Assessment of information needs in Finnish indoor radon policy

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This assessment report is part of a series of four information needs assessment reports of selected environment and health policies developed within a collaborative project on the establishment of an environment and health information system supporting policy making (ENHIS-2, Grant Agreement SPC 2004124, coordinated by the World Health Organization, Regional Office for Europe).

Information needs assessment is based on document analysis of Finnish radon policies and discussion in workshop setting with radon experts from the Finnish Radiation and Nuclear Safety Authority (STUK), officials from the Ministry of Social Affairs and the Ministry of the Environment and practitioners in municipal health authority and building inspection.

Information needs assessment covers the following phases in the policy process:

1. ***Science base***
2. ***Policy formulation and implementation***
3. ***Policy evaluation***

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Introduction

Natural radon background levels are rather high in certain areas in Finland; radon is more abundant above ground areas called eskers, which were formed by gravel deposits developed by glacial streams over 10.000 years ago. In addition, modern construction methods – concrete slab foundation and airtight under pressurised building envelopes - are prone to high radon concentrations.

Still, even the most radon prone areas are inhabited and new building activities are being approved of. Policy actions aim to attain the indoor radon standard of 400 Bq/m^3 in existing dwellings through measurement activities and radon mitigation; and the 200 Bq/m^3 guideline level in new buildings through preventive radon safe construction practices.
The attention of Finnish scientists, policymakers and home owners towards radon risk and existing policy standards is based on the occupational hygiene principles of setting and implementing limits to the maximum, rather than reducing the average indoor air concentration. In general, children's exposure to radon is treated as a part of life long exposure and therefore no separate regulation is in place.

Despite the policy attention, identification and mitigation of all residences, where the radon standards are exceeded, appears to be an impossible task. On the other hand considerable progress has occurred in both radon mitigation and radon prevention in new buildings. Based on results from nationwide representative surveys, the average residential radon levels indoors have been increasing in 1970-2000. In the radon policy workshop at the Finnish Radiation and Nuclear Safety Authority (STUK) in Helsinki on 28 August 2007, this trend was explained to be due to the lack of clear enforcement procedures for radon control measures in combination with regular application of radon prone building constructions. However, recent survey data from 2000's show

that the levels of indoor radon concentrations are at present decreasing (Mäkeläinen et al. 2007). This is due to changes in building practices, radon prevention in new buildings and indoor radon mitigation activities.

The following Finnish policy documents define radon control regulations and guidelines for residential settings. Policies related to radon in workplaces are not discussed; however good practice examples from the occupational field, in particular child-relevant locations such as day care centres, are discussed and referred to.

1) Ministry for Social Affairs and Health Order on the Upper Limits for Radon Concentration in Places of Residence (944/1992) (pursuant to Radiation Act section 48 and Radiation Decree)

2) Land Use and Building Act (132/1999), section 13 issued by the Ministry of Environment

- Decree of the Ministry of the Environment on indoor climate and ventilation of buildings - National Building Code of Finland, part D2 Indoor Climate and Ventilation of Buildings, section 2.3 Air Quality; Regulations and Guidelines 2003
  Regulation: New houses must be designed and constructed so that indoor air is free of harmful concentrations of gases, particles or microbes or odours which decrease the indoor comfort.
  Guideline: Radon building design value: 200 Bq/m3
- Decree of the Ministry of the Environment on foundations - National Building Code of Finland, part B3 Foundations, section 2.8 Radon; Regulations and Guidelines 2004
  Regulation: In the design and construction work, radon risks at the construction site shall be taken into account.
  Guidelines: The limit value 200 Bq/m3 is commonly exceeded in the most part of Finland, if no counter-measures are taken. A radon-technical design may be left out only in the case the local radon surveys clearly show that the radon concentration in residential buildings is consistently below the permitted maximum value. If radon is not taken into account in design, written grounds for that shall be the attached to the design documents of the building project.

The main radon website in Finland (www.radon.fi or www.stuk.fi + choose radon) provides plenty of information on radon activities in Finland such as mitigation, prevention, measurements, radon campaigns. The website entails an important part of the Finnish radon information policy.

Science base

Health studies

Uranium mine studies have established a strong association between lung cancer and exposure to uranium daughters (most importantly radon and radon daughters) at high exposure levels. In Finland, the first epidemiological case-control study on the risk of lung cancer lung cancer caused by residential exposure to radon was carried out in East Uusimaa in 1986-87 (Ruosteenoja 1991). The second Finnish health study was published in 1996 (Auvinen 1996). STUK participated in the EU project which performed a collaborative analysis of individual data from 13 European case-

control studies (Darby et al, 2005, 2006). The results give an excess relative risk of lung cancer of 0.16 (95% CI 0.05-0.31) per 100 Bq/m^3. The results confirm the earlier risk estimates based on miner studies. The data provide firm evidence that residential radon acts as a cause of lung cancer in the general population. The results are crucial to the development and refinement of policies to manage exposure to this form of natural radiation so as to reduce the annual number of deaths from the most common type of fatal cancer in Europe. The study also considers effects of uncertainties in the assessment of radon concentrations. It is expected that the uncertainties tend to increase the estimated excess relative risk per unit radon concentration.

Monitoring studies

The beginning of the 1980s was the period when the studies of the newly observed areas of high indoor radon concentration, building materials and natural radio nuclides in groundwater took place. The first nationwide survey was carried out in 1982. Studies on high radon concentrations on eskers and analysis of seasonal variations in indoor radon concentration were initiated. These studies have been reported in many native and international STUK-publications.
The last half of the 1980s was a time of active residential measurements; in 1985-1987 STUK measured more than 25,000 dwellings. As a result, Finland issued radon policies for residential settings as one of the first countries in the world.

Information needs assessment

The deliberation process concerning the scientific evidence about the radon source-to-exposure-to-health effect chain is addressed in background documents. The Finnish radon policy is adjusted in response to new evidence about health implications from exposure to the regulated radon limit levels.

i. In policy deliberation, information is needed about expected costs and benefits from policy implementation, preferably based on recent data from international, national or regional monitoring and health studies.
   - Policy benefits: Expected reduction of lung cancer risks, calculated from observed indoor radon concentration distributions in Finnish dwellings
   - Policy costs: Costs of practical measures required for radon mitigation

ii. Furthermore, the workshop discussion pointed out the need for information about and weighting of radon risk perceptions, economic consequences and equity issues when deliberating on radon policy adjustments.

A quotation from a unit head in the department of Environmental Health of the Finnish Ministry of Social Affairs and Health exemplifies bullet point ii:
"Policymaking involves 'qualified guessing' since data about risk levels are not always available. The evidence must be robust and relevant, many other factors such as economic impacts, also need to be considered. Equity also is an important condition. Consequently, the process of policy deliberation process is lengthy."

Policy formulation and implementation

A first radon directive was put into force in 1986 and applied to local authorities (National Board of Health, 1986) who started an active period of radon measurements in their municipalities. Measurement plans and radon prognoses were developed in co-operation with local authorities. Studies on strategies for finding high indoor radon concentrations and for reducing exposure as well as temporal variations in radon concentrations were carried out. The first guide for home owners about radon in dwellings was published in 1986 (STUK 1986).

The regulations and guidelines in the Building codes aim to ensure implementation of radon prevention practices during the building process. Radon prevention is cheaper and more effective when building a new house than carried out as a remedial measure in an existing building. The radon action level for existing dwellings (400 Bq/m3) is given by the Ministry of Social Affairs and Health. This level is not mandatory; however health authorities have the right to ban a dwelling containing very high radon concentrations. Health authorities are responsible for surveying the local indoor radon concentrations and to inform and advice house owners on radon mitigation. This is based on separate instruction given by the Ministry of Social Affairs and Health. In practice the limit of 400 Bq/m^3 is effective in buying and selling of houses – as stated in legislation for housing trade. The regulations of the Building Code are mandatory, meaning that the target value of 200 Bq/m^3 is obligatory for new buildings. Building companies are responsible for activating a preparatory radon piping through installation of a radon fan or other mitigation when the radon concentration in a new dwelling exceeds 200 Bq/m^3. Monitoring to verify compliance, however, is often neglected.

Authorities

Table 1 below summarizes the role of the principal authorities and organizations involved with the Finnish indoor radon policy. The Ministry of Social Affairs and Health has prime responsibility and stipulates upper limits for the radon content in indoor air in workplaces and residential settings. STUK supervises practices and compliance with the Radiation Act, Decree and the Ministerial Order: (i) general evaluation of the health hazards caused by radiation; (ii) evaluation of the need for measures to limit exposure to radiation, and imposition of requirements on such measures; (iii) requirements for monitoring the radiation exposure of workers and other persons exposed to radiation. In addition, STUK serves as the organization responsible for the monitoring referred to in Article 35 of the Euratom Treaty and attends to official duties, liaison and reporting involved in implementing regulatory control required by the Euratom Treaty. The Finnish Advisory Board for Radiation Safety serves as a co-ordinating and expert body to consider principle issues concerning radiation safety, to monitor general developments, to make proposals and suggestions and to issue opinions concerning radiation safety. The Ministry of the Environment has prime responsibility and stipulates design levels for radon content in new buildings. Building companies (the foreman in particular) are responsible to observe regulations and guidelines in the design and construction of foundations for buildings, structures and spaces as well as earth structures connected with them. Local building authorities advice and supervise local building through building permission process and inspections required. Health authorities are responsible for surveying the local indoor radon concentrations and to inform and advice house owners on radon mitigation. Universities have played an important role in developing the Finnish guidance for indoor radon mitigation and radon prevention in new building.

TABLE 1 Active participants of Finnish indoor radon policy		
Organization	**Role**	**Key work areas**
Ministry of Social Affairs and Health	Govermental, legislation guidance	Radon in health protection legislation Guidance and control of local authorities Funding of research and campaigns Publication of guides, Communication
Ministry of Environment	Governmental, legislation, guidance	Radon in building code Development and control of construction Funding of research Publication of guides, communication
Radiation and Nuclear Safety Authority - STUK, Research Department	Governmental expert organization	Radon mapping and surveys Research into mitigation and prevention Research into health effects Communication
Radiation and Nuclear Safety Authority - STUK, Authority Department	Governmental competent authority	Radon at workplaces Control of building materials Radioactivity in public drinking water Communication
Local health authorities	Local health protection work	Local radon surveys Guidance
Local building authorities	Local building control	Local regulations and guidance Requirements of radon prevention in building permission process Guidance
Universities	Research and education	Research into radon mitigation and radon prevention in new building
Societies in the area of indoor air	Promotion of public health	Radon information in health related guidance work

Radon mitigation and prevention measures

The role of the Ministry of Environment was central in the first research of radon entry into buildings and in developing national mitigation strategies suitable for Finnish housing. The Ministry of Environment widely funded the studies of Helsinki University of Technology, Department of Construction, which work resulted in several key publications providing radon results on effect of Finnish house construction on indoor radon entry, prevention and mitigation. The first reports on remedial actions to counteract radon in dwellings were published in 1986 (Ministry of Environment 1986). It was concluded that the mitigation must meet the requirements of the housing stock and take into consideration the foundation structures and ventilation strategies in the country. STUK carried out a follow-up study of the measures, and a short guide was published in 1992 (STUK 1992). Based on Finnish experiences, the costs of remedial actions were analysed. STUK published in 1995 a new guide for indoor radon mitigation (Arvela 1995). The report is based on national and international experiences from different mitigation methods. Sub-slab depressurization (SSD) is the most common and most effective method for indoor radon mitigation. The Ministry of Environment published in 1996 in special guide for implementation of SSD in Finnish buildings (Ministry of Environment 1996).

New Building Codes have come into force in 2003 and 2004 requiring that radon risks of the building site should be taken into account in planning and construction (Ministry of Environment 2003, 2004). Guidance on radon-safe building has been given already in the 80's. A first guide was issued in 1994, a new revised guide in 2003 (Ministry of Environment 1994, Building

Information Ltd. 2003). Municipal building inspection authorities increasingly require radon prevention practices in connection to the building permission process.

The role of local health authorities has been crucial in the Finnish radon policy development. The survey work carried out by them forms the basis for radon mitigation work. Guidance for municipal health authorities on practical implementation of indoor radon control in municipalities was issued in 1997 (Ministry of Social Affairs and Health 1997). The main content concerns:

- Definition of the accepted method for indoor radon measurements
- Estimation of the annual average concentration
- Definition of special radon prone areas
- Guidance of measures for health authorities on decreasing indoor radon concentrations.

Guidelines for indoor health 2003 and advice on its implementation were issued by the Ministry for Social Affairs and Health and replaced the 1997 guidance. The concept of radon prone has been omitted; the health authorities are responsible for surveying areas where indoor radon concentrations recurrently exceed 400 Bq/m^3. (Ministry of Social Affairs and Health 2003, 2005)

Information needs assessment

Policy formulation

i. The Finnish radon policy sets radon limit levels for indoor dwellings. Health-focused policy objectives would strengthen the public health importance of radon policies and lead to more accountable policy making. There is need to re-consider the Finnish radon policy targets.

In the radon workshop, the suggestion for setting health-focused radon policy targets was discussed. Policy objectives should guide the selection of the policy measures in the way that would help achieve the stated objectives. Current radon reduction measures are fine, but it is unclear how far they can be stretched, since this depends on the policy targets, which are not clearly formulated. The group agreed that policy targets should also be achievable and measurable. The current radon policy focuses on maximum allowable radon concentrations and individual exposure levels.

STUK has estimated that reduction of all dwellings exceeding 400 Bq/m^3 to a level of 200 Bq/m^3 would reduce the exposure of population by 15%. On the other hand the average dose reduction of the exposed group would be high, corresponding to an exposure at 600 Bq/m^3. Reduction of all dwellings exceeding 200 Bq/m^3 to a level of 50 Bq/m^3 would reduce the exposure of population by 38 %. The workshop considered an interim population exposure target: Reducing the radon exposure of the population by 1/3. Taking into account the realistic possibilities to go down to 50 Bq/m^3, the realistic interim target could be a reduction of approximately 20 %, which can be achieved by means of indoor radon mitigation, radon prevention in new buildings and through simultaneous changes in general building practices. There is convincing evidence that e.g. current changes in ventilation practices contribute positively to indoor radon reduction goals: a decrease in under pressure levels is achieved through utilization of mechanical supply- and exhaust ventilation instead of pure mechanical exhaust ventilation. STUK also emphasizes these benefits in radon communication.

ii. Quantitative targets are needed for specification and focus. A combination of different policy measures and practices can lead to achieving the primary health improvement targets.

Implementation process

Most radon measurements, if done, are paid by individual home owners or by local authorities in connection to local indoor radon surveys. Radon monitoring methods are harmonised but monitoring is not systematic; the level of activity varies according to AND independently of the radon levels. Awareness and community activity levels are very different across the country, much depending on the actual level of the problem. In Finland, personal contact and awareness-raising campaigns have a large impact. Testing in conjunction with house sales is strongly advised to be carried out in due time before the house transaction, but is almost never performed in practice.

Based on this assessment, it can be concluded that:

ii. There is need for further increasing public awareness on risks of indoor radon and consequent activation to carry out indoor radon measurements and mitigation. Health authorities could make a difference in activating indoor radon measurements and mitigation work at municipal level.
iii. The importance of radon regulation in connection to property transactions should be strengthened as well. The given reference levels for existing buildings and new buildings already play an important role in buying and selling transactions.
iv. In relation, a good number of companies that offer qualified radon mitigation services should be maintained. Training of mitigation companies is already part of STUK's radon campaign programme.

The number of single family houses with preventive measures to counteract radon has increased remarkably since 2000. In the highest concentration areas more than 50% of houses built after 2000 have been provided with preparatory radon piping. However, newly delivered buildings are often accepted without radon control measurements done. The new owner can still take initiative for radon measurements and if the levels demonstrate to exceed the limit value of 200 Bq/m^3, the builder is liable to mitigate. When the owner awaits action too long, the building is no more considered new and the owner becomes responsible for mitigation instead. Public health authorities are currently being contacted if owners like to have advice on measurements, but do not further connect to building companies and inspectors.

v. Municipal health authorities should communicate more with building construction companies and point out the importance of radon control measurements from the public health point of view.
vi. Procedures are needed for harmonizing the practices of building authorities in line with requirements of radon safe practices in new buildings. Regular utilization of radon prevention in the whole process of new building construction will provide a challenge for building companies and should be incorporated in structural engineering trainings. The Ministry of Environment has an important task in strengthening the control activities of building inspectors.
vii. Radon measurements in new buildings should be made by contractors, so that regulations can be complied with and health hazards can be regulated.

- Overall, it can be concluded that there is need for strengthening the enforcement procedures of Finnish radon policies. Radon mitigation activities in existing dwellings should increase and radon preventive construction techniques in new dwellings should be stricter applied. The focus should be on (i) finding the dwellings containing high indoor radon concentrations; (ii) to reduce radon levels; (iii) and to give priority to new dwellings and the latest Building Code 2004 requirements for indoor radon levels. Strengthening the importance of indoor radon regulations is part of the enforcement procedure.

In the radon workshop, good practices such as systematic workplace measurements were recognised to influence the strengthening of the regulations. In this line, a good practice example from a building inspector in Tampere to end with:

"According to my own practical experience the messages about radon safe building technologies have reached most of the building and HVAC engineers in Tampere. Radon safe designs have already become routine. In the future new instructions and guides can be very quickly distributed by e-mail to the relevant professional groups. Actual implementation errors due to sloppiness can never be fully avoided, not even by increased training or supervision."

Policy evaluation

STUK is active in initiating follow-up of current radon regulations, such as evaluation of different mitigation activities and their effectiveness. Evaluation involves communication and collaboration with the public and other actors responsible for monitoring and mitigation.

National surveys and radon mapping

In 1986, the Ministry of Social Affairs and Health issued an instruction to municipal health authorities. The authorities are responsible for measuring the local indoor residential radon concentrations and to inform and advice house owners on radon mitigation. They carried out this work in co-operation with STUK. This work has resulted in wide mapping work. In the first years of the 1990s a nationwide survey of indoor radon was carried out (Arvela et al. 1993, Castrén 1994). The study was based on random population sample and radon measurements were carried out in 3074 dwellings, 903 flats and 2171 low rise residential buildings. Information gained from measurement plans and prognoses gave decision-makers a more balanced view of the radon situation in municipalities as well as in the whole country (Castrén et al. 1992, Mäkeläinen et al. 1992, Voutilainen and Mäkeläinen 1994). The methods and equipment used in the indoor radon survey were further developed so that Finland has one of the most advanced technical systems for risk mapping and radon survey (Cole 1993).

The results from cooperation with municipal authorities and radon measurements ordered by private house owners were published in 1997 in the form of Radon Atlas of Finland (Voutilainen et al. 1997). The Atlas gives arithmetic means of 5-10 km squares on maps of the provinces as well as indoor radon statistics for all municipalities. Based on this cooperation, STUK has today a data base of 70.000 houses (potential contents of 100.000 houses, filing underway) including indoor radon concentrations, geological data of the building site and data on housing construction. This data base provides the basis for radon communication as well as research and e.g. when planning new campaigns. Based on the database of STUK it is estimated that altogether 1500-3000 dwellings have been mitigated with an average indoor radon reduction of 800 Bq/m3.

STUK started a new national survey based on a random population sample in 2006. The results of this study will be published in 2008. Preliminary results from this survey convincingly demonstrate that levels of indoor radon concentrations are presently decreasing (Mäkeläinen et al. 2007). This is due to changes in building practices, radon prevention in new buildings and indoor radon mitigation activities.

From 2003-2007 local authorities, in co-operation with STUK, are participating in a new radon campaign (Radon bee) in order to activate radon measurements and mitigation work. The campaign already resulted in 12.900 dwellings being measured - 1500 of these exceeded the limit of 400 Bq/m^3. Results of a survey on indoor radon concentration in newly built day care centres (Valmari et al. 2007) demonstrated lower radon concentrations than those built during 1980-1999.

In response to the revised Building Codes, municipal building authorities have revised their practices and are required to follow radon safe constructions in the building permission process more strictly. In relation, local building inspectors can better control requirements of radon-safe building.

Information needs assessment

In Finland, indoor radon concentrations in new buildings are higher than in average housing stock. This is due to the prevalent use of slab-on-ground instead of using foundation structures with lower average indoor concentration (crawl space and cellar houses). Changes in ventilation strategies have also affected indoor radon concentrations. STUK already carried out two nationwide representative indoor radon surveys with 3000 randomly chosen participants. These surveys give a good overview on trends in indoor radon concentrations in dwellings. The first survey was carried out in 1991. The second is ongoing and will be reported in 2008.

i. The implications of the use of diverse foundation structures, ventilation strategies and radon prevention are being characterized as part of the second national representative survey of indoor radon concentrations in dwellings (2005 – 2007). Preliminary results already demonstrate a decreasing trend in indoor radon levels. In the future, the increase in national indoor radon concentrations of Finnish dwellings can be prevented with improved foundation structures.

At present, individual radon measurements are confidential even when very high concentrations are found in particular residences. Local measurement results are openly available at municipal scale, outlined in provincial maps, municipal & postcode statistics. The health authority of Tampere communicates individual measurement results in response to requests from house buyers for example when they were done partly at the cost of the city.

ii. Clarity about the publicity of radon measurement results is needed. What information should be public and what should not?

STUK carries out studies on experiences with radon preventive building and mitigation guides and coordinates radon campaigns. However, STUK has no regular direct communication contacts to local building authorities; this is the responsibility of the Ministry of Environment. Only in connection to certain research projects, STUK had direct contacts to individual local building inspectors. Contact with local health authorities occurs in connection to radon campaigns and

training cooperation. This cooperation is based on annual agreement between the Ministry of Social Affairs and Health and STUK (STM-STUK Radon Project).

iii. Better communication between actors is necessary to make everyone aware of the possibilities for policy evaluation.

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