parosjärvi-Näsijärvi-route: after lake Vähä-Vahantajärvi	x	Arsenic concentrations exceed the quality standard for drinking water. Activities notable near the widening stream (grazing horses and sheep, saunas). Extent of human exposure not known, probably low.	The appearance of the stream water does not encourage using it for household consumption (brownish, containing plenty of organic matter).

5.3 Exposure of aquatic and terrestrial biota

The coarse mapping based on the aggregation of the geographic data on valuable nature areas with the data on the most important sources of environmental arsenic revealed a couple of interesting sites that may deserve special attention (see Figure 5). For example, the Haveri mine site in Viljakkala is situated adjacent to a lake with a bay which has been included in the NATURA 2000 program. It is not known whether the contaminants could migrate from the Haveri mine site to this valuable bay. Another obvious risk site is the protected creek – included in the NATURA 2000 program - that flows beside an old landfill in Tampere. A detailed risk assessment has been conducted for this landfill site (Montonen 2006). A more systematic analysis of the valuable nature areas prone to arsenic-related risks would need much more detailed and precise mapping and use of buffer zones around the potential arsenic sources. Such approach was tested with the four mine sites using buffer zones of 0.5 km, 1.0 km and 5.0 km (Table 7).

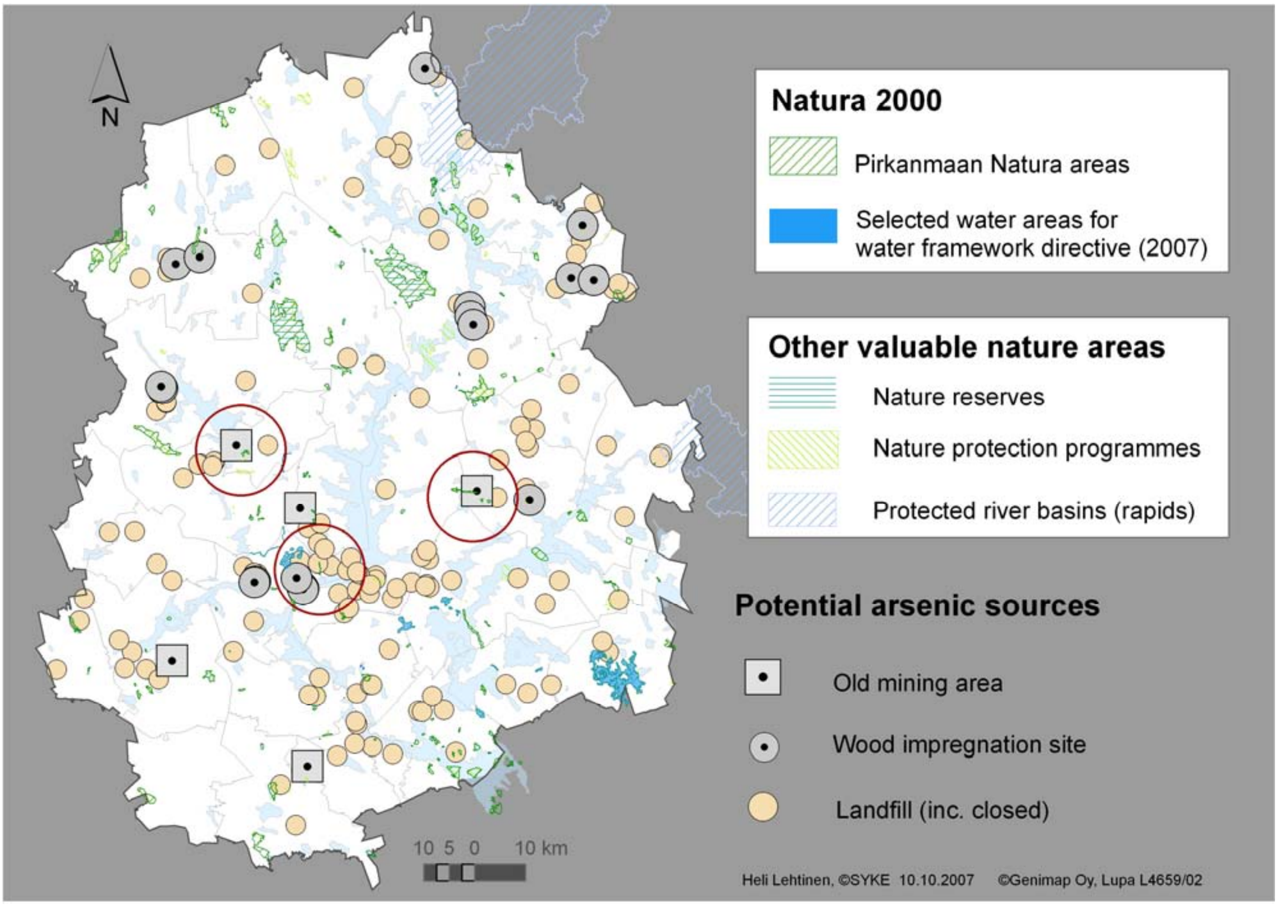


Figure 5. The location of valuable nature areas in the vicinity of the major anthropogenic arsenic sources in Pirkanmaa.

Table 7. Valuable nature areas in the surroundings of closed mine sites in Pirkanmaa and description of the areas within the buffer zones extending outwards from the mine site (distances: 0.5 km, 1 km, 5 km).

Mine	0,5 km	1 km	5 km
Haveri, Viljakkala		Land route to a small nature reserve (herb-rich forest)	Waterway to a NATURA 2000 area (birds, wetland), Land route to lakes (bird wetland), small nature reserves (herb-rich forest) and an esker formation
Lakiala, Ylöjärvi			Land routes to a Natura 2000 lake and to an old forest and a small nature reserve (diverse)
Kutemajärvi, Orivesi	Waterway to a NATURA 2000 area and a nature reserve (creek forest)		Land routes to mires, old forests and meadow sites A potential creek route flowing to a marsh area
Kylmäkoski			Land and a potential creek route to a large marsh area

There are no Finnish guideline values for arsenic in surface water that are based on ecological risks. During the implementation of the Water Framework Directive (60/2000/EY), arsenic and arsenic compounds were assessed as potential members of the national list of priority substances in surface waters, but they were not included (Londesborough, 2003). Similar assessment of priority substances has just been initiated for substances in ground waters. According to Londesborough (2003) arsenic concentrations have only in few places in Finland exceeded the guideline value of 5 µg As/L (issued in Sweden, Canada and in the IPCS/2001[6] assessment). One of the identified places with elevated concentrations of arsenic is the stream and lake route flowing outwards from the Parosjärvi Cu-W-As mine site towards the Näsijärvi Lake. This lake was also studied in RAMAS project and the water route has been monitored since 1970´s. Table 8 summarizes other examples of equivalent monitoring sites in Pirkanmaa.

The results of the ecological risk assessment carried out as a part of RAMAS –project showed that all site types studied (tailings of the Ylöjärvi Cu-W-As mine, the Ruovesi wood impregnation plant and a forest soil (till) that contains high levels of naturally occurring arsenic) pose a significant risk to some terrestrial organisms. Hence, some changes particularly in the abundance of As-sensitive species and individuals are expected. Moreover, the screening level risk assessment based on the determination of Hazard Quotients (HQ) showed at least moderate risks to wetland biota in the surroundings of the Ylöjärvi mine site. (Sorvari *et al*. 2007).

The ecological risks arising from As-contaminated soils have been taken into account in the Government Decree on the Assessment of Soil Pollution Level and Remediation Need (214/2007). Soil is generally defined as contaminated if the content of arsenic exceeds the value of 50 mg/kg (lower guideline value), or 100 mg/kg (upper guideline value) at industrial areas or other less vulnerable areas (the contents of the Decree are analyzed in more detail in section 7.2). The maximum concentrations in till documented in ore prospecting data, clearly exceed even the above-mentioned upper guideline value for soil. However, in the ore prospecting data corresponding the whole Pirkanmaa, the average content of arsenic in upper parts of till deposits was 22.3 mg/kg and in deeper parts 38.7 mg/kg.

[6] IPCS/2001 = International Programme on Chemical Safety (IPCS) 2001. Environmental Health Criteria 224 Arsenic and arsenic compounds [http://www.inchem.org/documents/ehc/ehc/ehc224.htm].

Table 8. Summary of the preliminary risk assessment of exposure of biota to arsenic in surface waters in Pirkanmaa region.

			Surface water	
Source	**Ramas sampling**	**Other**	**Risks**	**Uncertainties, comments**
Lake Parosjärvi	X	X	High concentrations of arsenic, evidently toxic	
Parosjärvi-Näsijärvi-route: before lake Vähä-Vahantajärvi	X	X		Very little notable activity near the narrow, nutrient rich stream. Some grazing sheep. Important bird area.
Landfills PIVET register		X	Concentrations exceed the guideline value based on ecological risk set in some countries. Examples: Ikuri, Tampere 24 µg As/l (small creek); Parkano 6 µg As/l (ditch); Murasuo, Ruovesi 6 µg As/l (ditch)	The contaminated water flows from the closed Ikuri landfill to a protected creek area (Natura 2000). A focused risk assessment has been conducted at this site.
CCA sites in Vilppula PIVET register		X	Arsenic concentrations in ditches exceed the guideline value based on ecological risk set in some countries. Maximum concentrations vary from 4 µg As/l (lake) to 21 µg As /l (ditch).	These sites have been at least partly remediated. The monitoring will show if the As-related risks will diminish to the target level.

5.4 Summary of the risks associated with natural and anthropogenic sources

The human health risk assessment showed that in Pirkanmaa, consumption of drinking water originating from the wells drilled into the bedrock is clearly the most significant route of human exposure to arsenic. In 25 % of the drilled well water samples taken from the two southern geological belts (Tampere belt and Pirkanmaa belt) the arsenic concentration exceeded the quality standard for drinking water (10 µ As/l). Other means of using water in household, such as shower or sauna, are unimportant in relation to the total human exposure to arsenic. However, the biomonitoring study among the 40 inhabitants in Pirkanmaa proved that consumption of drinking water does not cover all possible exposure.

RAMAS studies indicated that quarrying activities and soil excavation can release arsenic to the environment. This may pose additional ecological risks. Health risks are unlikely, unless arsenic migrates to groundwater. However, at the moment there is not enough information to conclude how immobilized natural arsenic is behaving in the environment or to evaluate the potential adverse impacts.

From the contaminated sites, i.e., sites with former anthropogenic arsenic sources, CCA treatment plants pose a risk which, owing to the scale of the activity, is expected to be spatially limited. However, such areas need to be considered in the case of change to more sensitive type of land use, e.g., to residential areas. In the case of ecological risks, mine areas are expected to cause the most important risks (Sorvari *et al.,* 2007). In addition, there are other possible arsenic sources which have not been studied in detail within RAMAS. Such areas include, e.g., landfills and shooting ranges. Without more detailed information on the potential arsenic release from these, it is not possible to estimate the spatial or temporal scale of the related risks.

6 Risk management actions in Pirkanmaa

6.1 Control of land use and construction

Wider contaminated areas, as well as some point sources of arsenic, should be taken into account in land use planning and along with the construction process. The Finnish Land Use and Building Act (132/1999) includes, among others, a general objective to ensure that the use of land and water areas and building activities on them create preconditions for a favorable living environment and promote ecologically sustainable development. The risk issues concerning harmful substances have not been the key point in the development of land use legislation and its implementation unlike, e.g. in the case of natural hazards such as flooding.

The Finnish land use planning system includes the municipal and regional levels - which are the local detailed plan; the local master plan; the joint municipal master plan; and the regional land use plan (Fig 6). The overall guidance concerning land use and the placement of various activities take place locally by means of master plans. Municipalities may also decide on joint municipal master plans. National and regional goals are expressed in regional plans prepared by the Regional Councils. The present national land use objectives were approved in 2000 by the Council of State and they were documented as a part of Finland's national land use guidelines in 2002. The Regional Councils initialize regional plans and programmes in consultation with central and local government authorities and companies and organizations functioning within the region. The Regional Councils also assist in the definition of targets for the national budget, and they also pursue the region’s interests when dealing with the European Union (in the case of e.g., Structural Funds). The Pirkanmaa Regional Council is an alliance of 25 municipalities (since 1.1.2007).

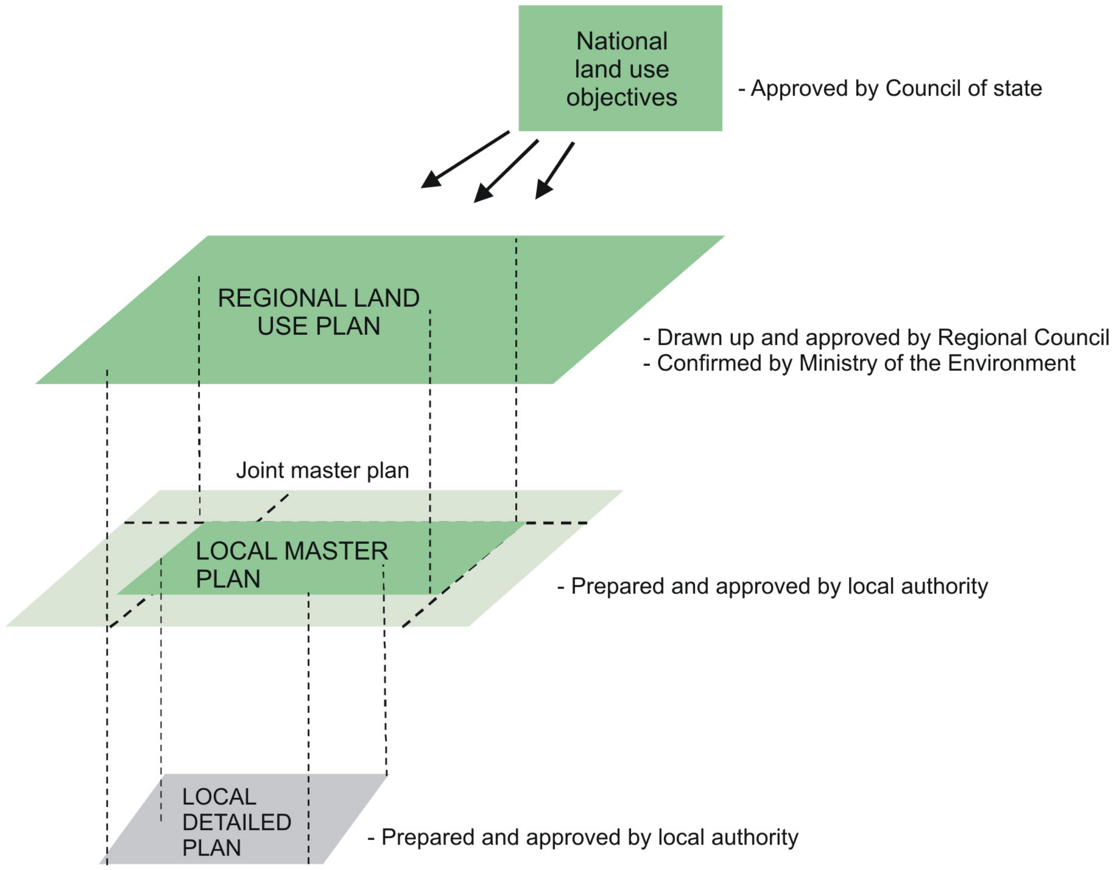


Figure 6. Finland’s land use planning system (SYKE, prepared by Outi Koskenniemi 2007).

National land use objective 2000	Some guidelines
A more coherent community structure and the quality of the living environment	In land use planning, • the suitability of the land and bedrock for the intended uses should be taken into account. The need for restoration of polluted land areas must be investigated prior to plan implementation. • sufficient distances should be left between the functions that may cause undesirable health effects or that have high accident risk and the sensible means of land use and activities

In addition to the chemical legislation and guidance, the risk management of a large scale chemical accident as defined by the Seveso II directive 2003/105/EC[7], has also been implemented in the guidance on land use and construction. The approach to avoid the risks of long term exposure to harmful substances is not as clearly illustrated in the national guidance of land use planning as the management of the risk associated with chemical accidents.

The production plants that may cause such chemical accidents in Finland were listed by the national Safety Technology Authority (TUKES) in 2006. Also the spatial range of the zones that "has to be consulted" according to the legislation has been defined for all the plants listed. The possible arsenic sources in Finland are usually minor compared to these and in addition, the directive is not adapted to landfills or closed mining areas. The largest operating mine sites with large tailings may make an exception. The present list includes 9 plants in Finland connected to existing mining activities, none of these located in Pirkanmaa region.

For the purposes of the regional scale risk management, one of the most important documents is the regional land use plan**.** It sets out the principles governing land use and community structure and apportions the land necessary for the development of the region. It is this plan that serves as a basis for the planning conducted by the local authority. The plants subject to the Seveso II directive are mapped in the regional land use plan but otherwise no particular attention is paid on any point sources of contamination.

In the figure 7 selected land reserves and developments zones from the regional land use plan are mapped with the major identified arsenic sources in Pirkanmaa. There is also found the planned extensions of water supply network in this map. The planned extensions of water supply network between municipalities and the new reserves for ground water extraction, including extensive plans for artificial groundwater extraction, are meant to ensure water supply also in the case of emergency. The contamination risks have not specifically been taken into consideration.

The are large development areas for traffic and services south of Tampere city, which are located right on the As-anomaly. Before starting major earthworks and transport of soils, precautionary measures are suggested in order to prevent contamination risks.

The control of building permits is carried out by local authorities, at municipal level. The undesirable effects on human health and on the environment originating from soil pollution may hinder the granting of building permits. It is also possible, and it has also been realized in practice in some municipalities of Pirkanmaa, to spread information on available RM tools, such as monitoring of well water, along with the permitting procedure concerning construction activities. The local au-

[7] Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances.

thority's building ordinance is also a possible tool for controlling building on or nearby risk areas such as areas with arsenic sources. The city of Tampere has attached geochemical arsenic and fluoride maps into its building ordinance already in year 2000 (see example on internet-pages: http://www.tampere.fi/tiedostot/4Q9fXpapX/5liite.pdf).

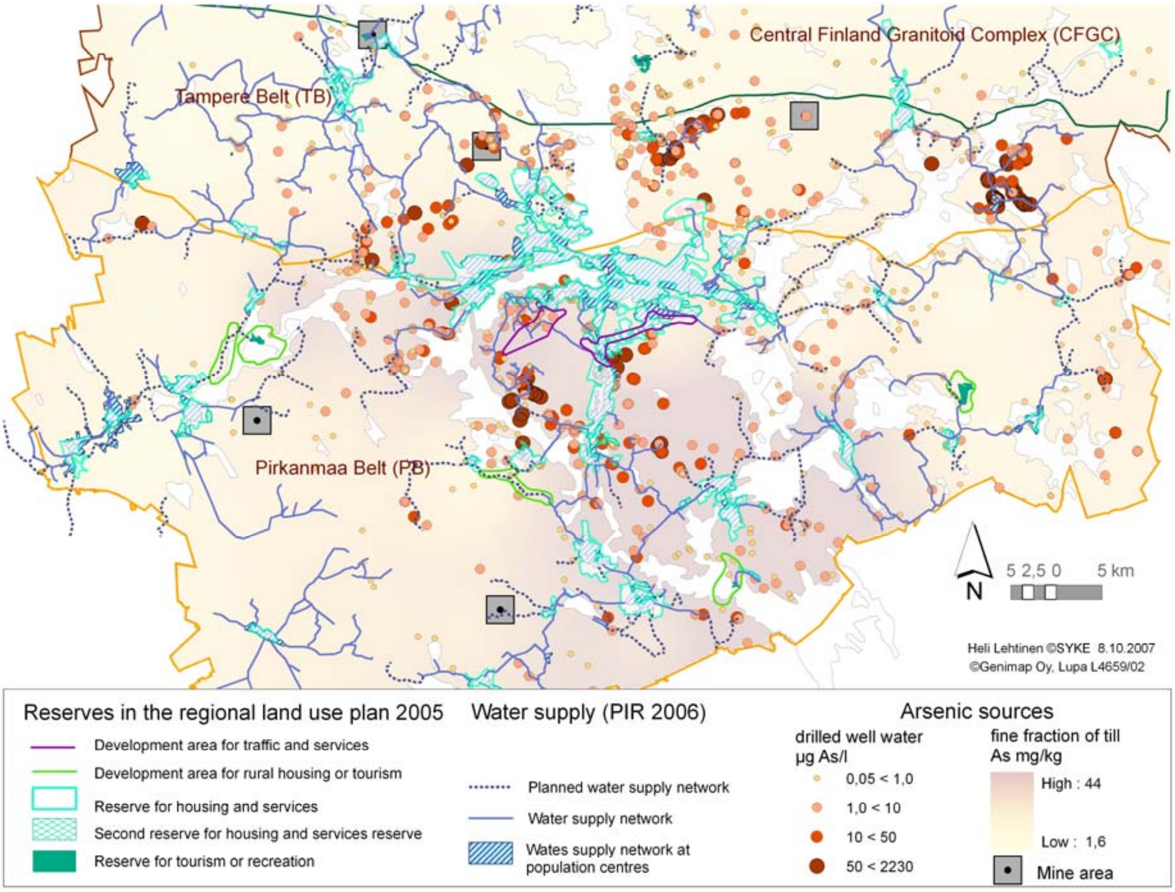


Figure 7. Some reserves in the regional land use plan on or nearby the identified arsenic sources.

6.2 Actions related to water supply

The quality control of raw water and of the processed household water supplied by waterworks is governed by separate legislation in Finland. The administration for the enforcement of water legislation is also divided in several ministries. The complicated legislative framework is reflected to activities at regional level. Hence, there are several regional and local actors responsible for the development of safe water supply.

The quality of drinking water, as defined in drinking water directive (Council Directive 98/83/E), is the primary concern of the health administration. The State Provincial Office of Western Finland (POW) is the regional actor in environmental health issues, such as arsenic in drinking water. The local health authorities are responsible for ensuring that drinking water is of good quality. They also enforce together with the local and regional environmental authorities that the Act on Water Services (119/2001) is followed. The extensive local surveys and monitoring data on arsenic concentrations in drilled wells conducted in a couple of municipalities, such as Tampere and Orivesi, exemplify active preventive policy steered by the local health authorities. Some local health authorities have actively informed households about an extended analysis kit for well water quality, also suitable for the investigation of arsenic. However, single households have no legislative obligation to analyze or monitor their well water quality. Moreover, there is no register containing information on (drilled) wells.

The general development of water supply services, both household water supply and waste water treatment, is administered pursuant to the Water Services Act 119/2001. According to this Act, a municipality must develop the water supply system in its own territory in accordance with the development of communities and participate in the general regional planning of water services. At the same time, the role of the waterworks is to ensure that all premises within their "defined area of operation" are connected to an adequate water supply. The biggest waterworks are usually own by the municipalities. Property owners and occupiers in turn must control the distribution of water within their property.

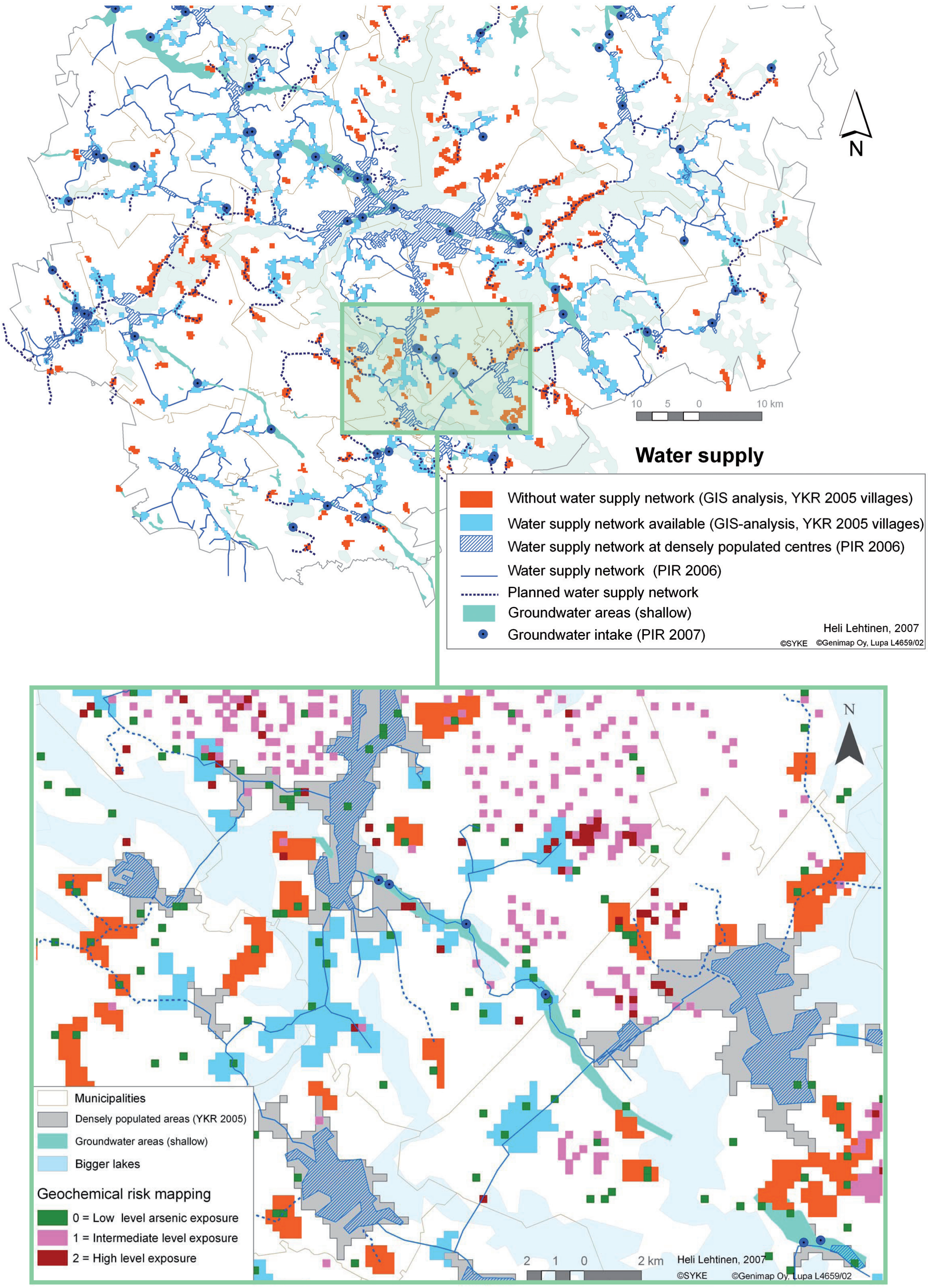
The Pirkanmaa regional environment centre (PREC) supervises the water supply systems and controls the planning of improvements. One of the most important tasks associated with the supervision of the waterworks is the approval of their "areas of operation". PREC also allocates state subsidies for the development of water supply. There are several mechanisms to support local water services and even single real estates, but the volume of state subsidies is not very significant. In fact, it constitutes only 10 % of the total yearly investments to the water services.

The criteria for the state subsidies such as, the direct financial support or employment support are defined in the Act on Subsidizing Water Services (30.7.2004/686). One of the four criteria is the prevention of surface or groundwater contamination or the improvement of their state. Concerning the prevention of exposure to arsenic, the development of organized water supply systems at small villages and sparsely populated rural areas is another important criterion. Both of these criteria have already been applied in Pirkanmaa when making decisions on state subsidies on As–anomaly areas (oral notice, PREC officer Ms Kaija Joensuu). The coverage of the current water supply network is illustrated in figure 8, page 32.

PREC has recently coordinated some regional planning processes in water supply and waste management (PREC, 2006; PREC, 2004). These regional plans do not include references on arsenic contamination. The municipalities of Ikaalinen, Viljakkala and Hämeenkyrö probably have the best secured water supply systems while the situation is worst in the municipality of Längelmäki (PREC, 2006).

PREC has also actively developed the planning of municipal water supply systems. Together with the municipality of Lempäälä, a pilot plan was prepared in 2003. The arsenic anomaly located in Lempäälä was taken into account in the pilot plan but, according to the regional water supply authorities, not yet with adequate fineness of spatial detail (oral notice, PREC officer Ms Kaija Joensuu). The villages in which high concentrations of arsenic had been found in groundwater were listed and the areas with suggested development of water supply network were only roughly marked in the regional map.

Figure 8 (page 32). The coverage of water supply network and important groundwater (shallow) areas on two different spatial scales. Some of the bigger lakes are also used for making household water, but not specified here. The GIS analysis for villages without water supply network (red color) explained in Appendix 1. The densely populated areas in the lower map are defined from the community structure (YKR 2005 = MOST database). Note that they are larger than the coarse mapped areas of current water supply network at densely populates areas, prepared by Pirkanmaa Regional Environment Centre. The method and data for geochemical risk mapping is explained in another RAMAS report (Sorvari *et al.* 2007).


N
10 5 0 10 km
Water supply
Without water supply network (GIS analysis, YKR 2005 villages)
Water supply network available (GIS-analysis, YKR 2005 villages)
Water supply network at densely populated centres (PIR 2006)
Water supply network (PIR 2006)
Planned water supply network
Groundwater areas (shallow)
Groundwater intake (PIR 2007)
Heli Lehtinen, 2007
©SYKE ©Genimap Oy, Lupa L4659/02
N
Municipalities
Densely populated areas (YKR 2005)
Groundwater areas (shallow)
Bigger lakes
Geochemical risk mapping
0 = Low level arsenic exposure
1 = Intermediate level exposure
2 = High level exposure
2 1 0 2 km
Heli Lehtinen, 2007
©SYKE ©Genimap Oy, Lupa L4659/02

Also the Employment and Economic Development Centre (TE Centre) of Pirkanmaa has been active in the regional planning concerning the development of water supply systems in rural areas (see Fig 9). TE Centres play a major role in granting EU-based regional subsidies and developing regional co-operation. They act as funding channels for projects through several EU structural funds and national public and private funding sources. In Pirkanmaa some development projects for water supply systems have received funding from the structural funds during the first two periods.

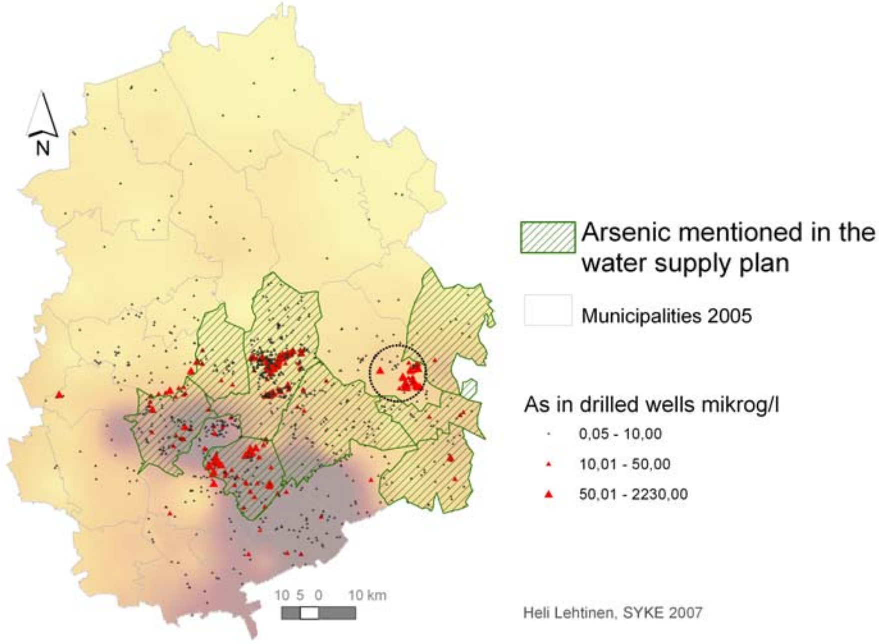


Figure 9. The regional extent of the arsenic-related groundwater problem as illustrated in the regional plan on water services at rural areas and small villages (TE Centre for Pirkanmaa, 2001) in Pirkanmaa. The planned extensions of water supply network have been fulfilled at the Eräjärvi village (black circle in the map).

At national level, the Finnish Environment Institute (SYKE) conducts applied research related to the water supply and also provides practical advice via internet pages for the users of private wells. SYKE has also published, together with other institutions, a guide for analyses of well waters, addressed to owners of private wells. This guide tells, e.g. that concentration exceeding the value of 1 μg As/l in well water analysis is to be considered as a sign of possible health risks and additional sampling is needed (Kaivoveden… 2007).

The practices of the preventive protection of the quality of fresh water resources will gradually change to comply with the Water Policy Framework Directive (WPD, 2000/60/EC). For instance, the national list of priority contaminants requiring special attention in the assessment and monitoring of ground water quality is in preparation. The regional environment centers have an important role in the implementation of WPD. Both surface and groundwater quality are taken into account in the regional monitoring programs and other regional plans are being prepared pursuant to the WPD. New policy will evidently increase the monitoring of fresh water quality at places were there is a risk for contamination. Monitoring has historically been focused on areas without any point sources of contaminants.

In Finland, the majority of the ground water resources belonging to the highest quality class (class I) have been and are to be protected on the basis of specific protection plans, often drafted by the local authorities in co-operation with the local waterworks. In Pirkanmaa special attention has been paid to the surroundings of the some 100 sites which are used for ground water abstraction.

Table 9. Summary of the major actors in water services and risk management tools available for the restriction of exposure to arsenic. WPD = Water Policy Framework Directive

Quality of water Services	Actors	Tools in Arsenic Risk Management
Water quality	customer, municipality, waterworks, region	• Regional surveys on arsenic concentrations • Monitoring, including single household wells if needed • Household-specific removal of arsenic from drinking water by suitable equipment.
Service security	customer, municipality, waterworks, region	• Anticipation of contamination, training may be needed • Care concerning the reliability of arsenic removal equipment, monitoring and other warning systems, accomplished e.g. by regular maintenance
Consumer price	customer, municipality, waterworks, region	• Establishment of broader water pools and cooperatives [increases purchasing power] • Application of financial support
Regional coverage of the water supply network	municipality, waterworks, region	• Further enlargement of water supply network on arsenic anomaly
Preparement for risks	municipality, waterworks, region	• River basin management plan, (implementation of WPD) • Protection plans for important ground water areas Municipal or joined municipal water supply plan (Water Services Act 119/2001). • Environmental health programs and plans
Ability to maintain infrastructure	waterworks, region	• State subsidy system, additional 10 % for investment costs when building on As-anomaly
Ability to persuade and keep qualified personnel	waterworks, region	• Education of the personnel
Ability to invest in future development	waterworks, region	• State subsidy system, informative instruments
Strength in supply contracts	Waterworks, region	• State subsidy system, informative instruments
Regional optimization of economical and social resources	region	• Regional land use plan • State subsidy system
Regional optimization of natural resources	region	• Survey on water resources • Protection of water resources, regional level planning • Control of land use and land use planning

6.3 Actions pursuant to environmental legislation

The Finnish Environmental Protection Act is a general act on the prevention of pollution applied to all activities that cause or may cause environmental harm or damage. This act is based on an integrated system for environmental permits. The state-level permitting authorities in Pirkanmaa include the Western Finland Environmental Permit Authority and the Pirkanmaa Regional Environment Centre (PREC). State authorities are responsible for permitting e.g., all active mines. In the municipalities, the municipal environmental protection committee is the primary permitting authority. They handle majority of the permits for quarrying and crushing. The amendment of this administrative organization of environmental permitting is ongoing.

According to the Environmental Protection Act the local authority, committee or an official, is also responsible for necessary monitoring of the state of the environment. The administrative duties of the state concerning environmental monitoring are laid down in legislation. Regional environment centers and the Finnish Environment Institute maintain an environmental protection database (VAHTI), into which also local authorities submit data.

There are almost 400 industrial plants with contamination risk that are supervised by the Pirkanmaa Regional Environment Centre. Waste management, energy production and metal industry outnumber other activities that are liable for environmental permit in Pirkanmaa (Fig. 10). For the purpose of the RAMAS-project, the supervisory authorities in PREC went through the most potential monitoring programmes (stated in environmental permits) in which arsenic issue could have appeared. Power plants are obliged to monitor arsenic and harmful metals and metalloids whereas there has not been set such an obligation in the most cases of waste management plants or metal industry sites.

The largest operating municipal landfill in Pirkanmaa has an obligation to monitor arsenic in leachate. The leachate is drained to a municipal waste water treatment plant. Arsenic has not been an issue of additional risk management, although the mean concentration in leachate has been 37 µg As/l with the maximum of 317 µg As/l. No data (from 2005) was available from the two other operating landfills. RAMAS-project organized additional sampling from the soil groundwater of two operating landfill sites and two closed landfill sites, located on As-anomaly. The samples were taken outside the waste heap. The concentrations of arsenic (total usually between 7.9–65.5 µg As/l) exceeded the median of the dug well water samples (0.2 µg As/l) in Pirkanmaa and also the national mean concentration of groundwater samples (9.5 µg As/l) taken form the landfill sites (Backman *et al.* 2007b). It remained unclear whether the source of arsenic is natural or anthropogenic in the additional samples. Further studies are needed.

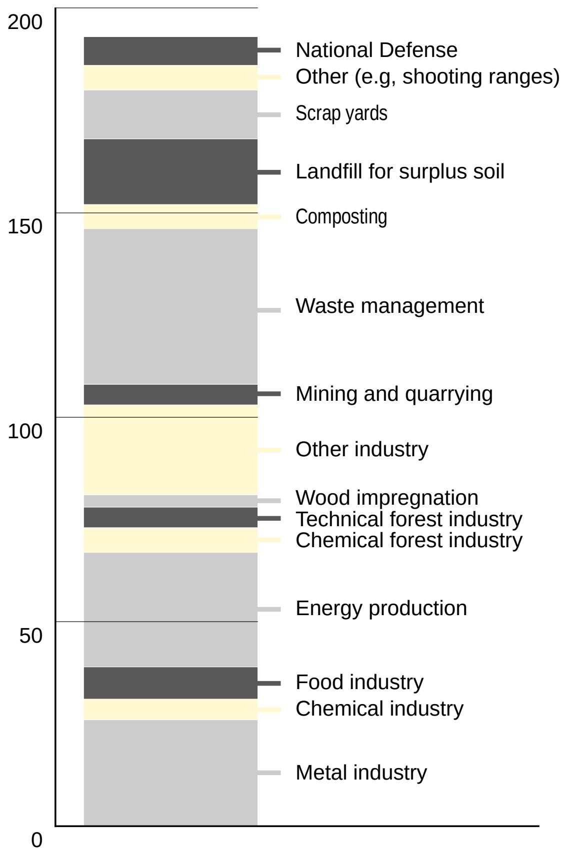


Figure 10. The number of sites liable for applying an environmental permit. Data classified according to the activity (PREC registers 2007, unpublished).

6.3.1 Contaminated land management

On RAMAS study sites the activities causing arsenic contamination, such as wood impregnation or mining have ceased in the 1960's, a long time before the present-day environmental protection legislation. The old CCA sites fall clearly into category of contaminated soil. There is no obligation to register potentially contaminated sites or to update this information. The data is, however gathered in a national database, because it is needed in planning future clean-up works done under state waste management system or to fulfill the obligations concerning land use planning. This database also includes data about suspected contamination, not only sites where research and remediation has started.

Finland has a waste management system which allows the state to take remedial actions, if the property owner is not able to pay and if the costs are high compared to the costs of waste management in a municipality. The state can, in co-operation with municipalities or property owners, participate in the remediation or cover on the average 45% of the remediation costs. However, the system suffers from the shortage of funds. So far the system has been applied to the remediation of some 280 contaminated sites around the country. Regional plan is needed for the application of the waste management subsidies for the remediation of contaminated sites. In Pirkanmaa, only one or two sites in a year have been remediated on the basis of this subsidy system.

The national database on potentially contaminated sites (Matti-register) includes more than 1600 sites in Pirkanmaa region. The contaminated sites found in Pirkanmaa have been classified in different categories (A–C) on the basis of urgency of site studies: A urgent, B within 5–10 years, C not urgent. Around 100 sites have been classified to the most urgent A-risk class. The classification was updated around 2000–2004 and the planning of the next update is ongoing.

The classification between categories A, B and C is based on a quite simple risk-based model (SMP). The model takes into account the characteristics and the range of contaminating activity, the observed contamination in groundwater, surface water and soil, distances and groundwater course to vulnerable targets and current and future land use. The different uses of surface water are also considered. The distances are counted with a help of GIS-program and readily available GIS data on classified, shallow ground water areas, groundwater abstraction sites and housing areas. The land use types are housing, nature conservation, recreation, services, agriculture, industry and landfill. Housing and nature conservation give the highest points and landfill the minimum points. (Silvola 1999).

In the national database (from 2005) for contaminated sites there were 14 sites in Pirkanmaa in which wood impregnation has been identified as the main source of potential contamination. By the year 2007 only one of these is still in operation, but it is not using anymore CCA chemical due to restrictions set in Arsenic Directive (2003/2/EC). Three wood impregnation sites have been prioritized into the class A. They are all situated within a four kilometers range and on a ground water area of the highest quality class (class I). At one of the sites, remediation was finished in year 2004. The other two sites (Ruovesi I, Kauttu and Ruovesi II, Ruhala) were selected as study cases for the risk assessment conducted in RAMAS. There are still four former impregnation plants in the database in which no field investigations have been carried out. By the year 2005, five sites had been remediated; at one site remediation is ongoing (see Fig 11).

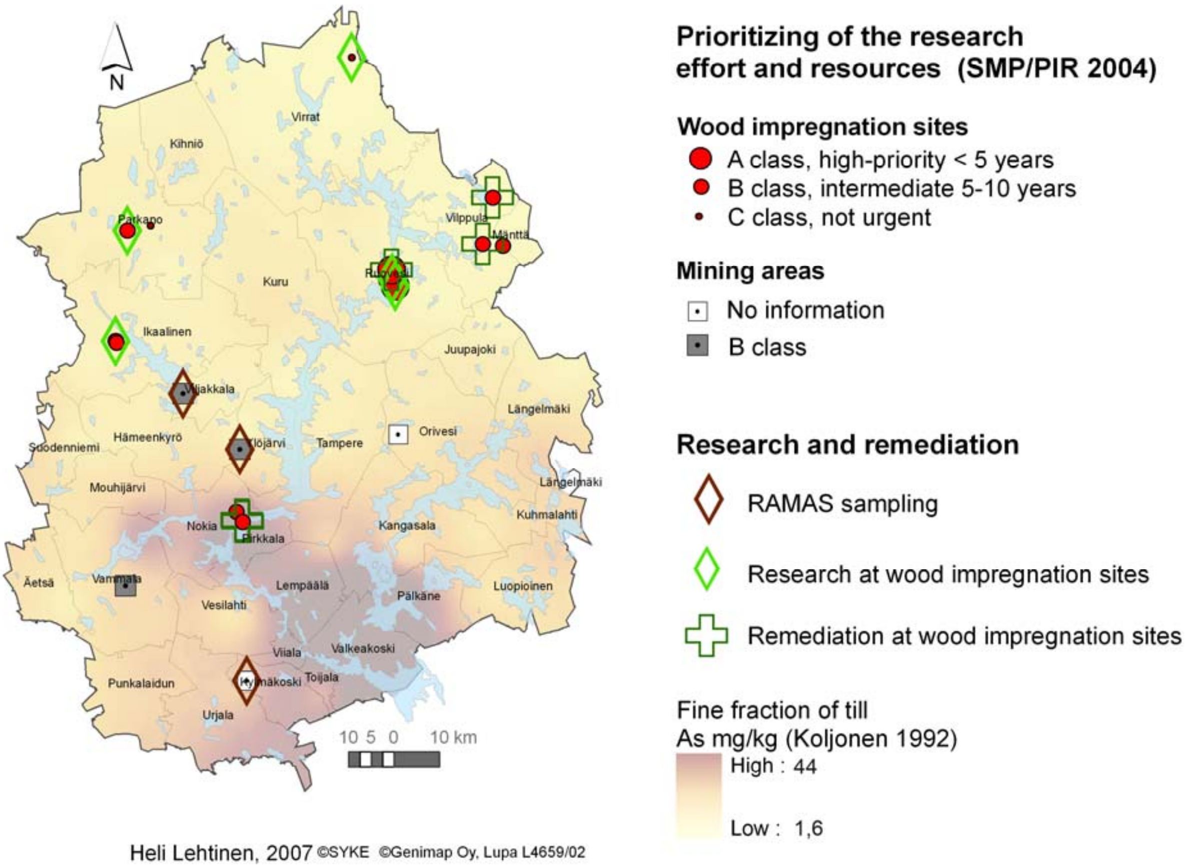


Figure 11. The risk management actions taken in Pirkanmaa mining areas and wood impregnation sites: prioritization, research and remediation.

The closed mine sites in Ylöjärvi and Viljakkala have been prioritized into the class B. They were also selected as study cases for RAMAS-project. Some sampling was also conducted at Kylmäkoski mine site. The mine sites in Kylmäkoski and Orivesi have not been classified yet owing to lack of data (Fig. 11). The surface waters around the Ylöjärvi mine site have been monitored according to a mandatory programme and there have also been some other investigations on this area (Carlson *et al*. 2002, Parviainen *et al.* 2006, and Bilaletdin *et al.* 2007). The Haveri mine site in Viljakkala has hardly been studied although a risk assessment of contaminated soils in the mine area has been run in 2004. However, in this assessment the open pit and tailings area were excluded.

Only single results of the landfill studies including arsenic were readily available since arsenic has generally not been included in the mandatory monitoring programmes. Still, some data sources and additional sampling implied that landfills may be potential arsenic sources in Pirkanmaa. A total of 142 landfills have been registered in the national database of potentially contaminated sites in Pirkanmaa area. Nearly all of the 90 municipal landfills in the register are already closed except one very large landfill inside the Tampere City. Only a minority of the closed landfills has already been investigated and only at 7 landfills active risk management actions have taken place (Fig 12).

The former industrial landfill in northern Pirkanmaa (Vilppula), where arsenic has been one of the main contaminants, has so far been the most challenging from the viewpoint of remediation. In the same area, other sites potentially contaminated with CCA impregnation chemical are found. Some of these sites have also been at least partly remediated. Environmental monitoring (including arsenic) is ongoing in the surface waters. On the basis of practical experience of the remediation of soils contaminated with CCA impregnation chemical, it is technically difficult to fractionate the contaminated wooden chips from the mineral soil. Therefore, remediation of such sites often turns out to be relatively expensive. (oral notice 24.1. 2006, Kari Pyötsiä, PREC).

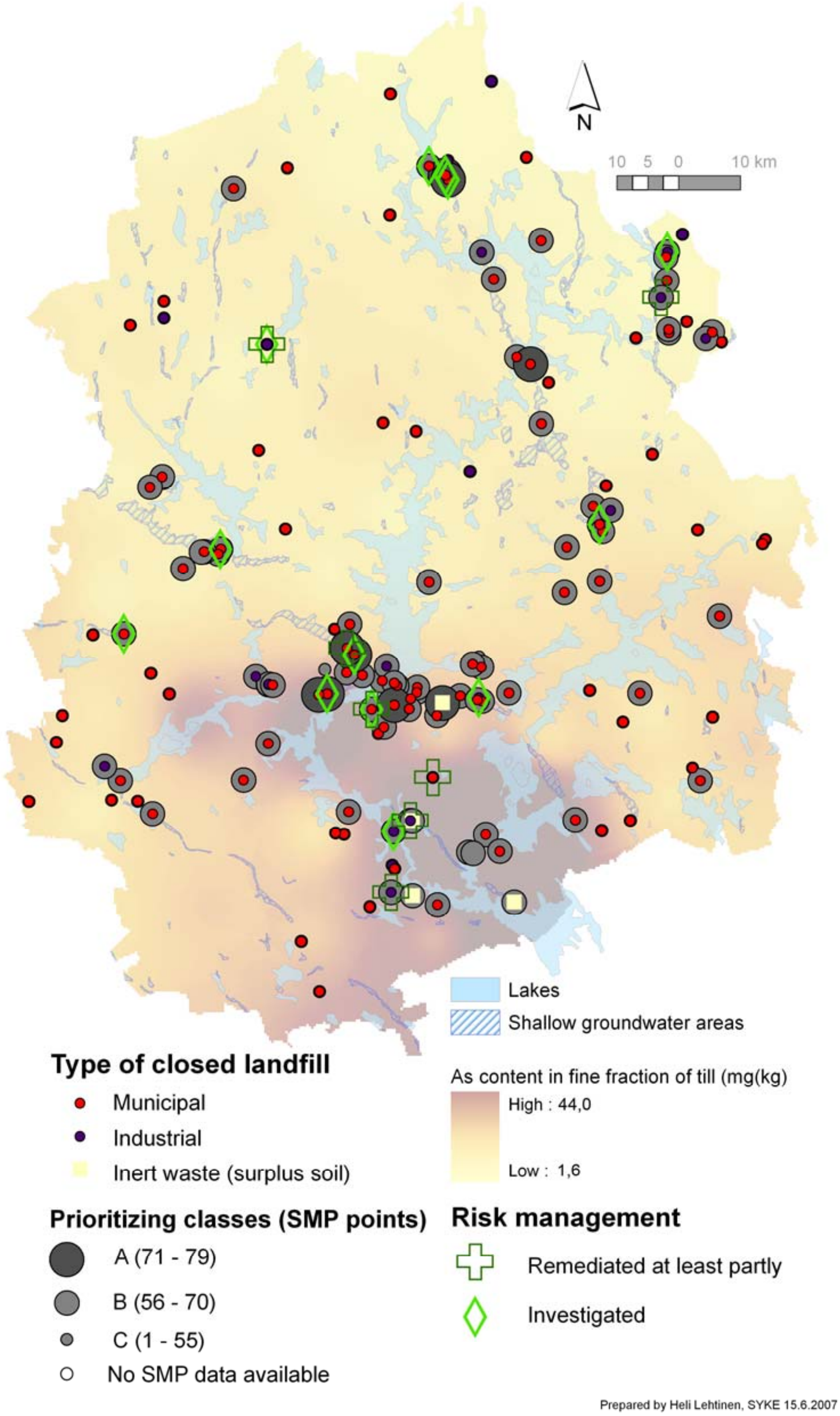


Figure 12. The risk management actions taken in Pirkanmaa landfills: prioritization, investigation and remediation.

6.3.2 Relocation of soils

The most common remediation method for contaminated sites in Finland has been mass exchange. Polluted soil is predominantly treated off site. In Pirkanmaa region, considerable volumes of contaminated soils have been transported from one place to another, sometimes also outside Pirkanmaa. The transport distances have reached even 200 km (Table 10). In the case there are no other options, the surplus soil from construction works are delivered to the landfills treating inert waste. These landfills are not allowed to receive contaminated soils. However, the excavated till masses from natural arsenic anomaly areas may unintentionally contain soluble arsenic above the limit value set for inert waste. Their arsenic load may also be released in time when the sulphides are weathered. For sulphide bearing soils the laboratory tests used to measure the concentrations of soluble compounds are not sufficient and hence, the total concentrations and the long-term behavior of the arsenic in soils should also be considered.

Table 10. Transport of contaminated soils which contain arsenic in 2004-2006.

Source, municipality	Ton-kilometres	Target	Out of Pirkanmaa region
2 wood impregnation (CCA) sites, Vilppula	370000	Loila capsule (Vilppula)	
2 metal sites, Tampere	160000	Landfill site at Tampere and waste management site at Forssa	Forssa is situated in a neighbouring region (90 km)
4 combined (metals + hydrocarbons) sites, Tampere	2310000	Landfill sites at Tampere and Valkeakoski, closing landfill at Virrat, waste management sites at Forssa and Heinola	Heinola is situated about 160 km from Tampere
2 metal sites, Akaa	360000	Landfill sites at Tampere and Nokia	
1 combined (metals + hydrocarbons) site, Akaa	160000	Waste management site at Ilmajoki and closing landfill at Virrat	Ilmajoki is situated about 200 km from Akaa
Sum (11 sites)	3360000	8 target sites	3 sites

In Pirkanmaa, parts of the most heavily contaminated CCA-soils have been put into a capsule construction in the vicinity of the remediated sites (see Fig 13). Some CCA+mixed contaminated soils have been solidificated and stabilized using a special bituminous material and then spread under a future waste treatment site. There are 4 similar fields in Pirkanmaa area (Tampere, Ylöjärvi and Valkeakoski, the oldest one - 15 years) where soils that are contaminated with heavy metals have been stabilized with special bituminous or cement concrete. No particular attention has been paid to arsenic. The environmental load has been acceptable i.e., in accordance with the environmental permit. (Oral notice 24.1. 2006, Kari Pyötsiä, PREC).

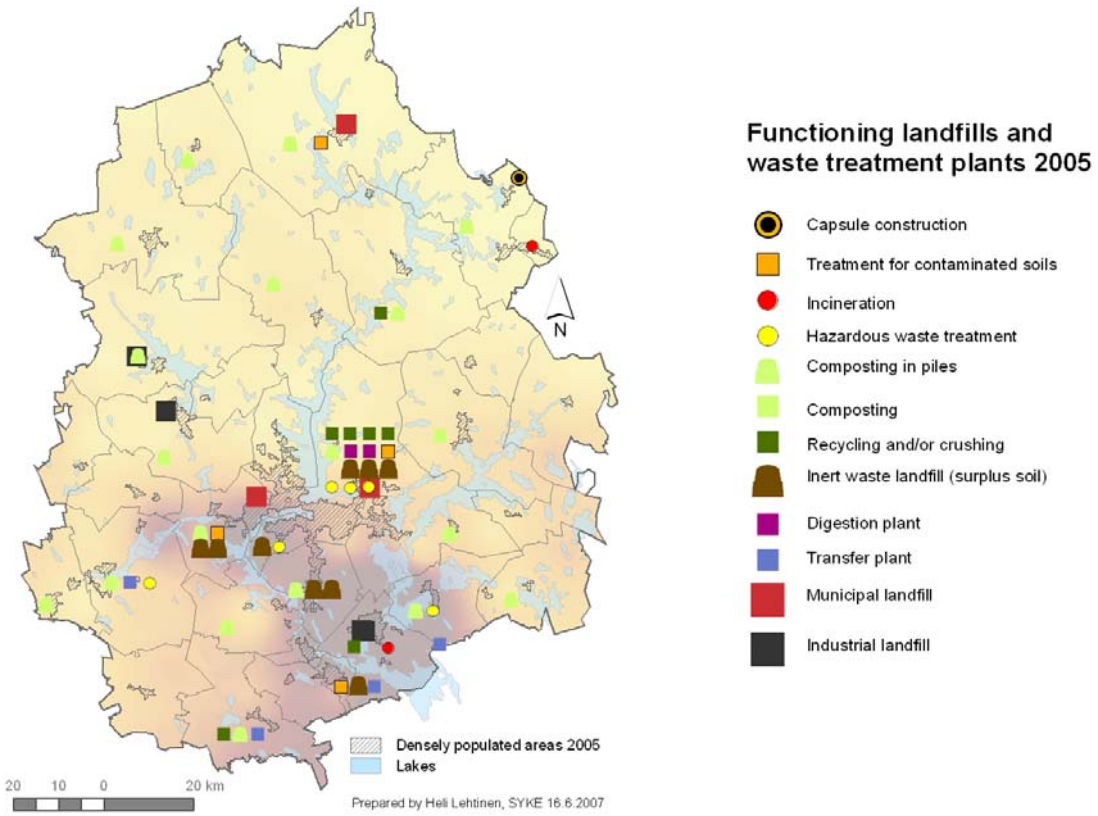


Figure 13. Location and type of the waste treatment plants in 2005. Capsule construction for CCA-soils.

6.3.3 Risk management of power plants and their ashes

In Pirkanmaa, peat ashes have lately been taken to the closest landfills. A few years ago, 91 % of the wastes from energy production were landfilled in Pirkanmaa region (Blinnikka 2004). Their chemical or technical quality was not suitable for other reuse than covering the waste heaps.

The peat ashes have been analyzed for arsenic concentration and solubility, because these analyses are required by virtue of current landfill legislation and a separate ordinance (Government Decree 591/2006) on the reuse of some waste materials in earthworks. The latter regulation includes e.g., a limit values of 50 mg As/kg dry weight for total of arsenic in ashes. In the Decree of the Ministry of Agriculture and Forestry on the fertilizer products (12/2007) the limit value for forestry fertilizers is 30 mg As/kg and in other fertilizers 25 mg As/kg.

There are plans to build an energy power plant in Pirkanmaa, where a measure of CCA-impregnated wood could be incinerated together with other fuels. No decision on the placement of the power plant has yet been made. The potential emissions of harmful substances, including arsenic, of such a plant have raised strong opposition to the plans.

Table 11. Total concentrations and solubility of some ashes generated in Pirkanmaa and measures taken to manage them.

Ashes		
Source	**Concentrations or solubility, As mg/kg**	**Risk management, comments**
(Sorvari 2000)	Max 72 mg/kg, leachability 0.02-1 mg/kg	
Naistenlahti power plant, Tampere	46-55 As mg/kg, ashes from peat and wood combustion (years 2004-2005)	One failed experiment on the utilization of the fly ashes. The receiving company did not handle the ashes according to the regulations. Naistenlahti power plant produced 0.26 t arsenic 2005 in the ashes. Fly ashes from peat combustion have been taken to the nearest operating landfill at Tampere.
Power plant at Virrat	58 As mg/kg, ashes from peat and wood combustion, leachability 3.7 mg/kg, L/S 10 (PREC laboratory analysis 15.2.2007)	Fly ashes from peat combustion have been taken to the nearest operating landfill at Virrat which started closing procedure in the beginning of the year 2007.
Power plants at Mänttä and Valkeakoski (Tervasaari)	Information not available	The ashes of Mänttä power plant are taken to the neighbouring region where the landfill of the power plant is situated. The ashes from Tervasaari are taken to landfills.

6.4 Summary of the most important RM actors in Pirkanmaa

In Finland, the administration associated with the control of environmental risks is divided into several ministries. At regional level, there are also various actors at local (municipalities) and regional level (state or county administration). The 'lowest' level of actors is a single property or household and even a single inhabitant. (Fig 14).

Because the number of RM actors at regional level is very high, some key institutions and stakeholders should be selected in order to identify development needs in risk management. Related to environmental arsenic, the following parties were identified as the key stakeholders at regional and local level:

- Particularly local, but also regional authorities responsible for healthy household water
- Local and regional authorities responsible for land use planning
- Local and regional authorities responsible for regional planning of water supply
- Decision makers in land use issues and concerning water supply services
- Environmental authorities at all regional levels, particularly regional
- Service providers, i.e., water companies, environmental consultants and landfill owners
- Generators of some wastes relevant as potential arsenic sources (e.g., energy plants)
- Researchers and experts working among the arsenic-topic and topics relevant to risk management (e.g., risk assessors both in Finland and in other countries).
- Regional and national media

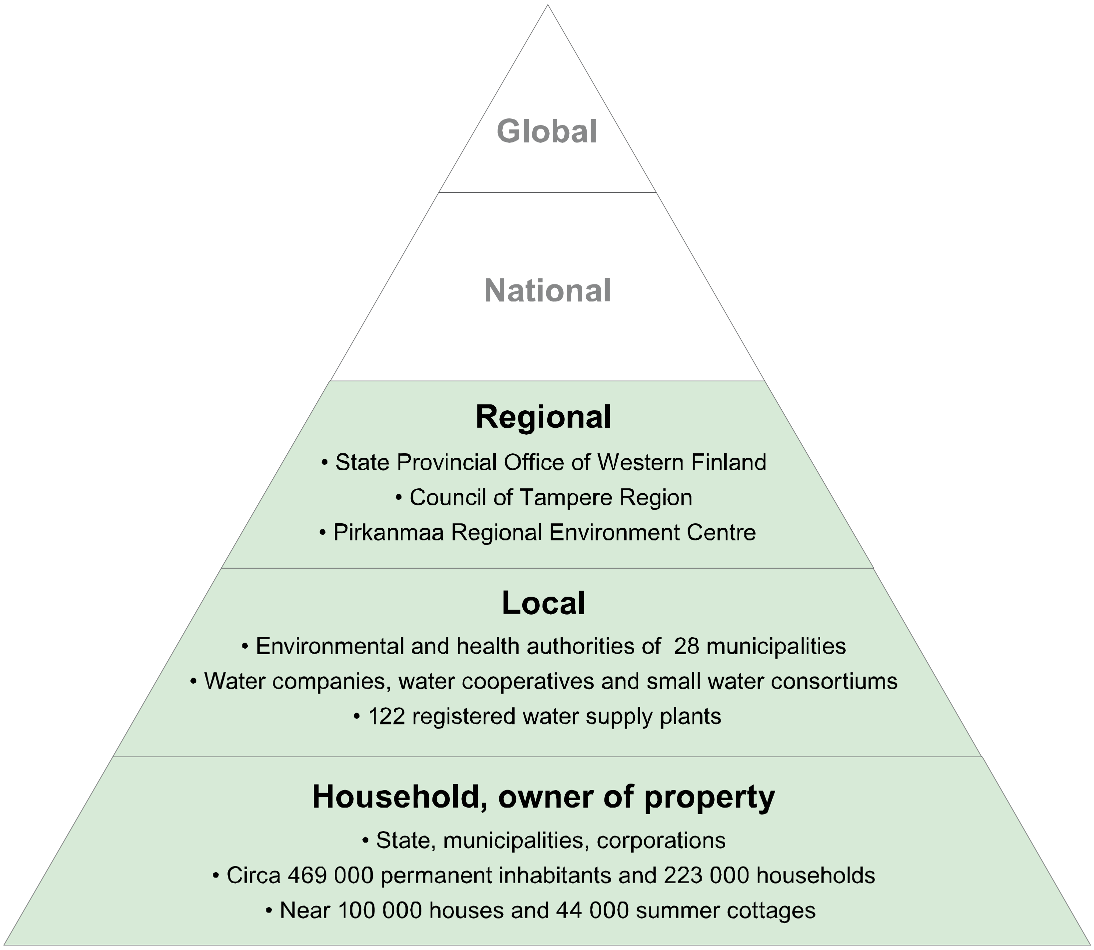


Figure 14. Actors in Pirkanmaa involved in the management of risks associated with environmental arsenic.

7 From risk assessment to targeted risk management

7.1 Existing mechanism to limit arsenic risks

7.1.1 Main instruments and tools

During the first survey (Lehtinen & Sorvari, 2006) it was decided that the concept of risk management referred to all control mechanisms and actions which aim to reduce the identified risks. The RM control mechanisms were classified according to the target to be controlled:

1. Control of the sources of arsenic emissions (source reduction)
2. Control of the quality of the environment (reduction of exposure)
3. Control of the distribution and structure of population and the use of natural resources (avoidance of exposure)

In Pirkanmaa area it is not possible to remove all the arsenic sources (mechanism 1) because of the geochemical characteristics of the bedrock and soils. The quality of drinking water (mechanism 2) is the key issue in the management of health risks. Other routes of human exposure routes were assessed to be regionally insignicant. Because there are usually alternative, safe water resources available, it should be possible to steer the future distribution of the population and water supply network (mechanism 3) into such direction that the inhabitants are not anymore dependent on their wells drilled into arsenic-rich bedrock.

The acceptance practises and quality control procedures of products and raw materials have turned out to be quite effective risk management tools (mechanism 1) in the case of arsenic. The anthropogenic sources of arsenic were found to be mainly historical in Pirkanmaa, equivalent to other parts of Finland with only a few exceptions (see also Table 12: A, B and C). There are no major active industrial processes in Pirkanmaa, which would generate As-containing emissions to air or water. The solid wastes, such as ashes from power plants, contaminated soils or waste rock from an arsenic-anomaly, may contain significant concentrations of arsenic. It is necessary to monitor and assess the quality of the environment in the vicinity of the remaining, most significant sources of environmental arsenic and launch active remedial actions if needed.

Table 12. Sources of arsenic and some existing administrative tools and means to restrict the risks associated with them.

A Agriculture and Forestry, imported foodstuffs

Use or source of arsenic	Means of risk management
Pesticide in agriculture and horticulture In Finland arsenic has been observed on market garden plots and in the waste and storage areas of old farms.	Since the 1960s the use of pesticides containing arsenic has been forbidden in Finland (Ministry of Agriculture and Forestry).
Chemical removal of potato stalks	Forbidden in Finland already in the 1960s (Ministry of Agriculture and Forestry).
Fodder and fodder additives Arsenic compounds Nitarsone and Roxarsone have been used outside the EU area e.g., against coccidiosis in poultry. It has been found to penetrate the earth through manure.	Not approved as a fodder additive in the EU, applications denied. In Finland fodders and their hazardous additives are controlled by EVIRA (the Finnish Food Safety Authority) according to the relevant legislation. Supported by Directive (1831/2003) and Directive (2002/32EY), updated (2003/57/EY) and (2003/100/EY).
Detergents for production animals Arsenic as an impurity in detergents for washing animals' cloven hooves in Finland, in copper sulphate.	In Finland the use of copper sulphate for this purpose was forbidden 2007. In the risk management of washing detergents Directive (98/8/EY) supporting or the Decree on detergents (648/2004/EY) when they are not classified as animal medicaments.
Fertilizers and fertilizer preparations In ashes used as soil amendment product, arsenic may limit use. Arsenic content may also be high in preparations containing seaweed.	EVIRA oversees hazardous substances in fertilizers and fertilizer preparations. Support from the legislation (539/2006) and the Decree (MMM 12/2007) on fertilizers, enclosure IV governing hazardous substances. The separate decree (MMM 13/2007) provides for the self-regulation of practitioners. (MMM = Ministry of Agriculture and Forestry).
Foreign foodstuffs The highest inorganic arsenic contents in foodstuffs have been measured in rice. Various organic arsenic compounds have been found in relatively large quantities in seafood (incl. seaweeds, crustaceans, and oily fish). The organic arsenic compounds in these aquatic organisms have not been found to be detrimental in the same way as inorganic arsenic.	In Finland substances extraneous to the food chain are monitored by EVIRA, with the exception of fodder; the monitoring of arsenic contents is not mandatory on the basis of legal provisions supporting the surveillance programme adhered to. In more extensive monitoring the metals have included cadmium, lead, tin and organo-tin compounds.

B Industrial activities

Use or source of arsenic	Means of risk management
Excavation and enrichment of minerals Arsenic occurs as an impurity in Finland in gold and nickel deposits. Risk management of arsenic is most demanding in the treatment of water from the enrichment process and waste.	Operating mines, refineries and their waste areas have environmental permits handled by the environmental permitting authorities. The implementation of EU Directive on mines (21/2006/EY) is ongoing in Finland. Risk management is further supported by other legislation on wastes, e.g. landfill regulations.
Quarrying and crushing of rock As an impurity in the bedrock of Pirkanmaa (Tampere Region) in arsenic anomalies. Arsenopyrite weakens the usability of the material.	Generally, quarrying and crushing operations require permits mainly on the basis of possible air emissions and noise. The permit is generally issued by the local authority. Arsenic is not included in mandatory monitoring in Pirkanmaa.
Wood treatment with chemicals, protection against slime Diarsenic pentoxide (CCA-chrome-copper-arsenic) impregnates. Used mostly for the impregnation of telephone poles and lamp-posts. Numerous observations of soil affected by CCA at sawmills and properties where impregnation has been carried out, generally sites with a small surface area. Other compounds hazardous to the environment found at the same location, such as chlorophenoles and creosotes.	There is one production facility in Finland producing CCA chemicals, and this has an environmental permit. The Arsenic Directive (2003/2/EY) and its amendments (in Finland VNa 440/2003) and amendment (787/2007) in practice prohibit the importing of wood treatment substances containing arsenic from outside the EU and their sale within the EU. There are strict limitations on the use of ready impregnated timber, including its recycling. Disused impregnated wood products are problem waste for which there is a centralized collection and storage system in Finland. The final means of processing has not yet been determined.
Metal and Metal products industry Arsenic is used in the process of refining cobalt from waste materials. Arsenic occurs as an impurity in the refining of nickel ore, among others. Arsenic is used in mixtures especially in products containing lead (ammunition, accumulators, solder). It has also been used in the surface treatment of metals, such as in dyeing aluminum black and in the chemical polishing of copper mixtures. Arsenic has been found in elevated quantities on premises for scrapping, demolition of accumulators, repair workshops, foundries, railway yards, and heating plants, among others.	In Finland, the highest atmospheric emissions of arsenic arise from the production facilities situated in Harjavalta and Kokkola. The plants have environmental permits. The quality of the environment is monitored; monitoring includes the measurements of arsenic content in air. Arsenic mostly ends up in solid waste.

C Other sources of arsenic

Use or source of arsenic	Means of risk management
Waste materials used in earth construction Waste materials including ash may contain levels and forms of arsenic which restrict utilization.	Government Decree (591/2006) includes limit values for contaminants, arsenic included.
Mixed waste, municipal waste Arsenic has been found in the inner waters of landfills, in leachates and in the ditches nearby. The primary source of arsenic may also be soil or bedrock, from which landfill effluents can immobilize arsenic.	The acceptability of wastes to be disposed off in landfills is monitored pursuant to the Government decree. Treated (incl. stabilized) soil containing arsenic has been used for landfill structures. Slightly contaminated soil can also be used as a daily cover. The content of arsenic is being monitored on some landfills but generally arsenic is not included in the mandatory inspection by the waste management facilities in Pirkanmaa (Tampere Region). Effluents from landfills are treated.
Ammunition, shot Arsenic is generally found in old rifle ranges, but not in significant quantities compared to lead. Due to the high mobility, arsenic can be risk particularly to groundwater quality.	No specific guidance means regarding arsenic. New and operating shooting ranges should have applied for permits by the end of 2004. The new permits require that the environmental risks are assessed and measures to limit these are adopted.
Pharmaceuticals A wide range of arsenic in historical applications in medication. Till the 1900's arsenic derivatives were used in the treatment of severe diseases such as syphilis, among others. In the medicines service of the National Agency for Medicines 2007 there is one product (Trisenox) which contains arsenic compounds. No information on arsenic derivatives in the effective agents in approved animal medications.	Current arsenic derivatives may be used only under surveillance in treatment provided by a medical specialist (Trisenox, acute leukemia).
Colorants of textiles, paper and paints Arsenic has been included in copper compounds used for producing various shades of green (poison green). In Finland arsenic has been found among others on the land occupied by shipyards and paint shops.	The first limitations date back to the 1800's and they concerned colors used in wallpapers. Alternative methods and chemical have been developed.

The RM actions needed to make the three control mechanisms (1, 2, 3) functional in practice could include, e.g., implementation of restricting policy instruments or economic policy instruments. Along with the legislative instruments, the quality guidelines, standards and other benchmarks have been widely used among the authorities responsible for controlling the risks of harmful substances.

Figure 15 summarizes the essential regulatory instruments and the level of decision making at which some important actions related to arsenic risk management are taken. For instance, the control of exposure to atmospheric arsenic has been implemented at EU level pursuant to the directive on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air (2004/107/EC), enacted also in Finland.

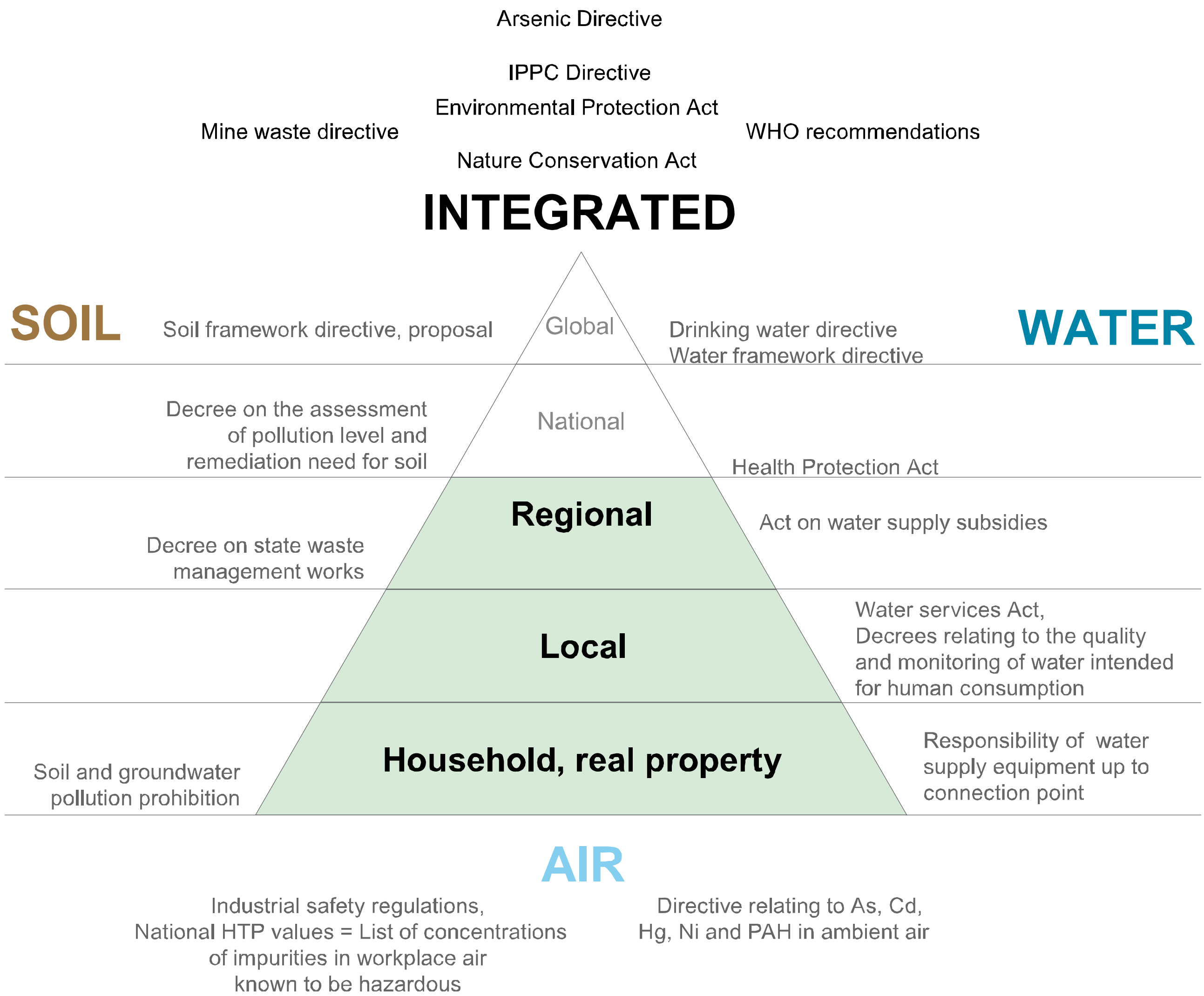


Figure 15. The most important existing regulations and policies to restrict human exposure to arsenic and the different actors involved.

In addition to policy instruments, some informational actions, land use planning and technical means to eliminate exposure or contaminant transport can be useful RM mechanisms. The technical standpoint gains significance when the risk management is aimed to solve well identified problems at a small regional scale, such as the thoroughly investigated contaminated sites. Pollard *et al.* (2004) have also classified RM measures, but their list did not include land use planning. At the regional level, also land use planning may play an important role in a preventive risk management.

Table 13. Some tools for the regional-scale management of arsenic-associated risks.

Risk management measures	Existing mechanism and tools in Finland
Communication • Information reporting, • Stakeholder dialogue, involvement in decisions • Data system development	• Water quality surveys on drilled well water at national and also local level. • Maps produced for, e.g., constructors. • Open, national database for potentially contaminated sites
Education • Internet guides or guidebooks • Training of the key persons • Technical assistance	• Internet pages focused on wells (Environmental administration) • Guides for well owners, e.g. to interpret the water quality analysis • Guides to help to implement the Decree on household water quality and monitoring
Technological intervention • Research basic processes, monitoring • Development of technology to reduce or counter harm	• Studies on the specification of arsenic in different environments • Studies on arsenic in mining environment • Development of adsorption material for arsenic contaminated water
Land use planning • Natural resources • Population • Valuable nature areas	• It is routine to take into account the valuable nature areas and important groundwater resources in the land use planning • There are official markings available for contaminated sites to be used in the master plans and local detailed plans
Market incentives • Pollution levies and charges • Subsidies	• Is possible to channel some national subsidies for developing water supply systems or rehabilitate contaminated sites
Regulation • Environmental standards • Permitting • Product bans • Technology-forcing regulations • Emergency procedures	• Finnish guidelines, standards and other benchmarks for arsenic reported in English (Lehtinen and Sorvari 2006): o domestic water, wash waters in food production, o fodder and fodder additives, o fertilizers and fertilizer preparations, o soil, o sediment to be dumped to marine ecosystem, o waste disposed on a landfill, waste recycled in earth construction, o ambient air, air at workplace
Enforcement • Liability • Compulsory insurance	• Modern legislation steers the liability of investigating and cleaning up a contaminated site (some exceptions)
Cooperation • International collaboration • Interorganizational action • Regulator-polluter dialogue	• Channel the EU funding for the development of the water supply network on natural arsenic anomaly • EU LIFE projects, such as RAMAS or SUMANAS • The development of international criteria, see e.g. WHO Environmental Health Criteria 224: Arsenic and Arsenic Compounds, 2001.

7.1.2 Ensuring a safe water quality

The drinking water directive has been an important instrument in the management of human health risks, although in Finland the standard for healthy drinking water was set to 10 µg As/l already in 1995. If the water is used for washing of food production facilities, the health-based benchmark 20 µg As/l is applied. No guidelines have been issued for arsenic concentration in bathing water[8]. The updated decrees related to the quality and monitoring of water used for human consumption have entered into force few years ago (2000–2001). Even smaller waterworks have now an obligation to monitor the quality of the water they supplied using a wider range of indicators. However, arsenic does not belong to the basic set of these indicators.

[8] A revised Bathing Water Directive (2006/7/EC) has been just recently adopted. The reform reduces the list of regularly monitored pollutants or other parameters to just two microbiological indicators of faecal contamination.

Different sources of financial support have been used to subsidy the expansion of the water supply network on arsenic-rich areas. The Act on state water supply subsidies (2004/986) controls the continuous, but relatively small financial flow to the water supply investments at rural areas and villages. Many investments at the Pirkanmaa As-anomalies would not have come true without this subsidy. The state subsidies (investment or work) can also be used for organizing regional co-operation, securing water supply at special events or preventing the contamination of important surface or groundwater reserves. The state subsidies are coordinated by the regional water supply authorities and municipalities. These coordinators and decision-makers need detailed, spatial data on the geochemistry of the potential water reserves.

There is a new guidance leaflet for the assessment of the quality of household well water, prepared by the "national well team" and Finnish Environment Institute (2007). This guidance presents a trigger value of 1 μg As/l, above which further monitoring is needed. Based on the human health risk assessment and other studies carried out in RAMAS -project, this relatively low trigger value could be justified.

The water framework directive has a wider perspective in the control of water quality. In Finland, arsenic and its compounds were not selected to the list of prioritized harmful substances in surface water. Hence, there are no guidelines for the acceptable arsenic concentration in freshwater ecosystems based on ecological risks.

7.1.3 Management of contaminated sites

The issues concerning contaminated soil or groundwater fall under the Environmental Protection Act (EPA, 86/2000), which came into force in 2000. Before that, problems related to soil contamination were addressed under the waste and waste management legislation. The issues concerning the treatment of contaminated soil and groundwater are aggregated in chapter 12 of the Environmental Protection Act. The central sections in EPA are:

- Soil pollution prohibition (§ 7)
- Groundwater pollution prohibition (§ 8)
- Duty to treat soil and groundwater (§ 75)
- Duty to notify (§ 76)
- Duty to investigate (§ 77)
- Restoration of soil (§ 78)
- Ordering restoration (§ 79)
- Reporting duty concerning a polluted area (§ 104)

The regional environment center can order the party responsible for clean-up to investigate and clean-up the site. The treatment of contaminated soil needs an approval from the environment authority. Usually, the competent permit and control authority is the regional environment centre, but in some cases the local environment authority or the environmental permit authority may also have competence. The approval is given as a decision on the notification or as an environmental permit Targets of the remediation are sustained in the approval.

According to the prohibition of soil pollution issued in the EPA, the contamination of soil is defined on the basis of the effects, and not on the concentration of the harmful substances. Based on the EPA, the Ministry of the Environment recently issued a Government Decree (214/2007) on the assessment of soil contamination and need for remedial actions. This decree emphasizes site-specific risk assessment. There are three categories of soil guideline values - the threshold value and the lower and the upper guideline value. The threshold value indicates negligible environmental risk and it is used as a trigger value. When the threshold value is exceeded, a site-specific assessment of contamination and remediation need has to be carried out. Generally soils with concentrations below the threshold values can be disposed (and utilised) without any further testing. The baseline concentration, however, is regarded as the trigger for the assessment in areas with a baseline concentration higher than the threshold value.

At the same time with the new Decree, a guidance (YM 2007) for the interpretation of the decree was published. The guidance also introduces the basis and background for the development of threshold and guideline values issued in the Decree. The lower guideline value means a concentration of a harmful substance in soil that in normal land use does not pose a significant hazard to soil functions or human health. The lower guideline value of 50 mg As/kg is based on the ecological reference value describing a concentration at which adverse effects can be expected to show up in 50% of the terrestrial species. The upper guideline value (100 mg As/kg) is equivalent to a concentration in which the soil would still remain ecologically viable and which does not pose a significant health risk in insensitive land use. Unless otherwise indicated by the risk assessment, soil is regarded as contaminated if the guideline value is exceeded.

Most of the old sawmills and wood impregnation sites have been registered as potentially contaminated, partly because of the use of diarsenic pentoxide (CCA-chrome-copper-arsenic) impregnates. There are also industrial landfills were the remains of diarsenic pentoxide have been found in Pirkanmaa. Investigation and clean-up of the sites is continuous, but suffers from inadequate funding. In Finland the total expenses of remediation have typically been high on wood impregnation sites (on average 306 000 euros) compared to the other types of contaminating activities (mean 141 000 euros, all remediations). According to the obligatory monitoring set in the remediation permits, the clean-ups have been successful from the viewpoint of restricting the emissions to environment.

7.2 Identified development and study needs

7.2.1 Water supply

In the vicinity of the Tampere city, the problem of arsenic in drilled wells has been acknowledged years ago. There are already mechanisms to reduce human exposure. These mechanisms should be further confirmed and expanded to all municipalities. From the viewpoint of reducing human health risks, the construction of water supply network on arsenic-anomaly areas has been the most important. However some 30 000 – 50 000 inhabitants still reside outside an organized water supply system in the two southern geological belts (TB and PB). Significant part of these inhabitants could be using household water abstracted from well drilled into bedrock. Unfortunately, there is no detailed data available on the distribution of the different types of wells.

It is not always feasible to build extensive water supply systems at rural areas, even though these areas would be characterized by arsenic anomaly. Firstly, the expenses per inhabitant may turn out to be very high at rural areas from which people are moving to population centers. For instance, the maximum connection charge to water supply network for one single house has varied from 1400 to 9802 euros during 2001–2006 in different parts of Pirkanmaa (VELVET-register 2007). In addition to the connection charges, a household has to pay fixed annual charges and expenses based on the water consumption. The proportion of water supply expenses may reach unacceptable levels of the net income for a single household. Longer water pipelines may also cause technical problems due to, e.g., low water flow. There will still be numerous households and small villages that are dependent on their own water source in the near future. These will need advice in reducing evident health risks caused by arsenic-rich drinking water.

A single household is the key stakeholder in the case of purchasing a real estate or applying for a building permit for a new house or for major renovation measures. The drilling of a new well on a clear arsenic-anomaly should always be carefully considered since usually alternative water sources are available. The quality of any well water should always be ensured. The quality check should include arsenic analysis at least in the southern parts of Pirkanmaa. Unfortunately, arsenic is generally not offered in the basic analysis sets. Single sampling will not always ensure the safe level of arsenic in household water since the concentration of arsenic can vary considerably in time.

The local health authorities are the key stakeholders in informing single households about different risk management options. So far, the arsenic removal equipment meant to be used by a single household, have not been very popular in Pirkanmaa. However, their technical development is promising. In the future, guidance will be needed in order to get suitable equipment (price, efficiency, ease of use) to Finnish market. The pilot test for the removal of arsenic carried out in RAMAS showed that the drilled well water could quite easily be cleaned if the concentrations are below 50 µg As/l or even below 100 µg As/l (Backman *et al.* 2007a).

7.2.2 Management of sites and wastes with anthropogenic or natural arsenic

The survey carried out in RAMAS -project confirmed that the major sources of anthropogenic arsenic are well known in Finland and their risk management is established. The closed mine sites have not been studied with the similar intensity than the wood impregnation sites in Pirkanmaa region or other parts of Finland. Here, RAMAS -project was able to produce valuable additional information. Yet, uncertainties still remain concerning the significance of some source-route-dose-response chains, such as old landfills or the quarrying sites on the natural arsenic-anomaly areas. Therefore, further studies are needed.

Owing to the naturally occurring arsenic above the threshold value (5 mg As/kg), the interpretation of the new soil guideline values issued in the Government Decree will not be easy in the southern parts of Pirkanmaa region. A more detailed regional survey for the setting of baseline for arsenic should be considered. It is noteworthy, that the soil threshold value is mainly based on the potential risk of groundwater contamination taking also into account the range of baseline concentrations of arsenic in the Finnish soil. The studies of vertical soil profiles conducted in RAMAS also showed that even the guideline value for arsenic was exceeded in the deeper layers of soil. The deepest soil profile samples were taken from the depth of 3.8 m where the maximum concentrations were 60 – 80 mg As/kg. However, most of the arsenic was in non-soluble form (Backman *et al*. 2007b).

The bioavailability and toxicity of arsenic in the soils taken from the natural arsenic-anomaly remained somewhat unclear. The study material was inadequate in order to find out the difference between the bioavailability of naturally occurring arsenic and anthropogenic arsenic. Hence, it would be worthwhile to conduct some further studies on this issue. The internal variation of the responses in the toxicological tests was very high (Sorvari *et al.* 2007). Therefore, it is not convenient to draw any conclusions that could directly be used in the decision making concerning e.g., remediation activities to restrict ecological risks.

It came up that the arsenic analysis were rather uncommon in the case of obligatory monitoring programmes of waste management plants and non-existent in the case of quarrying activities or landfills for inert waste. The preliminary investigations of the surface waters adjacent to municipal landfills and quarrying sites indicated a need to reconsider some monitoring obligations. More detailed research on these sites is also recommended.

The risk management needs and targets at contaminated sites are governed by the future land use plans. Extensive soil excavation and treatment off site is undoubtedly the most efficient way to eliminate arsenic-related risks at the site as well as future liabilities.

The *in situ* remediation of soil contaminated by metals or metalloids is still uncommon in Finland. Some solidifications/stabilizations have been carried out in the cases of soils polluted with a mixture of contaminants, including arsenic. The capability of arsenic to form relatively stabile compounds with ferrous material or manganese could be utilized more effectively particularly at sites where contamination is extensive e.g., at mine sites and their tailings areas.

There are no remediation strategies readily available in Finland for water ecosystems contaminated with arsenic. Arsenic contents have been monitored in the vicinity of some points sources, but there has not been any active clean-up measures yet (one treatment with sulfidizing bacteria has been permitted). The RAMAS project included a small pilot test for arsenic removal from surface water running from a tailings area. The treatment unit did not operate satisfactory (Backman *et al.* 2007a). It is clear that the removal of arsenic from highly contaminated surface water lays a great challenge to technical development.

Because the removal of arsenic from surface water is very demanding, we recommend to consider using other risk management strategy. Nearby the Ylöjärvi mine site the nutrient rich ditches and lakes were found to be able to retain significant quantities of arsenic (Bilaletdin *et al.* 2007). Also the *sphagnum*-mires are known to accumulate some arsenic (Carson *et al.* 2002, Ukonmaanaho *et al.* 2004). These natural processes of storing and binding arsenic compounds need more attention.

7.2.3 Management of former wood impregnation sites

The CCA-plant sites studied in RAMAS were quite small and the land was partly covered by dense vegetation. It is quite impossible for an occasional visitor to recognize the contamination in such area. Meanwhile further investigations are carried out to gather additional data for the planning of possible active clean-up measures; we recommend that these sites are clearly marked on site.

It is noteworthy, that the maximum soluble arsenic concentration measured (28.4 mg/kg, L/S=10) in the soil samples of one of the study sites exceeded even the threshold value (25 mg/kg, L/S=10) for the acceptance of a waste to be disposed off on a landfill for hazardous waste (Parviainen *et al.* 2006). Hence, there might be significant emissions through leachates. Some of the former impregnation plants are located on important groundwater areas (class I). At such areas it is important to acknowledge the risks to groundwater quality. Sufficient monitoring of surface and ground waters should be established at all the known sites and the extent and the level of contamination should be defined.

7.2.4 Control of risks at former mine sites

At present, all mines in Pirkanmaa with the exception of the Orivesi gold mine are closed. It is also possible that some of the gold prospects may be exploited in the future. The main contaminant in the surroundings of Ylöjärvi mine site is arsenic, in some extent also copper. The Viljakkala site has also been identified as a source of other metals and metalloids than arsenic. The tailings areas cover about 19 ha in Viljakkala and 17–20 ha in Ylöjärvi. Part of the tailings areas, the open pit and the underground galleries in Ylöjärvi are at present covered by the Lake Parosjärvi. The closed Ylöjärvi mine, tailings and even some surrounding land areas have been own by the state since the Outokumpu Oy sold the area, after the mine was exhausted in 1966. The territory is divided into several pieces of real estate The National Board of Forestry has been assigned to act as a property owner on these real estates.

During the year 2007 the property owners of all identified contaminated sites, such as the closed mines site in Ylöjärvi or Viljakkala received a letter for the collection of information on their real estates, the data was to be included in the national database. The inquiry also acted as a reminder of the liabilities and duties concerning land contamination. Another reminder of the problems connected with mining waste is provided through the national implementation of mine waste directive (2006/21/EC). The article 20 of this directive aims at to ensure that a national inventory of closed, including abandoned, waste facilities is drawn up in order to identify those areas which cause serious negative environmental impacts or have the potential of becoming a serious threat to human health or the environment in the medium or short term. These inventories should provide a basis for an appropriate programme of measures. The dead line for the execution of the inventories is May 1st, 2012.

A major change in stakeholder involvement has to take place before any large scale remediation on land areas or arsenic removal from the surface water can be started in Ylöjärvi since so far the general public has shown very little interest towards the contamination of their living environment (Pentti Keskitalo, local environmental officer, personal communication June 25, 2007). The risk management appears to have been only in the interest of researchers and local environmental officers. The high concentrations of metals and arsenic in the lake Parosjärvi and downward flowing streams are well-known among the local environmental officers. Regardless of this, there is a swimming school on the Lake Parosjärvi in summertime and there are also some residential areas along the contaminated river and smaller lakes. In land use planning, for instance, no attention has been paid on the contamination in the vicinity of the Ylöjärvi mine area. The master plan 2002 for villages and rural areas in Takamaa borders on state territory, but did not include any comments on this neighbouring area. In the regional plan the whole area is designated to the Defense Forces and the area is controlled by the Technical Research Centre of the Defense Forces. The access to the site is restricted (a separate permit is needed).

The application of the Environmental Protection Act may require exceptions because of the special nature of the activities practiced at the mine site (Defense Forces). The Defense Forces has a newly amended environmental permit for the activities of the Technical Research Centre, such as shooting ranges and storing of liquid fuels. The potential activities on old tailings or contaminated water system were not included in the permit procedure. It is known that the tailings area is used for exploding e.g. outdated pyrotechnical material. These explosions cause significant dust emissions.

The contaminated surface waters running down from Ylöjärvi mine site to the lake Näsijärvi have been taken into consideration in the statutory monitoring programme of the waste water treatment plant of the research centre. This plant lies some 300 meters down the creek running from the lake

Parosjärvi down to the lake Näsijärvi, but the creek water is not taken into the treatment plant process. There is arsenic monitoring data available since year 1976 and the yearly monitoring is still going on. The summaries of the monitoring results are available in the internet[9]. Moreover, the local environmental office also reports regularly on the state of the surface waters within its area.

Some additional sampling and modeling were carried out in Ylöjärvi within RAMAS project in order to investigate the potential for long-term environmental effects in the surroundings of the mining areas. The surface waters and sediments were on focus. Also some dust samples were taken from the tailings area. The studies at the water system indicated that contamination of the adjacent surface water systems and the transport of arsenic are still continuing. The Finnish quality standard for drinking water (10 µg arsenic/l) overruns in the whole, roughly seven kilometers route from the mining area (Lake Parosjärvi) to Lake Näsijärvi (see Fig. 16). The earlier studies revealed that the contaminants from tailings, including arsenic compounds, are also slowly migrating to the neighbouring marsh areas and the Lake Saarijärvi (Carson *et al.* 2002). No ecological studies or chemical analyses were yet realized in the surrounding land areas of the identified contaminated receptors. The risk assessments showed that the ecological risks are evident on the tailings area and at least moderate in the nearby water system. These results confirm the need for enhancement of the remediation procedure.

Figure 16. The location of the water sampling points in the water ecosystem initiating from the closed mine site and tailings in Ylöjärvi municipality. The marked blue route is about 7 km long. The tailings are marked in the map with a closed mine symbol and the Lake Parosjärvi is situated on the former mine galleries. The darker spots or squares are residential houses.

At the Ylöjärvi mine site, it could be worthwhile to establish different zones on which the risk management actions would be focused. At the core zone contamination would then be acceptable and the land use would be heavily restricted in order to eliminate exposure. At present, the only clear signs of remediation measures in Ylöjärvi are visible on the tailings area. Part of the edges of tailings has been covered with surplus soil masses exported from various construction works. There is a more intense vegetative cover on these surplus soils than on the hard tailings material. The impact of these coverings on the flows of contaminants has not been studied. The creek running

[9] http://www.kvvy.fi/cgi-bin/tietosivu_ylojarvi.pl?sivu=paasivu.html

from the tailings to the Lake Parosjärvi has also been limed. This is expected to promote the generation of ferrous precipitates which in turn, are able to bind arsenic from the water. However, according to the studies of Carson *et al.* (2002) liming is an inadequate remedial action. Their recommendations focused on finding solutions for arsenic removal from waters.

The problem of finding feasible removal methods for waters heavily contaminated by arsenic was also evident according to the environmental permits in 2000–2005 concerning operating mines and their waste areas in Finland. Mondo Minerals used ferric sulphate for the precipitation of arsenic in tailings pond in Lipasvaara, Polvijärvi. No other methods were mentioned in the permit documents (Lehtinen & Sorvari 2006).

In Viljakkala, ore exploration is active around the Haveri Au-Cu deposit. The other important actor is the Viljakkala municipality, which owns the land area. Because this site is situated in the vicinity of a village center, also the inhabitants of the village are important stakeholders. There are plans to convert the area into a museum and recreation area. Therefore, a risk assessment was performed by a consultant in 2004, excluding the open pit and tailings. According to the risk assessment, the top-soil contained unacceptable concentrations of arsenic, among others, but the overall health risks were estimated to be minor for people who do not reside long periods of time on the area. The assessment did not include very detailed information about the spatial extent of the contamination and further investigations were therefore recommended. Some remediation and additional groundwater monitoring was recommended on the contaminated land areas. The consultant proposed as a minimum risk management action to cover areas for open public usage, in order to prevent further dusting. The areas that will not be remediated should be banned from open access.

The tailings area at Haveri is now partly covered with soil and asphalt in order to restrict dusting caused by, e.g. motocross practiced on the area. The investigations of these tailings were started along with the RAMAS project. In addition some studies on the surrounding environment were conducted. The main source of continuous contamination from the mine sites is the tailings area and in Ylöjärvi also the dammed Lake Parosjärvi. The control over the water courses on these areas is essential as well as awareness of the geochemical conditions. Reactive walls or dams have preliminary been assessed as unsuitable for the water courses running downstream from the Ylöjärvi mine site.

Tailing areas are far too wide to be remediated with conventional methods, such as dig and dump. An American review (Bowell & Parshley 2003) on arsenic cycling in the mining environment concludes that there are usually four main approaches to solve arsenic contamination at the very end of the arsenic cycle:

- Physical stabilization on controlled site with sealed structures, such as on modern landfills
- Chemical stabilization with ferrous compounds or polymers, pH adjustment needed.
- Solidification in cement, ashes or silicon materials
- Chemical treatment of waters in order to reproduce products for sale.

The latter-mentioned alternative is questionable since the need for arsenic containing products is diminishing, at least in Finland and other EC countries. Arsenic has been used most extensively in wood impregnation, but such products are now banned. The *in situ* immobilization of arsenic in surface soil and tailings is one possible approach. This method can be implemented by using, e.g., amendments and/or uncontaminated soil. In addition, vegetation can be used to enhance immobilization and to restrict leaching and surface runoff.

In the review of suitable amendments for immobilization of certain metals and metalloids, Kumpiene *et al.* (2007) concluded that oxides of iron and manganese are the most efficient amendments for arsenic. In addition, clay and organic matter may be satisfactory whereas phosphorous or alkaline materials should be avoided. Organic matter had the most varying impact on the mobility of trace elements and chromium often responded in a similar way than arsenic. Results concerning copper, zinc and lead varied implying to difficulties in the remediation of media including mixtures of, e.g. copper and arsenic.

7.2.5 Control of exploitation and disposal of mineral materials

At present, there are no restrictions for the use of virgin rock material or soil originating from non-contaminated areas in earth construction. However, in Pirkanmaa region the extracted rock material may contain high concentrations of arsenic pyrite and high concentrations have also been detected particularly in deeper layer of till. Arsenic mineral in rock material deteriorates the quality of construction material and it can also become a source of contamination.

On the contrary to virgin rock material or soil, at present some waste materials used as secondary aggregates are controlled on the basis of statutory quality guidelines. These guidelines have been derived from the quality standards issued for wastes to be disposed off in landfills and they are assumed to protect groundwater quality from exceeding the quality standards of drinking water issued by the European Union. The composition standard for arsenic is 50 mg/kg and solubility standard 0.5 mg/kg or 1.5 mg/kg (Government Decree, VNA 591/2006). The higher solubility standard refers to paved structures. Some inconclusive guidance on the reuse of soil from contaminated sites has been issued along with the Government decree concerning the assessment and remediation of sites (VNA 214/2007). The origin of the mineral aggregates from areas not classified as potentially contaminated and its effect on the environmental suitability was taken up in the discussions already in the end of 1990s' during the preparation of the environmental criteria for secondary aggregates[10]. It is important that this subject is reconsidered and more detailed instructions are issued for the materials originating particularly from As-anomaly areas.

Technically unsuitable surplus soil from construction sites is normally disposed off in specific disposal sites designed for harmless material. These sites do not have any obligation to monitor possible emissions while at the same time, the requirements set for the structures of other types of landfills do not apply. Since arsenic-rich material can be mixed with other materials with e.g., a low pH, it is possible that the immobilization of arsenic is promoted. Therefore, it would be worthwhile to study the potential environmental releases to ensure the proper management of surplus soils and materials.

The environmental risks of the exploitation of bedrock are mainly controlled by the environmental permit procedure. Either regional of municipal environmental authorities handle the permits and decide about the monitoring programs. These permits have so far not included requirements to monitor arsenic. The few samplings from the surface waters in the vicinity of a quarrying site proved that there may be a need for monitoring. The control of the risks of ore prospecting or active mining can be more complicated, including, e.g., the EIA (environmental impact assessment) process or actions defined in the Mining Act (KaivosL 503/1965).

[10] Observation of J. Sorvari, who was in charge for the preparation of these environmental criteria during 1998-2000.

7.2.6 Regional planning and control of construction activities

The arsenic issue was not included in the preparation of the current regional water supply plan (PREC 2006). Still, the risk for arsenic exposure through drinking water is mentioned in many municipal water supply plans. In the forthcoming planning process, the produced arsenic risk maps should be made available to the stakeholders and they should also be connected to the other arsenic analysis data available in municipalities.

The anthropogenic sources of contamination are quite well documented in the new national database for contaminated site. In the case of large contaminated territories, the spatial data of contamination is often not presentable. For instance, the contaminated mine sites which were studied in RAMAS project, are documented in the national database with a small dot in a map. No information is available of the extension of the contamination. We recommend that the investigated sites, such as the contaminated waterways, are documented in the local and master plans with relevant markings, offered by the Ministry of Environment 2000-2001. Notice of the health and ecological risks can be added to the marked areas.

Until more knowledge is gained on the arsenic deposits in the vegetation and sediments, no dredging is recommended in the water ecosystem originating from the Ylöjärvi Cu-W-As mine and tailings.

7.2.7 General development needs

The identified general developments needs in the risk management of arsenic are mostly related to risk communication and guidance targeted to stakeholders. The concentration of arsenic in drilled well water is very difficult to predict in detail. Even adjacent wells may have very different arsenic levels and most wells in the risk area are safe. In addition, there is evidence that the major changes in the water consumption are reflected in the quality of the water (see Backman *et al*. 2006). In the case of arsenic and some other harmful elements chemical analyses is the only way to assess the safety of the drinking water. Therefore, major efforts should be taken to increase the awareness of the possible quality problems among the well-owners and the local authorities.

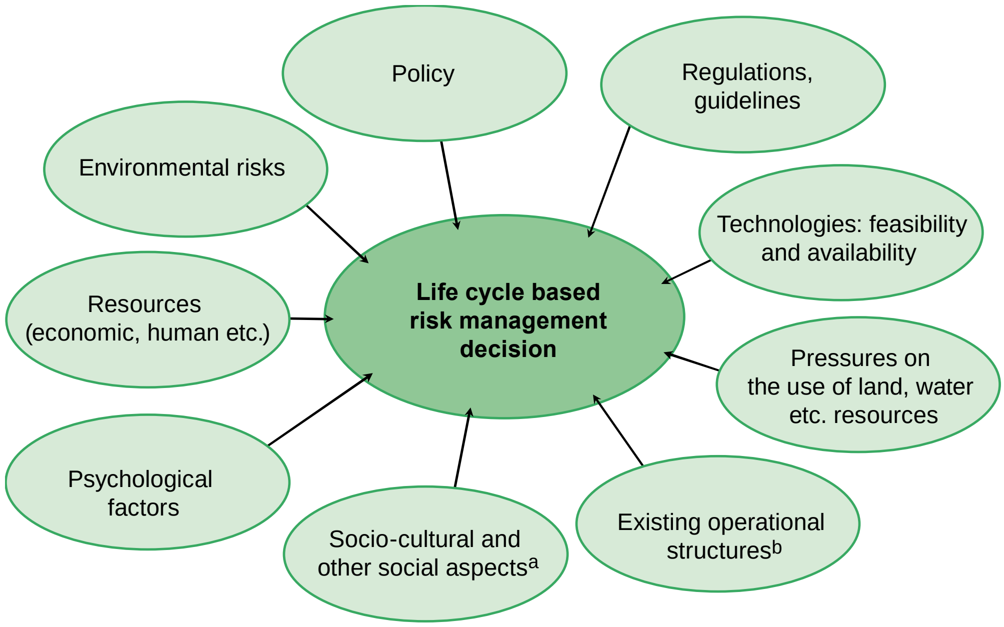
We also suggest establishing a register on drilled wells following the example of other Nordic countries. The register should include the information on water quality. However, first the problems associated with the protection of privacy, concerning for example the well water data, should be solved. The process of building the existing, open national database for potentially contaminated sited could serve as a model to be followed.

One development need is the increased serviceability of geochemical databases. There is a growing demand for regional baseline surveys of soils and groundwater. The GIS-based mapping of water supply systems with geochemical risk maps inspired the stakeholders in water supply planning. However, the spatial scale of the input data was still quite coarse. Consequently, the usability of the maps is somewhat restricted.

8 Discussion

8.1 Multidimensionality of decision making

Since risk management is based on the information on risks, risk assessment process is a vital element in the decision making on RM actions. However, there are several other additional components, i.e., decision criteria, involved. Above all, risk management (RM) as a procedure, should also involve social, cultural, ethical, political, and legal considerations (Fig 17). Unfortunately, it was not possible to study the importance of the different factors involved in RM decision-making within our RAMAS –project. Such study assumes detailed data on the available methods, their costs and other resource needs, on socio-cultural factors involved etc. Such detailed feasibility analysis was out of the scope of RAMAS.



[a] e.g. employment, image and valuation aspects, attractivity of the area
[b] e.g. administrative practices and responsibilities, ownerships

Figure 17. The elements influencing RM decisions in environmental and human health issues.

At the end, the decision-making on RM actions requires balancing between the different factors involved. Normally this assumes the acceptance of the fact that the "zero risk level" cannot be reached. Feasibility of RM actions, which is often straightforwardly related to the costs, is often the main reason to allow different risk levels. On the other hand, owing to the various uncertainties involved in risk assessment, in environmental policy it is customary to follow so called precautionary principle. The level of the precautionary principle and hence, the extent and form of risk management actions, are governed by many factors, the magnitude of risks being only one of these.

A group of Canadian risk experts (Jardine *et al.* 2003) have analyzed a wide group of risk management frameworks defined for human health risks and environmental risks. They concluded that risk should be understood as a multidimensional concept that must include the perspectives of those affected. Jardine *et al.* defined the objectives of risk management to ensure that significant risks are identified and that appropriate action is taken to manage these risks to the extent that is reasonably achievable. Appropriate actions were determined on the basis of the balance between risk treatment strategies; their effectiveness and cost; and needs, issues, and concerns of stakeholders. Jardine *et al*. stressed the importance of stakeholder involvement in all steps of the RM procedure to evaluate the significance of the risks and the appropriateness of the management actions. The flexibility of the procedure was also emphasized (Fig 18).

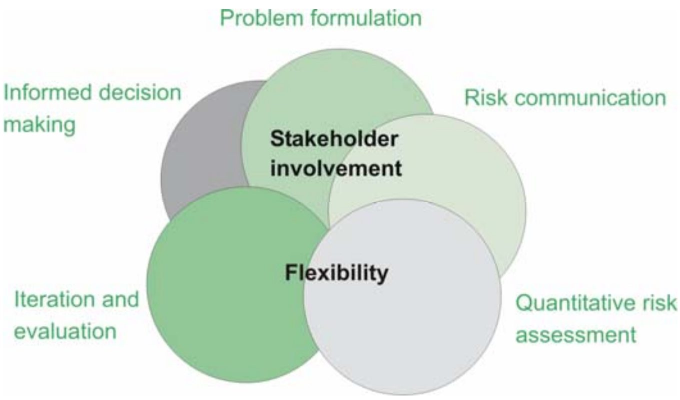


Figure 18. Seven key elements of the comprehensive framework for the assessment and management of human health risks and ecological risks (Jardine *et al.* 2003).

Active risk communication promotes participation and transparency in decision making. In our study area, Pirkanmaa, the awareness of the relatively high arsenic concentrations in drilled well waters was already on a quite high level. Still, particularly the release of the results from the epidemiological study on cancer incidences aroused public interest. The RAMAS project aimed to emphasize the positive actions that have already taken place in Pirkanmaa in order to manage the known health risks.

Multidimensionality and the endeavor to participatory decision making brings challenges owing to the variety in risk perceptions and knowledge level of participating stakeholders (see also section 8.2). Since in RAMAS, the relevant stakeholders were only identified after the completion of the RM task Phase 1, it was not possible to involve all of these in the RM process right from the beginning. We also acknowledge that it would have been worthwhile to include some important stakeholder groups more tightly in the realization of the RM task. Such stakeholders include particularly health authorities, the involvement of which could have been ensured e.g., by participation in the project steering group. On the other hand, it needs to be stressed that being an EU-LIFE project, the focus of RAMAS was to be on the ecological issues.

As the Jardine *et al*. 2003 emphasized the risk management solutions are seldom permanent and they should include some flexibility. Our environment changes and along with it the policies and risk management targets change. Hence, in the future, there might be a need to focus the efforts on other issues instead of ground water. For example, at present, the renewal of Mining Act and nomination of a list of prioritized substances in ground waters based on ecological risks are ongoing. These regulations may well change the direction of risk management actions towards the protection of other receptors than humans.

8.2 Uncertainties and valuation aspects concerning risks

Perhaps the most problematic issue in the risk management of arsenic is the uncertainty concerning the toxicity. The literature survey conducted in the beginning of the risk assessment task revealed that the results from the health studies are partly controversial (see Sorvari *et al.* 2007). The main problem in RAMAS health risk assessment was the evaluation of possible health effects at low doses. The acceptable daily doses which are assumed to represent the safe doses for human intake, and are issued by different organizations vary significantly implying the uncertainty of the dose-response estimates. The differences mainly arise from different safety factors applied in the derivation of the safe dose estimates. The estimation of adverse effects on biota and ecosystem functions is based on even more uncertain data mainly owing to the scarcity of toxicity data and the diversity among species. These uncertainties have a considerable impact on the dimensioning of the risk management measures, and hence on the allocation of resources to realize the measures. Consequently, depending on the data selected for the characterization of risks, the risk management actions may be either under or over dimensioned.

It seems that very often the priority is given to the minimization of risks which are related to severe effects with low probability whereas higher risk levels can be accepted in the case of moderate effects with high probability. In the case of arsenic, as in the case of many other substances, carcinogenicity has been the main concern in the protection of human health while less attention has generally been paid to other adverse health effects. This is undoubtedly greatly due to the lack of data.

The stakeholder involvement during this RAMAS demonstration project showed, e.g., that the human health effects and their regional extent, especially the risk of cancer, draws the greatest attention in arsenic issue. We were approached by some residents of Pirkanmaa who were concerned about arsenic contamination. Their questions handled either the safe options of water supply or the plans to build a power plant which would burn impregnated wood waste. If only the ecological risks were assessed to be significant, as in the case of the polluted mine area in Ylöjärvi, no major concern could be observed. Therefore, we can conclude that there is currently no social pressure to start active remediation at this particular mine site. However, it is noteworthy that the inhabitants of the nearby villages did not take part in the RAMAS stakeholder events.

Voluntarity is an important aspect when risk management actions are considered. It is evident that some people are more willing to take higher risks than others. In RAMAS project this emerged in single cases in which households preferred to use their ground water well despite the knowledge of high levels of arsenic. In such cases it is important to ascertain that the stakeholders really understand the consequences of their voluntary decision.

Valuation aspects are also clearly reflected in the society-level decision making and risk management. Traditionally, as also in the case of arsenic, the main focus has been on the protection of human health and hence, in the case of environmental arsenic, most efforts have been directed to the elimination of ground water related arsenic risks to residents while little attention has been paid to the protection of other receptors.

It is also noteworthy, that on national level the acceptable risk levels associated with environmental contaminants have not been clearly defined for the functioning and diversity of ecosystems. In the case of contaminated sites, the acceptable levels (covering both health and ecological risks) have for the first time been established in the guidance associated with the new Government decree (214/2007). Due to the novelty of the Decree and the guidance, the effects of these acceptable levels on risk management remains to be seen. Notice that they do not have a statutory status.

9 Risk management in other regions

9.1 Evaluation of the RAMAS risk management procedure and methods

The risk management procedure we conducted in RAMAS was based on the working plan set up in the beginning of the project. The first phase was focused on a generic survey on available and existing risk management actions while in Phase 2, the regional aspect was stressed (see section 3.1 and Fig. 1). Due to the nature of the project – EU-LIFE funded demonstration project - the allocation of resources was also predetermined which evidently diminished the flexibility of the process. Moreover, owing to practical reasons mainly related to project management, the risk assessment process was conducted within a separate task. In practice risk management and risk assessment are - and they should be – tightly linked with each other. Hence, in practice, risk management is a stepwise process (Fig 19). The major asset of the combined and stepwise risk assessment and management procedure is that it allows optimization and reasonable allocation of resources.

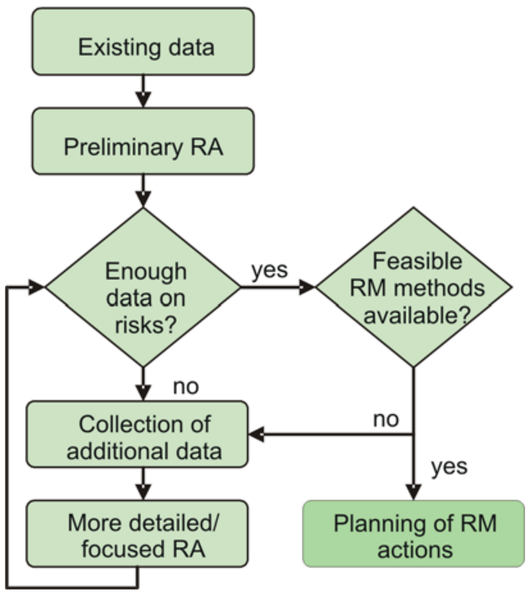


Figure 19. Generic description of a risk management procedure associated with environmental contamination. RA = risk assessment, RM = risk management

The aim of RAMAS risk management task was to cover the whole Pirkanmaa study area. This meant that the risk management had to be kept in a very generic level and hence, it was not possible to give very detailed site-specific recommendations although the risks were assessed site-specifically. Such recommendations also assume detailed information on the feasibility of different RM alternatives, the evaluation of which is based on various decision criteria (see section 8.1). This assumes also involvement of various stakeholders. On the other hand, moving from the mainly site-specific risk assessment to regional risk management proved to be challenging. Here, the geographical tools proved to be very helpful and a practical way to illustrate regional-level risks. Maps also provide a good tool to communicate on risks to different stakeholders. However, there are some difficulties involved in the development of risk maps, the protection of privacy being perhaps the most important. Hence, it is not possible to present very detailed data e.g., cancer incidence maps. There is also always the risk of misinterpretation, which needs to be carefully considered in the planning and presentation of risk maps.

Overall, it is not possible to judge the general 'goodness' of the risk management process since there are no steady criteria for a 'good' RM process other than those very general once mentioned above (i.e., connection with risk assessment process, participatory practices). Otherwise, different criteria can be used to define the 'goodness' of a RM process. Such criteria can include e.g., economic aspects ('the cheaper the better'), time aspects ('the quicker the better') or level of consensus reached in decision making. Now, when we have examined all the potential RM mechanisms for the restriction of arsenic-related risks, it is time to evaluate and develop local and regional policies and risk management procedures. Here, it is important to consider if all available tools to manage the risks originating from the environmental arsenic have been implemented and how efficiently the existing instruments are in fact applied.

9.2 Applicability of the results in other regions in Finland

Originally Pirkanmaa was selected as the study area in RAMAS due to the known arsenic anomaly. There was also quite a lot of data available on the levels of arsenic in ground water. However, there are several other arsenic anomaly areas in Finland which deserve attention (Fig. 20).

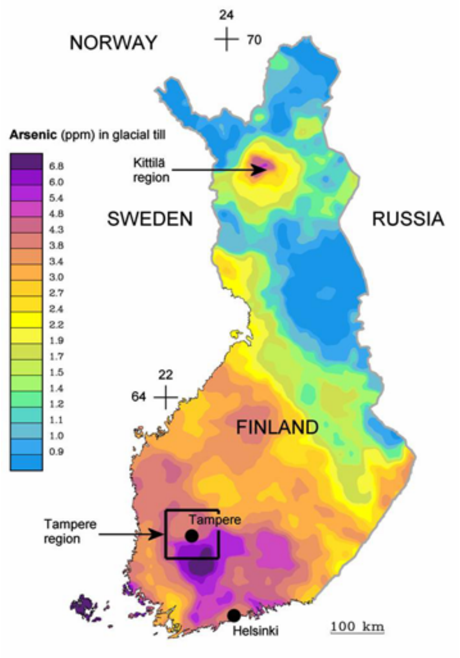


Figure 20. Identified arsenic anomaly areas in Finland.

There might be some differences between the anomaly areas in Pirkanmaa and other parts of the country which may reduce the applicability of the results from our study. Such differing factors may include population density and distribution and environmental conditions. However, Pirkanmaa covers a wide area with very different characteristics. Pirkanmaa represents a typical area in southern part of Finland. Missing characteristics in Pirkanmaa is a coastline with Baltic Sea. Near the coastline the quality of the water resources can be influences by the brackish sea water. There the equipment suitable for water desalination may also be used for the removal of arsenic.

In Finland, there are no separate regional laws or regulations hence, the national legislation should be adopted similarly all around the country. The arsenic anomaly extends to the neighbouring regions of Pirkanmaa. Similar risk assessment and management procedure could be adopted there, but less data on arsenic concentrations and forms is readily available.

The anthropogenic sources of arsenic may vary in the other regions, but CCA-treatment plants are found almost all over Finland. There are 59 wood impregnation sites in the national database which have been registered to need investigations or remediation. The CCA chemical has been widely used on them. The closed mining sites are not as well documented in the national database than the wood impregnation sites. There are total of 72 mining sites in the database and out of them circa 32 are metal or metalloid sites.

9.3 Applicability of the results in other countries

Many other countries share the problem of arsenic anomalies and have areas polluted by anthropogenic arsenic, see, e.g. Kinniburgh & Smedley 2001: Figure 2.1 Documented cases of arsenic problems in groundwater related to natural contamination. Cases include some of the major mining and geothermal occurrences reported in the literature[11]. Kinniburgh & Smedley divide the problematic areas by the type of environment under which they are developed:

1. Reducing environments
2. Arid oxidizing environments
3. Mixed oxidizing end reducing environments
4. Geothermal sources
5. Arsenic mineralization and mining-related problems

The natural environmental contamination of the groundwater is mainly developed in Pirkanmaa region in type 3 environment. The concentrations of arsenic are generally rather low compared with many other countries, hence it easier to find feasible risk management methods such as arsenic removal equipments. There are some also mining-related problems and other anthropogenic sources of arsenic. Similar types of arsenic anomalies are found at least in the United States, Canada and Sweden.

The mean annual temperature is about 5.5°C in southwestern Finland, decreasing towards the northeast. In winter, the mean temperature remains below 0°C. Winter usually begins during November. In summer, the mean daily temperature is consistently above 10°C. The relatively short growth season has an effect on the selection of microbes and vegetation. For instance, Finnish plants are not expected to accumulate soil arsenic in significant extent, excluding some mushrooms.

In addition to geochemical or climate conditions also other conditions may vary and hence, the results of our study are not straightforwardly applicable. The major differences arise from the:

- **Environmental policy**: Finland still has a lot of natural resources and nature and hence, there is seldom a true pressure for remediation on the basis of risks at former industrial sites
- **Land use and distribution of activities**: Finland is mainly rather sparsely populated and there is no pressure to change e.g., former mining sites to more sensitive land use (particularly residential areas, nature reserves), adjacent to population centers however, the situation is different and e.g., former CCA-treatment plants have been turned into residential areas. The contaminated sites are mainly rather small and distributed on a wide area in Finland. That is why it is difficult to find cost-effective remediation techniques. The number of landfills and requirements for them to receive contaminated material also affects the treatment options. Also the population distribution pattern can be highly scattered over a wide area. Again, the cost-effectiveness of the water supply system can be difficult to achieve.

[11] http://www.bgs.ac.uk/arsenic/bangladesh/reports.htm > 2 Arsenic in groundwater across the world

- **Legislation**: within EU, the framework of environmental legislation is the same but there are several specific national regulations concerning e.g., contaminated sites or reuse of wastes
- **Administrative structure and the duties, stakeholders involved**
- **Water resources**: Finnish groundwater areas are typically small but vulnerable to anthropogenic sources, however the resources are ample and hence, there is often an alternative source available for potable water. In Finland most of the household water is taken from surface waters which are normally readily available while in some countries with As anomaly problem, groundwater is often the only source (e.g., Hungary, Romania).
- **Standard of living**: Standard of living is on the average high which implies a high nutritional status compared with some development countries with arsenic problem (e.g., Bangladesh); hence the health risks are expected to be lower.
- **Availability of resources** (money): the available resources to manage As-related risks are more abundant compared e.g., with developing countries.
- **The 'remediation market'**: the arsenic contaminated sites in Finland are typically small and low in number, hence there is not a true market for different technical remediation and cleaning methods availability, hence the availability of alternative, cost-effective remediation techniques is low.

Because the risk management of arsenic problem requires both short-term and long-term solutions, Mahimairaja *et al.* 2005 have suggested that the risk management strategies should be aimed at multiscalar levels. They have studied arsenic contamination and its risk management in complex environmental settings. This study group holds positions in India, New Zealand and South Carolina, U.S.A, where environmental conditions differ greatly from the northern Europe. Still, their model for multiscalar risk management for arsenic-contaminated soil and aquatic ecosystems approved to be useful. Along with the growth of the spatial scale of the arsenic contamination grows also the need for long-term solutions and legislative backup for the actions.

The idea of a multiscalar risk management strategy was adapted to act as a structure for the evaluation of existing RM measures for arsenic in Pirkanmaa region (see figures 14 and 15). These multiscalar models can easily be further developed for the use of general planning in other regions around the world. For instance, Pirkanmaa multiscalar model does not include range lands, floodplains, irrigation or waste water streams, because these have not been identified as potential sources of arsenic in Finland. On the other hand two components were added: air and integrated risk management.

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Appendix I

The current status of the people who have connection to a registered waterworks was estimated with two different approaches using public registers and GIS analysis. The first approach was to use data saved to the database VELVET for waterworks. In principal the data about the people that have joined the registered waterworks should be saved to VELVET, but several shortcomings was found in the dataset. These data were roughly filled with a help of water supply officer from the PREC. This method does not take into account people who resign the waterworks contract, and thus overestimates the number of joined people by 5 - 6 %.

The waterworks registered area of the operation has not been digitized yet. That is why the data about the people without organized water supply was located with visual estimation inside the borders of the municipalities and geological belts. With this approach the population without organized water supply was estimated to be some 59 000 in whole Pirkanmaa and some 47 000 in southern risk areas.

The other approach was based on digitized main water network and spatial community structure data. The densely populated areas were proposed to have public water supply and the rural areas were proposed not to have organized water supply (34 519 inhabitants). The villages which have organized water supply were estimated with a GIS analysis. The villages that intersected the pipelines (with 200 meter buffer) or the densely populated areas (100 meter buffer) were proposed to have organized water supply, leaving out in all 171 villages and 8 651 inhabitants. With this approach the population without organized water supply was estimated to be some 43 000. This approach underestimates the total number of people using their own wells, because it is known that not all people have joined the waterworks inside the densely populated areas. It is possible that in larger cities (population >50 000) around 5-15 % of inhabitants use their own wells for water supply.

At least six types of households at risk can be identified. The households are situated
1. in an area of operation of a water supply plant, but have been granted an exemption from the connecting obligation (Water supply plant means plant which manages the water services of a community).
2. or in a neighbouring area of a densely-populated area with a water supply network or
3. in a separate village where only part of the properties are connected to water supply network or
4. in a separate village with a planned connection to water supply network or
5. in a separate village with no plans to develop water supply network or

in a rural, very sparsely populated area.

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The project will produce a number of Technical Reports. The following reports have been published:

1. Natural Occurrence of Arsenic in the Pirkanmaa Region in Finland
2. Anthropogenic Arsenic Sources in the Pirkanmaa Region in Finland
3. Arseenista aiheutuvien riskien hallinta Pirkanmaalla – Esiselvitys ohjaus keinoista ja teknisistä menetelmistä riskien vähentämiseksi (Management of arsenic risks in the Pirkanmaa region – Survey of available risk management instruments and tools)
4. Arsenic and other elements in agro-ecosystems in Finland and particularly in the Pirkanmaa region
5. A transport model of arsenic for surface waters - an application in Finland
6. Arsenic Ecotoxicity in Soils
7. Arsenic removal from groundwater and surface water - Field tests in the Pirkanmaa Region, Finland
8. Risk Assessment of Natural and Anthropogenic Arsenic in the Pirkanmaa Region, Finland
9. Risk Management of Environmental Arsenic in Finnish Conditions - case Pirkanmaa region

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