Socio-economic Assessment of Groundwater Threshold Values

The Finnish case study - the socio-economic effects of road salting and groundwater protection in Lahti

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Abstract

In recent years, much attention has been directed towards the formulation of sustainable development in environmental issues. The European Water Framework Directive (WFD; 2000/60/EC) is the first European Directive to explicitly recognize the importance of interdependency between aquatic ecosystems and their socio-economic values and to provide an integrated approach to water policy.

This study is a part of an EU/Bridge (Background Criteria for the Identification of Groundwater Thresholds) projects' WP5. The aim of the Bridge/WP5 is to support of setting threshold values for specific ground water pollutants and to evaluate social and economic consequences of specific threshold values.

In this study, socio economic effects of road winter maintenance strategies in the Lahti area in Finland were investigated. Road salting in road winter maintenance proved to be an environmental problem especially in 1980 – 1990. Although the use of salt has decreased ever since, NaCl –concentrations may still occasionally rise up to 75 mg/l in the Lahti aquifer.

Three alternatives to reduce the NaCl –concentration in the Lahti aquifer have been formed. A status quo -alternative has been compared with two other strategies: reducing the use of salt in combination with road slopes or using of an alternative chemical. In status quo, no additional road winter maintenance measures are implemented so that the ambient NaCl –concentration does not change and no additional costs or other socio economic effects occur.

Because of the lack of consistent monitoring data and an appropriate assessment model, the connection between NaCl-threshold values and their socio economic effects remains indicative. Instead, the emphasis in the study lies in comparing appropriate road winter maintenance alternatives with taking their socio economic consequences into account.

The three alternatives were compared on the bases of their direct and indirect costs. In the study it was noticed that the use of an alternative chemical like potassium formate proved to be more cost-effective than the other alternatives in road winter maintenance. Although the market price of the alternative chemical is about 15 - 20 times higher than that of the salt, the negative environmental effects of salt makes the use of the alternative chemical profitable from the socio-economic point of view.

From legislative point of view the road winter maintenance is a multidimensional issue. On the one hand, it is forbidden to pollute ground waters in Finland (§ 8 in the Environmental Protection Law (86/2000)). On the other hand the road administration is responsible to take care of the traffic safety by taking care, among other things, of road winter maintenance and minimizing traffic accidents in winter time. It is not simple to find the level of the road winter maintenance which is optimal from the point of view of society and road users, traffic administration and the environment. Research results are available to show that the use of an alternative chemical could be reasonable from the society point of view. Also technical know-how concerning
the use of this alternative exists. To conclude, it is a matter of political preferences to increase the research of alternative road winter maintenance measures and to promote their utilization.
1 Introduction

Aquatic ecosystems are adaptive, but ecologically sensitive systems, which provide many important services to human society. This explains why in recent years much attention has been directed towards the formulation and operation of sustainable management strategies, the recent adoption of the European Water Framework Directive (2000/60/EC) being a good case in point. Both natural and social sciences can contribute to an increased understanding of relevant processes and problems associated with such strategies. The key to a better understanding of aquatic ecosystem problems and their mitigation through more sustainable management, lies in the recognition of the importance of the diversity of functions and values supplied to society at different spatial and time scales. This includes a better scientific understanding of aquatic ecosystem structure and processes and the significance of the associated socio-economic and cultural values.

The Water Framework Directive (WFD) is the first European Directive to explicitly recognize the importance of this interdependency between aquatic ecosystems and their socio-economic values and provides a much more integrated catchment approach to water policy. Investments and water resource allocations in river basin management plans will be guided by cost recovery, cost-effectiveness criteria and the polluter pays principle. The plan formulation and assessment process must furthermore include a meaningful consultative dialogue with relevant stakeholders. Such a dialogue will inevitably raise socio-political equity issues across the range of interest groups and therefore affect the management strategies.

Although groundwater resources are an integral part of catchment wide aquatic ecosystems, their position and role are not well defined in the WFD. No new quality standards were listed that apply uniformly to all groundwater bodies throughout Europe to define good groundwater chemical status, because of the natural variability of groundwater chemical composition and the present lack of monitoring data and knowledge. Article 17 stipulates that the European Parliament and the Council shall adopt specific measures to prevent and control groundwater pollution on the basis of a proposal for a new Groundwater Directive. The new Groundwater Directive (GWD) complements the provisions already in place in the WFD and in the existing Groundwater Directive 80/68/EEC, which will be repealed in 2013 under the WFD.

In its communication COM(2003)550, the European Commission states that groundwater bodies shall be considered as having good groundwater chemical status when the measured or predicted concentration of nitrates, pesticides and biocides do not exceed standards laid down in existing legislation (Directives 91/676/EEC, 91/414/EEC and 98/8/EC respectively). For other pollutants good groundwater chemical status is reached when it can be demonstrated that the concentrations of substances do not undermine the achievement of the environmental objectives (good ecological and chemical status) for associated surface waters or result in any significant deterioration of the ecological or chemical status of these surface water bodies, nor should concentrations result in any significant damage to terrestrial ecosystems which depend directly on the groundwater body. For these other pollutants, groundwater quality threshold values have to be established by Member States in all bodies
of groundwater that were characterized in the recent first WFD reporting obligations as being at risk.

In order to support this process of determining future groundwater quality threshold values for European groundwater bodies, the Environment Directorate-General of the European Commission commissioned a 2-year project to develop a general methodology for establishing groundwater threshold values called BRIDGE (Background cRiteria for the IDentification of Groundwater thresholds). The methodology has to apply to substances from both natural and anthropogenic sources and threshold values defined at the level of national river basin districts or groundwater body levels should be representative for the groundwater bodies at risk in accordance with the analysis of pressures and impacts carried out under the WFD. In the proposal for the new GWD these threshold values will be used for defining good groundwater chemical status.

As part of BRIDGE, a socio-economic assessment is carried out in support of setting thresholds values for specific groundwater pollutants and the evaluation of the social and economic consequences of specific threshold values. The assessment procedure follows the economic analysis outlined in the Water Framework Directive (WFD) and more specifically in the WATECO guidance for the economic analysis. Based on a common methodology (Brouwer, 2005), the socio-economic assessment procedure is tested and illustrated in a number of practical case studies in France, Finland, Latvia, the Netherlands and Portugal. The main objective of this paper is to present the results of the socio-economic assessment procedure applied in the Finnish case study area.

The remainder of this paper is organized as follows. Chapter 2 briefly reviews the methodological steps in the socio-economic assessment procedure. These steps are subsequently elaborated in separate chapters (chapters 3-6). General background for the socio-economic analysis of groundwater use is given in Chapter 3. Changes in population and traffic amounts in Lahti, the Finnish case study area, is shortly dealt with in Chapter 4. Ground water protection measures like legislation, permit procedure, public participation and environmental impact assessment as well as important actors in ground water issues are described in Chapter 5. Economic analysis is carried out in Chapter 6. Results of an interview of main stakeholders of winter road maintenance are shortly reported in Chapter 7 and in Chapter 8, conclusions are drawn concerning road winter maintenance and its impacts on ground waters.
2 Methodological Framework

2.1 The role of socio-economics in the WFD

The WFD is one of the first European Directives in the domain of water, which explicitly recognizes the role of economics in reaching environmental and ecological objectives. The Directive calls for the application of economic principles (e.g. polluter pays principle), approaches and tools (e.g. cost-effectiveness analysis) and for the consideration of economic instruments (e.g. water pricing methods) for achieving good water status for water bodies in the most effective manner. The Guidance Document on the Economic Analysis prepared in 2002 by the European Water and Economics Working Group (WATECO) advises that the various elements of the economic analysis should be integrated in the policy and management cycle in order to aid decision-making when preparing the river basin management plans. The integration of economics throughout the WFD policy and decision-making cycle is presented in Figure 1.

Source: WATECO Guidance Document

Figure 1: The role of economics throughout the WFD implementation process
The main elements of the economic analysis are found in Articles 5 and 9 and Annex III in the WFD. Economic arguments also play an important role in the political decision-making process surrounding the preparation of RBMP in Article 4 where derogation can be supported by the strength of economic arguments when setting environmental objectives. The economic analysis can be summarized as follows:

1) Economic characterization of the river basin (Article 5)
   - Assessment of the economic significance of water use in the river basin.
   - Forecast of supply and demand of water in the river basin up to 2015.
   - Assessment of current cost recovery by estimating the volume, prices, investments and costs associated with water services in order to be able to assess cost recovery of these water services, including environmental and resource costs.

2) Cost-effectiveness analysis (Article 11 and Annex III)
   - Evaluation of the costs and effectiveness of the proposed programme of measures to reach the environmental objectives.

3) Disproportional costs (Article 4)
   - Evaluation whether costs are disproportionate.

4) Cost recovery and incentive pricing (Article 9)
   - Assessment of the distribution of costs and benefits and the potential impact on cost recovery and incentive pricing.

The financial implications of the basic and additional measures for different groups in society has to be evaluated by 2010, including the level of cost recovery, changes in the use and level of economic instruments (e.g. levies, taxes, water prices) and their role in achieving a more efficient and sustainable water use.

Source: modified from the WATECO Guidance Document

2.2 Practical steps

In the common methodological framework for the socio-economic assessment procedure in BRIDGE, the steps in the economic analysis in the WFD presented in the previous section have been translated in the following practical steps:

1) Socio-economic analysis of current and future groundwater use and corresponding pressures and impacts

2) Risk and uncertainty analysis of non-compliance (‘gap analysis’)

3) Estimation of costs and effectiveness of possible compliance measures to bridge gap in cost-effectiveness analysis (least cost way to achieve threshold values)

4) Assessment and estimation of benefits of meeting groundwater threshold values

5) Cost-benefit analysis supporting decision-making regarding groundwater threshold levels

These steps are taken iteratively but usually include various feedbacks to previous levels of analysis and evaluation. The main objective of the first step is to describe and analyze current groundwater use patterns and the pressures exerted by key socio-economic sectors, possibly resulting in non-compliance with existing or new threshold values. This analysis, based on existing data and information, will be done for a number of selected substances and for key sectors exerting significant pressure on groundwater bodies. Related to this is the prediction of expected future pressures and impacts on groundwater chemical status from socio-economic driving forces, i.e. the identified key sectors. Based on current relationships between socio-economic groundwater use and corresponding pressures and impacts on groundwater quality, socioeconomic trends are estimated and translated in terms of expected future pressures and impacts on groundwater systems.

In the second step, current and future pressures from socio-economic driving forces and their expected impact on groundwater chemical status are compared with possible groundwater quality threshold values. The main objectives of the second step are to identify (i) the gap between expected groundwater quality and these thresholds values in the future (2015) and (ii) the key factors determining this gap and the uncertainty surrounding these factors. The uncertainty analysis is introduced here explicitly in view of the often complex source-pathway-risk relationships in the context of groundwater contamination.

Once the gap has been assessed (in a qualitative or quantitative way depending on available data and information) for specific key pollutants and clusters of groundwater bodies, possible measures to meet the groundwater quality thresholds can be identified in step 3. A list of possible measures or strategies in order to prevent and abate groundwater contamination and meet the established threshold values for a selection of groundwater pollutants will be compiled. A distinction will be made between preventive and remediation measures. For each measure in the list, the direct financial costs will be estimated and, where possible, the indirect economic costs. Besides costs, also the direct and indirect effects on groundwater chemical status will be assessed. Based on this information, the least cost way to reach proposed groundwater threshold values will be estimated.

Besides costs, the proposed measures to reach groundwater threshold values may also result in significant and substantial socio-economic benefits, such as clean drinking water or ecological benefits. Preventive measures may result in significantly different types of benefits than remediation measures, depending on the pollution source. Besides market valuation techniques, also specific non-market valuation methods should be used in this fourth step to assess the non-priced socio-economic
and environmental benefits involved of meeting groundwater threshold values in the case studies, such as contingent valuation. As in previous European funded research projects, a standard valuation format will be developed and applied in the case studies. On the basis of a subsequent cross-country comparison the validity and reliability of benefits transfer will be tested, i.e. using benefit estimates for groundwater threshold values in different, case study specific policy contexts.

Finally, based on the results from the previous steps, a cost-benefit analysis (CBA) will be carried out in the fifth step to assess the economic efficiency of proposed groundwater threshold value(s) for specific pollutants. The outcome of the CBA provides information about the extent to which costs exceed benefits or vice versa. Besides economic efficiency, also other criteria that are expected to play an important role in the real life decision-making process will be investigated in a qualitative and where possible quantitative way. These include the distribution of costs and benefits across the various relevant stakeholder groups involved (in time also across generations in view of the important temporal aspect of groundwater contamination and protection), the possible interaction effects between different pollutants and the expected ecological benefits of improved groundwater quality. Multi-criteria techniques can in that case be applied if sufficient information is available, resulting in a ranking of threshold value options using top-down ranking methods (assigning weights to different criteria) or interactive and participative bottom-up methods, involving the various stakeholders involved.

The steps above are part of (1) the economic analysis in the WFD as outlined in Article 5 and Annex III (economic characterization of water use, projection of future water demand and cost-effectiveness analysis) (2) the risk analysis carried out in the WFD to assess the extent to which the objectives of the WFD are expected to be met in 2015 (also Article 5), (3) the identification of strategies to prevent and control groundwater pollution in order to reach good chemical groundwater status (Article 11 and 17), and (4) the socio-economic underpinning of possible time or objective derogation (Article 4). The various steps when evaluating groundwater threshold values have been visualized in Figure 2.
Figure 2: Contribution of the socio-economic analysis to the process of setting groundwater threshold values and achieving good chemical groundwater status (related to the relevant articles in the WFD)

The socio-economic characterization of groundwater bodies in a river basin provides the basis for the estimation of expected future socio-economic trends and their impact on chemical groundwater status. The risk analysis in the WFD consists of comparing the expected future development of pressures and impacts on groundwater bodies as a result of socio-economic driving forces and the WFD objectives related to groundwater chemical status, which need to be made operational. In this way, the socio-economic analysis can also provide input in the process of setting groundwater threshold values, based on the assessment of the least cost way to reach groundwater threshold values compared to their expected social and economic benefits.
3 Socio-economic analysis of groundwater use

3.1 General background

Hydrogeology and use of groundwater in Finland

In Finland the most common surficial deposit is glacial till. About half of Finland’s surface area is covered by till or moraine formations deposited by glaciers. Peat deposits cover some 15 percent of surface area. Glaciofluvial (eskers) and ice-marginal formations cover only some 5 percent of the total surface area. About 13 percent of surface area is rocky terrain or the deposit cover is less than one meter thick.

The main aquifers in Finland are located in the Salpausselkä ice-marginal and in the esker formations. The Finnish sand and gravel aquifers are shallow and unconsolidated, which were formed during the Quaternary period, mainly during the Weichsel Ice Age or thereafter, and are results of various geological processes. The retention time of groundwater is generally quite short. The aquifers are small due to the topography of the crystalline bedrock and the thinness of the unconsolidated sediments. Aquifers situated in larger eskers or ice-marginal deposits are wider and deeper, and the retention time is longer.

It has been estimated that the groundwater recharge in the mapped and classified Quaternary aquifers amounts to altogether about 5.8 million cubic metres a day. Of this, some 2.77 million cubic metres is recharged in the aquifers classified as important for water supply (Class I). About 4.5 million Finns enjoy municipal water supply. At present, groundwater and artificial groundwater cover about 59 percent (239 million cubic metres a year) of the water distributed by the waterworks. The portion of artificial groundwater is about 9 percent of this volume (included in the 59 percent). Additionally, some 350 000 households in rural areas use groundwater for household purposes.

In Finland, the use of groundwater and artificial groundwater for the public water supply has continuously increased over the period of 1970-2001. At the beginning of 1970s, the share of groundwater used in water supply was only 30 % but in 2001, approximately 61 % of total public water abstraction was groundwater or artificially recharged groundwater. Of the 1560 public water works in the country nearly 1500 use groundwater as raw water. The percentage of groundwater or artificially recharged groundwater used as raw water in public water supply is foreseen to rise to about 70 % by the year 2010.

3.2 Case study area description

The case study focuses on one aquifer, which is one of the delineated WFD groundwater bodies and it belongs to a preliminary defined group of groundwater bodies. The groundwater body is situated in Southern part of Finland. It has been assigned to the Kymijoki-Suomenlahti river basin district. The competent authority regarding the
WFD and groundwater protection is Hämé regional environment centre. The groundwater body is part of the I Salpausselkä ice-marginal formation.

Table 1. The aquifers in the preliminary group of groundwater bodies.

<table>
<thead>
<tr>
<th>Aquifer name</th>
<th>Code</th>
<th>Total area of the aquifer (km²)</th>
<th>Recharge area (km²)</th>
<th>Estimated recharged amount of groundwater (m³/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lahti</td>
<td>0439801</td>
<td>40,36</td>
<td>19,95</td>
<td>30000</td>
</tr>
<tr>
<td>Renkomäki</td>
<td>0439802</td>
<td>6,19</td>
<td>3,45</td>
<td>2500</td>
</tr>
<tr>
<td>Kolava</td>
<td>0439805</td>
<td>3,05</td>
<td>2,18</td>
<td>1200</td>
</tr>
<tr>
<td>Kukonkoivu-Hatsina</td>
<td>0409851</td>
<td>61,09</td>
<td>48,84</td>
<td>45000</td>
</tr>
<tr>
<td>Salpakangas</td>
<td>0409852</td>
<td>11,5</td>
<td>8,37</td>
<td>6500</td>
</tr>
<tr>
<td>Villähde</td>
<td>0453251</td>
<td>3,25</td>
<td>1,42</td>
<td>900</td>
</tr>
<tr>
<td>Nastonharju-Uusikylä</td>
<td>0453252_A</td>
<td>8,4</td>
<td>6,2</td>
<td>4000</td>
</tr>
<tr>
<td>Nastonharju-Uusikylä</td>
<td>0453252_B</td>
<td>11,87</td>
<td>5,95</td>
<td>3800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>145,71</strong></td>
<td><strong>96,36</strong></td>
<td><strong>93900</strong></td>
</tr>
</tbody>
</table>

Figure 3. Left: The River Basin Districts and competent authorities (Regional Environment Centres) in Finland. Right: The Hämé regional environment centre and identified groundwater bodies.
Figure 4. The preliminary defined group of groundwater bodies and the Lahti aquifer on which this report focuses.

The area is a part of the large quaternary ice-marginal formation deposited between 10 700 – 10 900 years ago during the Younger Dryas time. The Salpausselkä formations have their counterparts in Sweden, Norway, Russian Karelia and the Kola Peninsula. The Salpausselkä formation is mainly composed of glaciofluvial gravel and sand. Especially in the proximal slope till occurs as intermediate layers. The layers are tectonically deformed. The structure of the formation is complicated; in the lower parts of the formation there can be found coarser sediments in a form of an esker e.g. hidden esker.

Figure 5. The bedrock types (left) and the superficial deposits (right).
The bedrock is mainly plutonic rocks – quartz diorite and granodiorite in the western part of the study area. In the north part of the study area there is also some acid gneiss and quartzite (yellow) in the shore on Lake Vesijärvi. In the eastern part of the study area the bedrock is mainly composed of rapakivi granite with mica gneiss inclusions (red) and mica gneiss (blue).

Approximately 22% of the total area is used for settlement and only approximately 1% of the total area is used for agriculture. The main land use is forestry; more than 55% of the total area. There is however a distinct difference in the land use between Kukkonovi-Hatsina aquifer situated west from the Lahti aquifer in Hollola municipality. In the Lahti aquifer there is more urban fabric and industrial and commercial units than in the Hollola municipality west from the Lahti aquifer.
Table 2. The land use in the groundwater bodies based on the CORINE Land Cover 2000-database.

<table>
<thead>
<tr>
<th>Corine class</th>
<th>Area (km²)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coniferous forest</td>
<td>312</td>
<td>48,83</td>
</tr>
<tr>
<td>Discontinuous urban fabric</td>
<td>112</td>
<td>21,33</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>313</td>
<td>7,79</td>
</tr>
<tr>
<td>Transitional woodland</td>
<td>324</td>
<td>6,24</td>
</tr>
<tr>
<td>Industrial or commercial units</td>
<td>121</td>
<td>6,11</td>
</tr>
<tr>
<td>Non-irrigated arable land</td>
<td>211</td>
<td>2,46</td>
</tr>
<tr>
<td>Mineral extraction site</td>
<td>131</td>
<td>1,41</td>
</tr>
<tr>
<td>Land principally occupied by agriculture</td>
<td>243</td>
<td>0,82</td>
</tr>
<tr>
<td>Sport and leisure facilities</td>
<td>142</td>
<td>0,77</td>
</tr>
<tr>
<td>Water bodies</td>
<td>512</td>
<td>0,56</td>
</tr>
<tr>
<td>Dump sites</td>
<td>132</td>
<td>0,27</td>
</tr>
<tr>
<td>Green urban areas</td>
<td>141</td>
<td>0,06</td>
</tr>
<tr>
<td>Peatbods</td>
<td>412</td>
<td>0,05</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>96,70</strong></td>
<td><strong>100,00</strong></td>
</tr>
</tbody>
</table>

Status groundwater body in the implementation of the WFD

Finnish aquifers have been mapped and classified on the basis of suitability for water supply and the need for protection into three classes. In connection with the inventory of groundwater resources, activities and land use possibly causing risk to the groundwater quality were also mapped. The identification of the groundwater bodies have based on this mapping.

The grouping is essential because of the number of the small and scattered situated aquifers or groundwater bodies to achieve feasible management of the groundwater resources. Groundwater resources in Finland have been mapped since the 1970s. The most extensive and, so far, most detailed survey was made in 1988-1995. Altogether some 7000 areas (aquifers) were then mapped. The aim of the project was to map and classify all aquifers and to increase information on hydrogeology of these areas, suitability for water supply, quality of groundwater, possible risk activities and contaminated sites (industry, roads, depositories, farming, gravel extraction sites etc.) As a result altogether 7000 areas (aquifers) where then mapped, delineated and classified. Aquifers have been also classified on the basis of suitability for water supply and the need for protection into three classes: Class I holds areas important for water supply; Class II holds areas suitable for water supply, and Class III holds other groundwater areas. All the information collected during the project is stored into a database and it is regularly updated by the regional authorities. The information collected as the result of the mapping and classification project corresponds well the requirements of the initial characterization.

The Lahti aquifer

The Lahti aquifer is a part of the large quaternary ice-marginal formation deposited between 10 700 – 10 900 years ago during the Younger Dryas time. The Salpausselkä formations have their counterparts in Sweden, Norway, Russian Karelia and the Kola Peninsula. The Salpausselkä formation is mainly composed of glasiofluvial
gravel and sand. Especially in the proximal slope till occurs as intermediate layers. The layers are tectonically deformed. The structure of the formation is complicated; in the lower parts of the formation there can be found coarser sediments in a form of an esker e.g. hidden esker. Underneath the loose sediments there is the Precambrian bedrock, in which several fracture zone have been detected. The most obvious is the so called Vesijärvi-Laune fracture zone, on which a more coarse sediments has been deposited in a form of a esker in the early phases of the sedimentation of the whole formation.

The groundwater is in general of a type Ca-HCO$_3$ - water, which is typical of the Quaternary deposits of the Precambrian Shield area on the whole.

The total area of the Lahti groundwater body is approximately 40 km$^2$ of which half of the area is mapped as a recharge area. It is estimated that approximately 50% of the precipitation is recharged to groundwater. Based on the total area and the rainfall (about 600 mm/year) it is estimated that the amount of groundwater recharged on this area is approximately 30 000 m$^3$/day. In addition there is some bank-infiltration, which increases the amount of groundwater. There are five main groundwater intakes situated on the aquifer. The infiltration of the surface water from the Lake Vesijärvi increases the recharged amount of the water.

According to permits for the water abstraction issued within the Lahti aquifer, the groundwater abstraction might have been 36 200 m$^3$/d, while the total actual groundwater abstraction has been varying between 19 000 – 21 000 m$^2$/d. In two water intakes the abstracted water is partly bank-infiltrated surface water. The amount of groundwater discharged via springs to the surface waters is quite significant.
Figure 7. The Lahti groundwater body. The inner line is the recharge area and the outer line in the administrative border of the groundwater body or aquifer.

Main groundwater pressures in the Lahti aquifer

On the Lahti aquifer there are eight contaminated soil sites and, additionally, there are 11 restored contaminated soil sites. The typical activities which have caused soil contamination are chemical laundry, sawmill and a former foundry. Also the soil beneath of the petrol stations is contaminated in most cases. On the aquifer there have been totally 24 petrol stations of which nowadays only 14 is still operational.

The Lahti town (98 000 inhabitants) is situated mainly on the aquifer. According to the mapping of risk activities for soil contamination there are totally 134 risk sites on the aquifer. The risk activities mainly small enterprises like scrap yards, repair shops, garages, paint shops, woodworking industry, market garden and private gardens, old waste tips, sawmill, graveyard, sewage treatment plant, garrison area and industrial areas. The utilization of oil products and chemicals and their storage and transport in the region have considered to cause potential groundwater risks.

Figure 8. The contaminated soil sites (●), risk activities (*) and clean or remediated soil sites (●).

There are number of companies and enterprises situated on the aquifer, many of them use solvents and oil in their production processes. There are approximately 1000 properties, which use or have been used oil for heating. Many of the properties have still own under ground heating oil storage. The underground heating oil containers in the private houses or on the back yards of industrial properties possess a potential risk to groundwater pollution. (Mäntylä et al., 1999)

Lahti is one of the areas in Finland where the transit transport of dangerous substances is heavy. Most of the transit has taken place on the railroads and on the high-
highway 4. Combustible fuels has been one of the biggest category of substances. No environmental accidents have happened in the transit so far, but the groundwater of Lahti is nevertheless exposed to risks. It has to be considered that the dangerous transits have to be guided by the groundwater areas. Furthermore, all the highways on the groundwater areas should be equipped by efficient road slopes.

The former use of pesticides has caused elevated pesticide concentrations in some areas on the aquifer. The highest concentration detected in one of the monitoring tubes was 5,0 µg/l in year 2000. Additionally one of the groundwater intakes has been out of use because of the pesticides. A mapping of occurrence of pesticides in groundwater is ongoing in Finland. The project "TOPO" was launched in 2002. During the years 2002-2004 approximately 200 groundwater samples in over 100 aquifers have been taken (Gustafsson, 2004, Rapala and Gustafsson 2005).

The road salting is a wider problem on the Lahti aquifer along with the pesticide pollution. In 1980-1990, the main risk factor was road salting, in 1990-2000 solvents and, currently, pesticides. The use, transport and storage of oil products and chemicals in the region have also considered to be potential groundwater risk.

The background level of chloride

The maximum background concentration of chloride is in average 3,8 mg/l in fine grain deposits. The background concentration of chloride in sand and gravel deposits is in average 1,4 mg/l. (Soveri, 1985). Based on the groundwater network of the Finnish environment administration the mean concentration was 2,82 mg/l (n=5636). The 90 percentile of chloride concentration based on monitoring results of the national reference monitoring network is 5,3 mg/l. The monitoring sites of the groundwater network are situated in area with only little human pressure (Soveri et al. 2001). The nearest monitoring site of pristine groundwater is situated in Myskylä (Fig.11).

If we apply the methodology developed in work package 3 of BRIDGE-project, the threshold value for chloride, which is based on the background levels would be (two times the 97,7 percentile; 2 x 5,3 mg/l) 10,6 mg/l. The threshold value for chloride concentration in the drinking water directive is 250 mg/l. In Finland there is also a recommendation for chloride concentration which is 25 mg/l. It is based on the fact that the Finnish groundwater are soft and acidic. The corrosive effects of Finnish groundwater increases when the chloride concentration rises over 25 mg/l.

![Figure 9. The development of chloride concentration in Myskylä reference monitoring site.](image-url)
**Road salting**

At the end of the 1980’s it was discovered in Finland that chloride concentrations in groundwater have risen because of the use of the road salt. The use of salt (NaCl) in general has increased since 1987, due to the stricter objectives adopted for winter maintenance. The peak was attained in 1990 when 157,000 t of salt were used in Finland. The risks of road salting for groundwater was assessed in the late 1990’s. As a result of the risk assessment 290 (MRN >65) aquifers were found to be affected by the road salting in quantity that some measures should be implemented to prevent the further deterioration of ground water quality. Nowadays there are approximately 600 kilometers road on which salt is used for winter maintenance on important aquifers. The Finnish National Road Administration has set a target for used road salt to 70,000 t/y for years 2000 – 2003. Currently the amount of salt used annually is about 100,000 t. It has been estimated that the amount of salt used for de-icing will be approximately 88,000 tonnes annually. The target level for the use of road salt is set to 80,000 tonnes annually by the Road Administration (Road Administration 2006).

![Fig 10. The total amount road salt used (NaCl) in Finland](image)

**The groundwater protection measures**

The risk caused by road salting to groundwater resources, especially to groundwater quality, were assessed in late 1990’s in Finland. The mapping covered 1129 aquifers. According to the results the use of salt in de-icing caused clear risk on the quality of groundwater in 290 aquifers. (Gustafsson & Oinonen, 1998, Gustafsson, 2000 a and Gustafsson & Nysten, 2000 b).

The reduction of road salting has been tested in highway 25 during the winter maintenance periods in years 1999-2003 in Southern Finland. The test area covered totally 142 kilometers of road situated on the Salpausselkä ice-marginal formation. The nor-
The normal amount of salt used for deicing was 5.7 tons/kilometer in the test area in average. The average reduction in road salt was approximately 40% of the normal amount used. In the end of the test the amount salt used was 4.1 t/km in average. The impacts of the reduction of road salting was monitored in 51 sites. The average concentration based on the monitoring results from years 1999-2003 in all monitoring sites shows an increase in chloride concentrations of totally 0.52 mg/l. The chloride concentrations increased during the test years in 23 monitoring sites in average 5.0 mg/l. In 19 points a decrease of average 8.20 mg/l on chloride concentration was monitored. In 9 monitoring points no changes in the chloride concentrations was monitored. (Uusimaa Road District 2004).

In the 1990’s the behavior of road salt in typical Finnish aquifers were studied. The models were based on artificial aquifers chosen to represent the average conditions in different Finnish aquifer types. Also the reduction of the amount of salt applied were simulated and to illustrate the effects in long run. In Salpausselkä- type aquifer (ice marginal formation) the amount of 10 tonnes/km used for road salting would keep the chloride concentration in groundwater in the starting level (15 mg/l) in this case. The reduction of amount of salting to 5 tonnes/km would lower the concentration to level of 9 mg/l level. The reduction in groundwater would take according to the simulation approximately 20 years and after that the concentration would be quite steady. (de Coster et al., 1993, Nysten & Hänninen, 1997, Niemi et al. 1994, Kling et al. 1993)

The slope protection constructions have been built totally 230 kilometers along the roads on important aquifers. It has been estimated that there is a urgent need for building new road slope protections on total length of 120 kilometers.

A study was made on how effective the existing slope protection constructions were to prevent the effects of road salting on groundwater on selected 15 sites. The chloride concentration was clearly decreased or the increase of concentration became slower after the building of the slope protections approximately in third of the studied sites. The most effective protections was those which covered to whole recharge areas (Finnish Road Enterprise 42/2000).

![Figure 11. The length of existing slope protection constructions and the building costs.](image)
On airports acetates and formats have been used for de-icing purposes on runways. Sodium chloride (NaCl) has never been used on runways because of its corrosive effects. Earlier urea was commonly used on runways. The use of urea was finished because it caused increase in nitrate concentrations in ground waters. The suitability of formats for de-icing of roads was studied in a research project co-coordinated by Finnish Environment Institute SYKE (Hellsten et al., 2004). In the laboratory tests it was found that the potassium format was efficiently degraded in cold environment. After the laboratory scale studies the effects of potassium format was tested in pilot scale in field in Suomenniemi. A study on long-term effects of format on groundwater quality is still going on. More information on the study concerning suitability of the potassium format for de-icing of roads is in MIDAS-projects www-pages. (www.environment.fi/syke/midas).

**The road salting on the Lahti aquifer**

The length of public roads (maintained by the Road Administration) on the Lahti aquifer is approximately 13 kilometers of which 8 kilometers of road belongs to the highest maintenance class. In year 2001 the amount of salt used for de-icing on the roads in the highest maintenance class was in total 12.3 tons per road kilometer.

In year 2001 the total amount of salt used for de-icing of the roads maintained by the Road Administration was approximately 121 tons. In addition there is approximately 110 kilometers of the roads which are winter maintained by the city of Lahti. In the same year 2001, the city used road salt for de-icing approximately 300 tones and for dust binding 69 tons. So totally the amount of salt used for de-icing on the roads situated on the aquifer was approximately 420 tons.

There are existing road slope protections totally 1.4 kilometers on the Lahti aquifer. Approximately 660 meters on highway 12 in the middle of the aquifer and 720 meters on the highway 4 which is crossing the aquifer in the eastern part.

**The impacts of road salting on groundwater in the study area**

The use of sodium chloride (NaCl) for de-icing has been identified as a pressure to the groundwater quality in the area. The chloride concentrations in some monitoring tubes has had an upward trend and the maximum analyzed concentration was 75 mg/l in 1997. Because of the natural low concentrations of bicarbonate and quite low pH, the chloride concentration above 25 mg/l increases the corrosive properties of the water.

The average of the annual average concentrations (years 1999-2000) in different monitoring tubes varies from 5.82 mg/l up to 68.54 mg/l. There were in total 37 monitoring points in Lahti aquifer of which the monitoring results were available for this study. In 10 monitoring points the chloride concentration were under 10 mg/l. The chloride concentration were between 10 -25 mg/l in 15 monitoring points and in 8 monitoring points the concentration were over 25, but under 50 mg/l. Over 50 mg/l average concentrations was measured in 4 monitoring points.
Figure 12. The average chloride concentration in Lahti aquifer. The annual average concentration is calculated from annual averages of each monitoring points.

Figure 13. Chloride concentrations (mg/l) in five groundwater monitoring tubes in the Urheilukeskus water intake area during years 1990-2000.
4 Changes in population and traffic amounts in Lahti

The Lahti city is one of the growing cities in the Southern Finland. It is estimated that the number of inhabitants will grow up to 106 000 by year 2030 (Statistics Finland, 2004). The consumption of water was approximately 220 liters per inhabitant per day in year 2004. Although the consumption of water has been decreasing per inhabitant, due to the growing population in Lahti city the need for good quality groundwater will increase in the future. Also the traffic amounts has been estimated to increase 25 % in average by year 2030.

Figure 14. The estimated development in population in between years 2003 and 2030 (left) source Statistics Finland and the estimated increase in traffic amounts in highways (right) source: Road Administration.
5 Groundwater policy instruments

5.1 Current policy

Legislation

Groundwater issues are mainly regulated through the Water Act (264/1961, amendment Act 121/2001) and the Environmental Protection Act (86/2000). The Water Act is currently under review in Finland.

A good groundwater chemical status is safeguarded by means of the prohibition against groundwater pollution laid down in Section 8 of the Environmental Protection Act. Under this regulation, no substance shall be deposited in or energy conducted to a place or handled in a way that it leads to negative health effects, or otherwise violate the public or private good. The prohibition on groundwater pollution means that a permit may not be granted for an activity which does not conform to this regulation.

The prohibition on altering groundwater in Section 18, Chapter 1 of the Water Act refers to maintaining a good groundwater quantitative status. Accordingly, use of the groundwater or activity causing groundwater extraction is forbidden without a permit from the environmental authorities.

According to the decision of the Ministry of the Trade and Industry (nr 415/1998) and the regulations by the city of Lahti for protecting the environment (nr 2004/12), hazardous activities may not be situated on groundwater areas. These may concern the handling and storage of the hazardous chemicals on gas stations, waste water management, the use of pesticides, the washing of cars, boats or machines, the dumping places of snow.

In 2000, the Ministry of the Environment has given guidelines for the monitoring of the groundwater in the connection with road management. According to the guidelines, road planning as a policy instrument is the most cost-effective way to protect groundwater from the point of view of road management.

Permit procedure

According to the Environmental Protection Act (86/2000) the use of the groundwater or activity causing groundwater extraction is forbidden without a permit from the environmental permit authorities, if this may affect the quality or quantity of the groundwater. The permit authorities will, in the permits, lay down conditions which have to be observed and which are aimed at preventing adverse effects on the groundwater as laid down in the environmental legislation. The permit conditions may, among other things, refer to compensations, as the applicant is required, under law, to compensate any damage resulting from his actions. The permit holder may also be required to draft a programme for monitoring the groundwater, which has to be approved by the regional environment authorities.

In accordance with the Environmental Protection Act (86/2000) the permit authority shall request an opinion on the permit application from the regional environment authority and the municipal environmental protection committee in municipalities...
where the activity referred to in the application may have environmental impact. The permit authority also has to arrange public hearing to those whom the permits issue may concern.

Groundwater protection is also taken into account in other permit issues like land extraction permits. Road winter maintenance like the use of salt or an alternative chemical or construction of road slopes are not liable for an environmental permit. These activities may, however, include into a large traffic plan eligible for a permit.

**Public participation**

The Constitution of Finland (731/1999) stipulates that the powers of the State in Finland are vested in the people, who are represented by the Parliament. Democracy entails the right of the individual to participate in and influence the development of society and his or her living conditions. The exercise of public powers shall be based on an Act. In all public activity, the law shall be strictly observed.

In accordance with the Local Government Act (365/1995), the municipal council has to take care of that the inhabitants and the users of the services have the possibilities to participate in and influence the activities of the municipality.

**Environmental planning and environmental impact assessment (EIA)**

*Environmental planning*

The protection plan procedure was introduced in the 1990’s to clarify the application of legislation, to specify the groundwater protection measures and to ensure the quality and quantity of the groundwater. These are not sent for ratification but are for guidance purposes. They are voluntary agreements where of all the interest groups commit themselves to reduce the risk from human activities on the groundwater. The protection plan procedure is highly comparable with further characterization and review of the impact of human activity on ground waters stated in the WFD. The groundwater protection plan was done for the Lahti aquifer in 1993-1994.

Also land use planning may considerably influence the protection of groundwater bodies. As a rule, installations which are potentially harmful to the groundwater are to be placed elsewhere than over aquifers.

*EIA*

The Act of Environmental Impact Assessment Procedure (EIA; 468/1994) came into force on September 1, 1994, and the Degree of Environmental Impact Assessment Procedure (268/1999) in 1999. The aim of the legislation is to further the assessment of environmental impact and the consistent consideration of this impact in planning and decision-making, and at the same time to increase the information available to citizens and their opportunities to participate in the decision-making.

The Act on the Assessment of the Impacts of the Authorities Plans and Programmes on the Environment came into force in 2005. Its objective is to advance the assessment of environmental impacts and their consideration in preparing and approving
plans and programmes of the authorities, to improve the availability of information to
the public and the opportunities for public participation.

According to the paragraphs 8 and 9, the responsible authority has to inform au-
thorities and the great public of the purpose and the preliminary contents of the plan
and the draft planning report. The other authorities and the great public also have a
right to give their opinion on these issues (see also section 'Public participation'
above). According to the paragraph 11, the responsible authority has to notify official-
ly of the decision concerning the plan or the programme. The final report has also
to be available for the great public and other stakeholders.

Road winter maintenance activities, including road salting or the use of an alternative
chemical or utilization of road slopes do not demand an EIA –procedure as such. As
a part of a plan or programme concerning ground water protection or traffic issues,
also road winter maintenance and especially road salting may be a part of an EIA-
procedure.

5.2 Important actors

The city of Lahti
A key aim of environmental protection in the City of Lahti is to reduce the load on
the environment and to prevent the spoiling of the environment. Protection of ground
water is a major priority of the City of Lahti, because Lahti is situated near to one of
Finland's largest areas of ground water. Most of the area of the city belongs to a
ground water region classed by the environmental authorities as important, and all
the water used in Lahti is ground water.

The city of Lahti is, together with the Finnish Road Administration, responsible for
the road winter maintenance in the Lahti area.

Environmental administration
The Finnish environmental administration consists of the Ministry of the Environ-
ment, the regional environment centres, the environmental permit authorities and the
Finnish Environment Institute. The Ministry of the Environment is responsible for
environment policies, preparation of the environmental legislation and the guidance
of environmental administration. The regional environment centres, 13 in all, take
care of issues related to environmental protection, land use, building, nature conserv-
ation, protection of the cultural environment, and the management and use of water
resources.

The Häme Environmental Center has an essential role in the groundwater protection
in the Lahti region.

Road administration
Finnish Road Administration is responsible for Finland’s highway network. Its mis-
sion is to provide smooth, safe and environmentally friendly road connections. Fin-
nish Road Administration plans, maintains and develops transport system in coopera-
tion with the authorities responsible for the other modes of transport. Its clients are
road users and those who need transport, information or official services.

As a road management expert, Finnish Road Administration participates actively in the planning of land use and transport systems.

Environmental issues are vital to Finnish Road Administration, and they will be taken into consideration in both transport system planning and road management. Road administration has carried out experiments to reduce the use of salt in road winter maintenance in the Lahti area. (Uusimaa Road District 2001)

**Water and sewage undertakings**
The owner and the operator of an water and sewage undertaking in Finland can in principle be a supra municipal or a municipal organisation, private association or privately or publicly or jointly owned joint-stock company. Traditionally, most of the operators are municipal undertakings. LV Lahti Water Ltd. is the only bigger water and sewage undertaking, which is municipality-owned joint-stock company. It was founded in the beginning of 1994 to continue the activities of a former water and waste water establishment in Lahti. In 2003, the turnover of the company was 14,6 milj.euros, of which the share of water charges (0,76 euros/m³) amounts to 32%, waste water charges (1,20 euros/m³) up to 56% and other activities up to 12%.

**Non-governmental organisations**
Associations and citizen organizations have traditionally had a strong role in Finland. Also people in Lahti area take part in improving their living conditions in many different ways. There are organizations that take stand on environmental issues as well as public events and inquiries that can serve as a way of influencing the city environmental policy. Shared environment requires open and participative planning and decision making.
6 Costs and benefits of road winter maintenance in the Lahti area

6.1 General assessment procedure

The aim of this study is to find out socio-economic effects of different ground water chloride concentrations. The economic effects will be assessed in the status quo and in alternative case where the prevailing chloride concentration will be lower than in status quo. Because the lack of appropriate monitoring data e.g., the emphasis lies on comparison of road winter maintenance alternatives with taking their socio-economic effects into account.

In Finland, there are big variations in chloride concentrations, but the trend in concentration is upward based on the annual averages of monitoring tubes in the aquifer. Maximum chloride concentration is approximately 70 mg/l in some part of the aquifer. The procedure of the assessment of the economic effects of different road winter maintenance alternatives is illustrated by the following figure.

![Figure 15. Assessment of costs and benefits of road winter maintenance alternatives.](image)

- **Alternative ground water chloride standards**
- **Alternative measures to reach the chloride standards**
  - Road salting – a status quo
  - Road salting with road slope protection
  - Use of an alternative chemical
- **Socio-economic effects of reaching the standards**
  - Costs - direct - indirect
  - Benefits - direct - indirect
- **Comparison of different ground water chloride standards with**
  - Quantitative decision criteria
  - Qualitative decision criteria
In an ideal case, dose-response relationships need to be assessed. To be able to assess the dose-response in an aquifer level accurate information on the amounts of salt used and groundwater conditions should be applicable. This means usually that the aquifer is mathematically modeled, flow and transport models. In this study, however, necessary knowledge and information for the assessment applied in Lahti aquifer case study is mostly based on the studies made on national or regional level or they are based on a general conceptual models in different geological type-formations.

Identification of costs and benefits

A breakdown of costs and benefits of the winter maintenance, the road-salting as an example, is presented in Table 1 below.

<table>
<thead>
<tr>
<th>Costs</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Direct</td>
<td>3 Direct</td>
</tr>
<tr>
<td>Material costs (road salts)</td>
<td>Fuel saving</td>
</tr>
<tr>
<td>Equipment costs</td>
<td>Travel time saving</td>
</tr>
<tr>
<td>Labour costs</td>
<td>Avoided fatality, injury and vehicle damage (saving of accidents and accident costs)</td>
</tr>
</tbody>
</table>

2 Indirect

<table>
<thead>
<tr>
<th>Costs</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Indirect</td>
<td></td>
</tr>
<tr>
<td>Costs to infrastructures (underground utilities; bridges; garages)</td>
<td>Reduction in liabilities to road authority (associated to hazardous driving conditions)</td>
</tr>
<tr>
<td>Cost to motor vehicles (vehicle depreciation costs; vehicle protection costs to salt-related corrosion)</td>
<td>Maintain the economic activity (reduction in production losses; reduction of losses in good shipments; reduction in wage losses due to absenteeism from work)</td>
</tr>
<tr>
<td>Cost to the environment: surface and ground waters, water wells; ascertaining of water supply in exceptional circumstances (may involve protective pumping, carrying out investigations for a new abstraction site, drilling of a new well) soil and biota, trees</td>
<td>Maintain access to social activities (emergency response time in case of workplace accidents or at home; benefits derived from ability to participate in social activities despite of a stormy weather)</td>
</tr>
<tr>
<td>Reduction of feeling threat or fear in wintertime car driving</td>
<td></td>
</tr>
</tbody>
</table>
Cost-benefit and cost effectiveness analysis

In order to estimate the direct costs and indirect economic effects (Table 1) of the alternatives the unit cost calculation has been applied. A standardized unit cost for each cost item has been found out. When multiplying the unit cost with the quantity relevant from the case study area point of view the magnitude of the different kind of economic effects has been investigated.

The road winter maintenance alternatives are compared with taking the direct and indirect costs of each alternative into account. On the bases of these calculations it is possible to determine a cost-effectiveness ratio for each alternative and find out the alternative which seems to be the most cost-effective. Distribution of costs, damages and benefits among identifiable groups are shortly discussed in the Chapter 7.

Data collecting

The basic data has been collected by interviewing important stakeholders like Road Administration and environmental and health authorities. Articles and other literature concerning the winter maintenance of roads have been analyzed as well as citizen's complaints towards traffic authorities. Various plans and programs concerning the traffic sector and winter maintenance have been utilized. Results from these have been used to weight and prioritize different winter maintenance strategies.

In this study, no separate contingent valuation is carried out. Instead, a limited literature based meta-analysis is utilized for ground water valuation. An indicative list of cost/benefit indicators is presented in Appendix 1.

The road salting causes various kinds of socio-economic effects: quantitative and qualitative, measurable and non-measurable, measurable in monetary terms and measurable in other dimensions. To be able to compare the alternative groundwater quality standards or alternative road winter maintenance strategies all these effects should be taken into account. The multi-criteria approach makes it possible to compare ground water quality standards or specific strategies with taking benefit/cost and other purely economic criteria and qualitative criteria like acceptability, equity and sustainability into account. A modified multi-criteria discussion is presented in Chapter 7.

6.2 Road winter maintenance alternatives

In this section, alternatives to reduce the chloride concentration will be described which is operationalized by comparing the road winter maintenance alternatives with each other.

Alt 0: Use of salt in status quo includes the present winter maintenance costs. In this alternative no additional groundwater protection measures will be carried out. We assume that the status quo -alternative (the prevailing chloride concentration ) of the road salting does not increase direct costs although it causes indirect costs in e.g. negative environmental and technical effects and future pressure to water treatment if chloride concentrations continue to increase.
Alt 1: Road salt reduction and road slope protections. In this alternative it is assumed that the use of salt decreases but also road slope protections will be utilized. These kinds of protections are not carried out due to winter maintenance but for groundwater protection. In most cases, the protections are made of betonies. Important from the environmental point of view is that the melt water (precipitation water) should be managed with wastewater facilities.

The investment lifetime of the road slopes is estimated to be about 30 years in maximum. According to the studies concerning road slope protections, they have significant economic and environmental effects.

Alt 2: Using of an alternative chemical. The use of potassium formate as de-icing chemical in winter maintenance on roads has been studied in Finland. The field experiments show that, in the short run, potassium formate has no or minor effects on the groundwater quality. The reason why the use of the chemical is still used in modest quantities is the lack of information concerning its long term effects and its high price.

6.3 Identification of costs and benefits

The winter maintenance is an essential part of the road management, and it benefits the society in many ways. However, it has been observed that especially the utilization of the road salting has also negative effects on the groundwater.

In this section, monetary costs and benefits of the winter maintenance of the Lahti area have been estimated. Direct costs due to winter maintenance activities have been induced by the following issues

- use of salt or another de-icing chemical (material costs, equipment costs, labour costs).
- road slopes protection (construction; operation and maintenance)

Indirect socio-economic costs and benefits in our focus include (see also the Ministry of Traffic and Communication 2003)

- costs of the road accidents due to the slippery roads and their reductions
- environmental and health effects
- corrosive damages for the infrastructure and the cars
- liability claims and their reductions (bad water in wells or ponds; traffic accident compensations)
- fuel and travel time savings
- fatality, injury and vehicle damage avoided
- changes in the logistics of the road traffic (maintenance of the traffic conditions even in dangerous winter times)

The direct costs of the winter maintenance have been estimated in the study in market prices. In order to estimate indirect socio-economic costs unit cost calculation have been utilized. After a volume of an activity or an effect has been found out in
the Lahti area, the volume has been multiplied by a unit cost or a cost indicator specific for it.

The magnitude of an activity or an effect is described by a relevant indicator. This can be the number of accidents or kilometres (nr), the length of the underground corrosive metal pipe (m), the volume of the ground water treatment (m³) or the renewal of a coverage made of metal on a floor in a parking hall (m²). The case-by-case prices or costs include among other things accident costs, and operation and maintenance costs.

In the following chapters, the most important economic effects of the winter road maintenance are shortly described and assessed. If it has not been possible to describe the activity or the effect in monetary terms, it has been described qualitatively. The economic evaluation in the study is mostly an indicative one.

6.4 Direct cost calculation

The three alternatives or scenarios are described in Tables 4 - 6 below.

Table 4. Use of salt in status quo.

<table>
<thead>
<tr>
<th>Alt 0: Use of salt in status quo</th>
<th>km</th>
<th>tons/km</th>
<th>Salt, tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnish Road Administration</td>
<td>13,7</td>
<td>8,8</td>
<td>120,6</td>
</tr>
<tr>
<td>City of Lahti</td>
<td>110</td>
<td>2,7</td>
<td>297</td>
</tr>
<tr>
<td>Total</td>
<td>123,7</td>
<td></td>
<td>417,6</td>
</tr>
</tbody>
</table>

Source: Statistics of the use of salt in the Lahti area; the Finnish Road Administration and the City of Lahti

This study uses an estimation for the price of the road salt of 50 €/ton, which is an average standard price used by the Road Administration. The cost of the road salting, which in addition to the salt material includes also the equipment and labor costs, amounts approximately to 200 €/ton (price information from the Finnish Road Administration).

In 2001, salt was used for the winter maintenance in the Lahti area about 420 tons and the costs of salting were about 84 000 € (= 420 tons x 200 €/ton)

Table 5. Use of salt and road slope protections.

<table>
<thead>
<tr>
<th>Alt 2: Reducing the use of salt + road slope protections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finnish Road Administration</td>
</tr>
<tr>
<td>City of Lahti</td>
</tr>
</tbody>
</table>

1 Häme Road District and the Plancenter 2005.
The costs of the road slopes are, depending on the technique utilized, about 200 000 € - 500 000 €/km. According to a report prepared by the Plancenter in Finland with co-operation of the Finnish Road Administration (25.8.2005) costs of the road slopes for highway 12 (14 km) are 4 730 000 € – 5 130 000 €.

Road salting in this example will cost around 300 tons x 200 €/ton = 60 000 €.

Table 6. Use of Potassium Formate

<table>
<thead>
<tr>
<th>Alt 2: Use of Potassium Formate</th>
<th>a)</th>
<th>b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>km</td>
<td>tons/km</td>
<td>tons</td>
</tr>
<tr>
<td>Finnish Road Administration</td>
<td>13,7</td>
<td>3</td>
</tr>
<tr>
<td>City of Lahti</td>
<td>110</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>123,7</td>
<td>123,7</td>
</tr>
</tbody>
</table>

According to the research results (Midas2-MeMo 2005), potassium formate is spread in an experiment in Kauriansalmi 5,190 ton/road-km. In this study, we assume that potassium formate were used in the Lahti area a little bit less, 3 tons/km, and salt respectively 3 tons/km In alternative 2a) the Finnish Road Administration is assumed to use 41,1 tons potassium formate and the City of Lahti respectively 330 tons of NaCl. In the alternative 2b) both stakeholders use potassium formate, 371,1 tons in total.

The price of the potassium formate is about 15 – 20 times higher than that of the salt. The total costs of spreading the potassium formate, including the price of the chemical, equipment and labor costs amounts up to 3060 € - 4080 €/ton. The costs of potassium formate in Alt 2a) would be = 41,1 x (3060 € - 4080 €) = 125 766 € - 167 688 € and the cost of the road salting respectively 330 x 200 € = 66 000 € so the total costs of Alt 2a) are 191 766 – 233 688 €.

The total costs of spreading the potassium formate in alternative 2b) are 371,1 tons x (3060 € - 4080 €) = 1 135 566 € - 1 514088 €.
6.5 Traffic safety

Needs of the society and the expectations of the citizens and other interest groups are the basis of the road and traffic planning. Traffic safety is assured by maintaining the traffic network and its functionality. The vision of the traffic safety is that no-one needs to die or to get damaged in the traffic. The Decision of the State Council of 2006 stipulates that traffic safety shall continuously become better so that in 2010, the amount of fatal traffic accidents would not exceed 250 cases on national level.

Traffic accidents can be fatal, or cause injury or property damages. On slippery winter roads also accidents with animals like dears, foxes or rabbits may take place.

In 2005, 155 persons were injured in 115 traffic accidents in the Lahti area. According to the information from the Hâme Road District, 7 persons were in injured in wintertime 2004 and 6 persons in wintertime 2005 on the highway 12 (see Figure 12), the road cover having been snowy, slushy or icy.\(^{5}\) It is possible to calculate a monetary price for road accidents by using the guidelines of the Ministry of the Traffic and Communication. Traffic safety has been valuated with the figures presented in Table 7 below.

Table 7. Unit costs for traffic accidents in 2000 prices.

<table>
<thead>
<tr>
<th>Type of accident</th>
<th>Costs, €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>1 934 161</td>
</tr>
<tr>
<td>Permanent injury</td>
<td>1 084 812</td>
</tr>
<tr>
<td>Casual injury</td>
<td></td>
</tr>
<tr>
<td>• serious</td>
<td>260 691</td>
</tr>
<tr>
<td>• slight</td>
<td>50 456</td>
</tr>
<tr>
<td>Injuries in average</td>
<td>248 077</td>
</tr>
<tr>
<td>Accident to death</td>
<td>2 430 316</td>
</tr>
<tr>
<td>Accident to injury</td>
<td>315 352</td>
</tr>
<tr>
<td>Personal injuries</td>
<td>386 832</td>
</tr>
<tr>
<td>Property damage</td>
<td>16 819</td>
</tr>
<tr>
<td>Traffic accident in average</td>
<td>84 094</td>
</tr>
</tbody>
</table>


In the status quo alternative, the costs of winter time accidents in 2004 were 6 x (0.177\(^6\) x 386 832) € = 410 815 €, and in 2005 7 x (0.179\(^7\) x 386 832 €) = 484 700 €. In the alternative 1, it is assumed that two more personal accidents (2 x (0.179 x 386 832) = 138 485) occurred because of salt reduction. The rate of traffic accidents in the alternative 2 is assumed the same as in the status quo –alternative.

No data is available concerning the liabilities due to road-related vehicle accidents

\(^5\) Number of injured persons is higher in case all the accidents on whole Lahti area were included.


\(^7\) Statistics Finland. Price Indexes 1860 - 2005
6.6 Environmental impacts

Ground and surface waters

Winter maintenance road salting has increased the NaCl –concentration in ground waters in the case study area from time to time (see also Ch 3.2). At the moment the concentration seems to be stabilizing. Although the NaCl –concentrations have not had big environmental impacts (expert opinion in connection of interviews) concentrations on the level of 30 -100 mg/l have, nevertheless, serious corrosive effects.

Increased NaCl –concentrations have not in general been observed in the surface waters of the area. One exception is the Kinttere pond, in which the NaCl –concentrations have increased till 120 mg/l. The reason is that the salty waters gathered by the road slopes have been led directly into this pond. However, there are no recreational activities around the pond. It has been observed, too, that in the Mytäjäinen pond, there is a slight increase in the NaCl –concentration, which is about 7mg/l. In Likolampi the respective concentration is 1,5 mg/l.

Because the Lahti area is situated on one of the biggest groundwater areas in Finland, the households are connected to an organized water supply network and there are only a few private wells around. Some liability claims have been discussed so far.

Polluted soils and roadside vegetation

There have been some discussion of the damages the road winter maintenance may cause to the roadside soils and vegetation, but there are practically taken no research results concerning this subject. Evident is, however, that salt storages will be a kind of hot spots in the future.8

On the roadside of the highway 12 there are some observations of brownish color in conifers like pines. In Savo-Karjala Road District it was observed that even a slight utilization of road salting causes remarkable NaCl –concentrations in pine needles. The concentrations were not high enough to cause any visible damage (opinion of an interviewee).

Because of the salt damages, no new trees or bushes have been planted on the roadside of the highway 12. In a survey from Canada following impacts and prices were reported concerning roadside vegetation:

- Trees: it is estimated that, on the side of a highway, an average of 1.86 trees per km are affected by salt and need to be replaced each year. According to the Canadian research the price to replace one mature tree is about 250 €
- Grass: repair cost of salt damaged grass is estimated to be on average 313 € per hectare per year

8 According to a Canadian research, soil contaminated by salt can be treated at an estimated total cost of 300 € per hectare per year (2002 price level).
Shrub: 0.6 salt contaminated shrub per km need to be replaced at a cost of 95 € on average per year. The City of Ottawa has estimated that the replacement cost per year of one shrub were about 20 €.

On the basis of a Finnish study (Kärenlampi and Hautala 1994) the decreasing of the utilization of the road salting seemed to be beneficial for roadside vegetation.

### 6.7 Corrosion damages

Damages caused by salt corrosion for vehicles, bridges and other constructions made of metal are remarkable in economic terms. Corrosion costs per vehicle per year has been estimated to be about 136.5 € in 2005\(^9\) (700 Fmk by Rönnholm et al. 1994). Considering advances in modern technology of automobile industry, this indicator can be considered as being somewhat overestimated. However, the amount of salt utilized in road winter maintenance has a great effect on corrosion costs and the effects vary from region to region.

It has been estimated that in Pirkanmaa there are 435 cars per 1000 inhabitants. If we assume that this relationship is relevant also on Lahti area, there are about 50 000 – 60 000 vehicles on the area and the corrosion costs are about 6.8 – 8.2 M€ per year.

According to cost calculations from 1994 the additional costs of the maintenance of the bridges caused by corrosion were about 29 Milj.Fmk (5.655 M€\(^10\)) per year on the national level and the prevention costs correspondingly 8 Milj.Fmk (1.56 M€\(^11\)) per year. Assuming that the Lahti region bears approximately 5% of the national costs of 7.215 M€ Lahti's cost share were in status quo –alternative around 0.360 M€ per year on 2005 price level. Corrosion costs in other alternatives have been estimated in relation to the quantity of salt used.

There is much evidence that road salting shortens the lifetime of steel constructions like bridges and water pipes. In groundwater stations, water is treated in order to decrease its corrosive characteristics. High temperature increases corrosiveness, which is one of the reasons that pipes made for warm water are more sensitive for corrosion than pipes for cold water. Also various soil properties have an effect on the water pipes networks.

\[^9\] = 0.195 x 700Fmk
\[^10\] = 0.195 x 29 MFmk
\[^11\] = 0.195 x 8 MFmk
6.8 Total costs

To summarize, the most indicative total costs of the preliminary alternatives in 2005 are the following.

Table 8. Road winter maintenance costs

<table>
<thead>
<tr>
<th>Cost indicators</th>
<th>Alt 0: Use of salt in status quo, €</th>
<th>Alt 1: Reducing the use of salt + road slope protections, €</th>
<th>Alt 2: Use of Potassium Formate, €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Salt</td>
<td>84 000$^{12}$</td>
<td>60 000$^{13}$</td>
<td>66 000$^{15}$</td>
</tr>
<tr>
<td>• Road slopes</td>
<td>4 730 000 – 5 130 000$^{14}$</td>
<td>191 766 – 233 688$^{16}$</td>
<td>1 514 088$^{17}$</td>
</tr>
<tr>
<td>• Potassium formate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct costs in total</td>
<td>84 000</td>
<td>4 790 000 – 5 190 000</td>
<td>257 766 – 299 688</td>
</tr>
<tr>
<td>Traffic accidents</td>
<td>484 700$^{18}$</td>
<td>623 185$^{19}$</td>
<td>484 700$^{20}$</td>
</tr>
<tr>
<td>Corrosion damages</td>
<td></td>
<td></td>
<td>484 700$^{21}$</td>
</tr>
<tr>
<td>Vehicles</td>
<td>6 800 000 – 8 200 000$^{22}$</td>
<td>4 760 000 – 6 499 999$^{23}$</td>
<td>5 440 000 – 6 560 000$^{24}$</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>360 000$^{25}$</td>
<td>252 000$^{26}$</td>
<td>288 000$^{27}$</td>
</tr>
<tr>
<td>Costs in total</td>
<td>7 728 700 – 9 128 700</td>
<td>10 425 185 – 12 565 184</td>
<td>6 470 466 – 7 632 388</td>
</tr>
</tbody>
</table>

$^{12}$ See Section 6.4 and Table 4
$^{13}$ See Section 6.4 and Table 5
$^{14}$ See Section 6.4 and Table 5
$^{15}$ See Section 6.4 and Table 6
$^{16}$ See Section 6.4 and Table 6
$^{17}$ See Section 6.4 and Table 6
$^{18}$ See Section 6.5 and Table 7
$^{19}$ See Section 6.5 and Table 7
$^{20}$ See Section 6.5 and Table 7
$^{21}$ See Section 6.5 and Table 7
$^{22}$ See Section 6.7
$^{23}$ See Section 6.7; estimation in relation of the use of salt compared with Alt 0.
$^{24}$ See Section 6.7; estimation in relation of the use of salt compared with Alt 0.
$^{25}$ See Section 6.7.
$^{26}$ See Section 6.7.; estimation in the relation of the use of salt compared with Alt 0
$^{27}$ See Section 6.7; estimation in the relation of the use of salt compared with Alt 0.
In the table above, the total costs of each alternative have been presented. According to the figures, it is the alternative chemical potassium formate which has the lowest social costs, while the costs of the other alternatives were on an equal level. The reason is that no NaCl is used in alternative 2b) and because of that, no considerable corrosion damages have been reported.

In this study, they are the most important impact categories that has been able to put in monetary terms. Although there are indications e.g. of environmental and health effects caused by the road winter maintenance (some newspaper discussions), it has not been possible to monetarize these impacts. In recent discussions concerns has been expressed that potassium formate might have some adverse effects on the airport asphalt. This may cause additional costs in the form of replacement investments. Because of the lack of the basic data it has not been possible to put these effects in monetary terms and further studies are still needed.

The water treatment is not usually needed because of the increased chloride concentrations. In Finland the concentrations are quite low, even in areas effected by road salting, compared to the threshold value set for chloride concentration in drinking water. The main reason to control the increase of the chloride concentrations in groundwater in addition to the groundwater protection, is its effect to increase the corrosive properties of water. The Finnish groundwater is naturally soft and acidic and that is why the waterworks usually use alkalization.

A cost effective treatment process for NaCl is reverse osmosis. It is a process where water is de-mineralized using a semi permeable membrane at high pressure. A global treatment cost by reverse osmosis is about 1€/m$^3$ (Technical Research Center in Finland, Research Notes nr 2060, 2000). In some cases it may be necessary to invest in a new water intakes. If the capacity of the intakes is about 120 m$^3$/d and the operation of the intake presumes 15 km of water pipe network, the total costs of the water works would be approximately 1.3 M€ (Utriainen 2006).

### 6.9 Benefits

**Ground water valuation**

This study does not include contingent valuation or willingness to pay – research to estimate ground water benefits. However, also market prices of the water can be utilized in the ground water valuation.

In a study concerning the willingness to pay in 20 international studies, the monetary willingness to pay proved to bee approximately 745 $/households/year in 2000 price level (Brouwer 2005). When using the market price in the monetary estimation of ground water, water charges paid for the drinking water can be utilized. For a four-person family in Finland the charge is about 528 €/household/year (= 4 x 12 x 11 €). Using this formula the total use value of the drinking water in Lahti area were around $100\times12\times11\times4 = 13\,200\,000\,€$.

**Fuel and travel time savings**
According to the Canadian experiences, road winter maintenance brings about fuel and travel time savings. Driving in bare road conditions allow savings in fuel up to 33% as compared to when roads are snowy or icy. In that case, fuel efficiency per 100 kilometers was approximately 11 liters for autos and light trucks, and 17 liters for gas trucks. The monetary value of fuel savings for autos and light trucks was estimated to be around 1.55 €/100 kms.

Transport Canada estimated that idling of cars results in 0.832 liters of fuels consumed per hour. According to the same study, travel time savings was on average 9 € per hour for auto (travelers) and 8 € per hour for bus (travelers).

The Road Administration in Finland found in 1994 (Rönnholm et al.) that decreasing the use of salt increases both fuel and travel time costs. The fuel consumption on a slippery, snowy and icy road increased about 15% in comparison with fuel consumption on a dry and bare road. Increases in travel time was 1 – 5% respectively.

According to the research carried out by the Finnish Road Enterprise (56/1995) decreasing of the utilization of the salt increases fatal accidents on the slippery winter roads by 5% in certain circumstances. On the roads in the maintenance class I the fatal accidents increased about 20%. On the basis of this information it would be possible, at least in theory, to estimate a winter maintenance accident reduction rate, which would in this case be approximately 80 – 95%. This indicator, although not used in this study, could be utilized when calculating traffic accident costs savings.

6.10 Cost-effectiveness

In a situation where a policy is focused on one environmental pressure (one benefit) and when this pressure may be difficult to monetarise, the cost-effectiveness analysis could be a sensible alternative to the cost-benefit analysis (Nordic Council of Ministers Guidelines for CBA, draft 2006).

Cost-effectiveness of road winter maintenance alternatives has indicatively been presented in Table 9 below (For methodology, see also Brouwer 2005).

Table 9. The cost effectiveness of alternatives
<table>
<thead>
<tr>
<th>Measure</th>
<th>Costs, €²⁸</th>
<th>Effectiveness²⁹ (decrease of NaCl-load, %)</th>
<th>Unit cost, €³⁰</th>
<th>Rating³¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt 0: Use of salt in status quo, €</td>
<td>7 728 700 – 9 128 700</td>
<td>50³²</td>
<td>18 402 – 21 735</td>
<td>4</td>
</tr>
<tr>
<td>Alt 1: Reducing the use of salt + road slope protections, €</td>
<td>10 425 185 – 12 565 184</td>
<td>70³³ – 80³⁴</td>
<td>338 057 – 366 628</td>
<td>3</td>
</tr>
<tr>
<td>Alt 2: Use of Potassium Formate, €</td>
<td>a) 6 470 466 – 7 632 388</td>
<td>70</td>
<td>17 435 – 20 566</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>b) 1 998 788</td>
<td>80³⁵ – 90³⁶</td>
<td>5 386</td>
<td>1</td>
</tr>
</tbody>
</table>

According to the table, alternative 2b), use of potassium formate, seems to be most cost-effective measure in road winter maintenance whereas use of salt in combination with road slopes looks least cost-effective. Alternatives 0 and 2a) seems to be approximately on the same level. On the basis of an elementary benefit – cost – analysis, too, alternative 2b) looks like the most beneficial. It is to be kept in mind, however, that there still exists uncertainty on the environmental effects of potassium formate in the long run. Contrary to the cost-benefit analysis, the cost-effectiveness approach cannot, however, reveal whether a project or policy is beneficial for society and hence worth undertaking. The cost-effectiveness analysis can only show which of several policies that has the lowest cost per unit given that is already decided that one of the policies should be implemented.

²⁸ See Table 8  
²⁹ Expert opinion  
³⁰ Total costs divided by the quantity (salt, tons; slopes, km; alternative chemical like potassium formate, tons).  
³¹ Expert estimate  
³² Gustafsson and Nystén 2000 b)  
³³ See Section 3.2; Plancenter Ltd and the Finnish Road Administration 2005.  
³⁴ See Section 3.2; Plancenter Ltd and the Finnish Road Administration 2005,  
³⁵ MIDAS2 - MeMo  
³⁶ MIDAS2 - MeMo
7 Interest groups' attitudes and public discussion

Authorities attitudes

In this study, stakeholders' attitudes towards road winter maintenance alternatives were studied by interviewing road authorities, environmental authorities and the authorities in the City of Lahti (Full list of interviewees in Appendix 2).

Questions asked concerned themes like targets to reduce salt use in road winter maintenance, need to increase road slope protection, utilization of potassium formate and simultaneous use of these measures. Also questions concerning traffic safety, environmental effects, effects on infrastructure and vehicles, on the average fuel consumption and travel time were asked (see questionnaire in Appendix 2). The interviews were carried out through telephone or face to face. The questionnaire was delivered beforehand to the interviewees by e-mail. One interview lasted about one hour. The interviewees represented their organisations.

There was a level of uncertainty among the interviewees whether the targets to reduce the use of salt were attained, but a kind of unanimity existed that the use of salt in winter maintenance is decreased on Lahti area. Traffic safety was mentioned as one of the most important reason not to decrease winter maintenance too much. It was also pointed out that the road winter maintenance is a multidimensional problem, in which also the amount of traffic, weather conditions, speed limits and studded tyre policy have to be taken into account. A single factor like salt reduction in winter maintenance does not solve the problem.

On the Lahti area, a certain amount of road slopes have been constructed. A general opinion of the stakeholders was that constructing them should continue also in the future. The Road Administration has stated highway 12 (Figure 14) to be one of the most urgent objects where road slope protections should be built. A general criteria, mentioned by some of the interviewees for constructing the slopes, was as follows: it would be reasonable to build those on ground water areas, where there are roads of high maintenance class and where transport of dangerous chemicals takes place. The building of road slope protections helps also in pesticide control.

According to the interviewees, potassium formate should be used on ground water areas where the road salting leads to risks for ground waters. Because of the high price of the chemical it could be utilized also on the roads where it seems to be more costs-effective than alternative techniques, e.g. road slopes. Although the research results concerning potassium formate seems promising, there is no certainty of long term effects of this chemical. According to the stakeholders, cost – benefit analysis should be done more often concerning different road winter maintenance techniques.

Some interviewees claimed that the simultaneous use of maintenance techniques, and especially the optimal combination of them, has to be considered on ad hoc –basis. A reasonable combination of salt and potassium formate in connection with road slope protections might represent best practice on critical spots on the roads. Appropriate
management of melting waters in connection of road slope systems was also emphasized.

The interviewees seemed to have only slim comprehension of the influence of the road winter maintenance on the travel time or fuel consumption. Corrosion problems caused by the road salting on vehicles, bridges, tubes and other constructions made of metal were well known but no quantitative data was presented in the connection of the interviews.

Because of the long tradition in water monitoring in Finland, NaCl–concentration in ground waters in Lahti area was well known by the interviewees. High NaCl–concentrations have also been discovered in surface waters, Kinttere pond as an example. In that pond, the NaCl–concentration has from time to time risen to 120 mg/litre. The main reason for this is the melting waters which have been led into the pond along a road slopes protection system.

In Lahti area, main part of the households are connected in the water supply system and there are only a few wells on the area. NaCl–concentrations in the wells have not proved to be a problem. According to the interviewees the use of salt in road winter maintenance has not caused damages to soil, roadside vegetation or wetland biodiversity. Some nuisance have been experienced because of the slush on the roads in winter time.

**Earlier surveys of attitudes towards road winter maintenance**

In Uudenmaa Road District in Finland an experiment with limited use of salt in road winter maintenance was made in winter 1993 – 1994 on three roads besides of a highway (The Finnish Road Enterprise 56/1995). Experimental roads were managed according to 1b –maintenance policy. That means that the salting decreased by around 60 %. A survey was focused on professional drivers, and around 300 answers were received. Both bus and truck drivers regarded the experiment successful. Some of the drivers were hoping even a greater decrease in the use of the salt. 63 % of bus drivers and 83 % of truck drivers regarded that the experiment did not make it more difficult to follow the time table. Only 1 % of the respondents assumed that the experiment had made their driving more difficult.

In 1993, the attitudes towards limited salt use were investigated (The Finnish Road Administration 1995a). The research focused on attitudes towards traffic safety, way of driving, use of salt from the point of view of environmental and traffic policy, and the condition of the road network. The traffic safety was regarded to be of great importance. Although salting was generally resisted, it nevertheless was considered to be important in unexpected circumstances such as rush hours and sudden road slipperiness.

In Kuopio, Kymi and Uusimaa districts in Finland, the attitudes of the inhabitants and three expert groups towards road winter maintenance were investigated in 1993. The experts were from road administration and environmental and road traffic sectors. The main factors investigated were the use of salt, the restrictions of winter
speed limits, the use of studded tires, the NaCl–concentration of ground waters, vehicle corrosion, environmental protection and traffic safety.

The opinions of the top of the road administration resembled that of an ordinary driver's as far as the use of salt was concerned. Environmental experts supported limited salting which traffic safety experts favoured, too. All the other experts prioritized ground water protection. When comparing the future alternatives the ordinary car drivers prioritized very moderate salting policy in combination with studded tires and keeping winter speed limits unchanged. The top of the road administration prioritized decreasing the use of salt till the half, keeping the tire policy unchanged and changing speed limits. Despite of making traffic safety and environmental protection more effective, the NaCl–contents might be increased in the limit of recommendations. Experts in the environmental and traffic sectors prioritized moderate salting and tire policy of that time. In addition, they hoped for lower speed limits and better traffic safety.

Public discussion

In the national and regional Finnish newspapers from the beginning of 1990's till 2005 road winter maintenance has been much debated. Especially the use of salt and its environmental impacts have become almost 'a permanent celebrity'. During the last few years alternative chemical like potassium formate and road slope protections have entered into discussions. The Public has also been active by sending individual protest bills to the Attorney General.

According to some of the most critical newspaper articles the use of salt in winter maintenance has even been regarded as an environmental crime. Some requests have been made to the Attorney General to investigate road salting as an environmental crime. However, no evidence of crime has been found.

Interesting regarding the public discussion is the proposal by the Natural Resources Council of Finland to considerably decrease the use of salt in winter maintenance on ground water areas (a letter of the Natural Resources Council of Finland to the Ministry of Traffic and Communication, dated 12th October, 2000). The Council continued the discussion in summer 2001 by making a proposal to end up the use of salt on important ground water areas (MeMo June 2001). In autumn 2001 it prepared the third proposal to change the Environmental Act so that the road salting would be prescribed liable for a permit (MeMo August 2001).

In some cases (Decision of the Court of Administration 1998: 146) the Road Administration has been sentenced to pay indemnities because of neglects in road winter maintenance, like on the road 21 in Pello in Finland.
8 Conclusions

The European Water Framework Directive is the first European Directive to explicitly recognize the importance of interdependency between aquatic ecosystems and their socio-economic values and to provide an integrated approach to water policy. In EU-countries, it has been implemented through WATECO-guidelines, according to which various elements of the economic analysis should be integrated in the water policy and management in order to aid decision-making when preparing water management plans.

In this study, economic analysis presented in the WATECO-guidelines have been applied to an appropriate extent. The final goal of the study is to find out socio-economic effects of different ground water chloride concentrations (threshold values) in the Lahti aquifer. Because of the lack of experimental data from the study area and applicable models to verify the dose-response effects, the emphasis on the study lies on comparing road winter maintenance alternatives and analyzing their socio-economic effects.

In this case study, two road winter maintenance alternatives were compared with the status quo situation: road salt reduction together with road slope protections and the use of an alternative chemical instead of salt. Their socio-economic effects identified were the direct costs of each alternative, there impacts on traffic safety and environmental and corrosive damages. The main conclusion seems to be that when including the indirect effects of each alternative into the cost analysis the use of an alternative chemical as a road winter maintenance instrument is the most beneficial from the socio-economic point of view. According to the results from some field experiments in the Southern part of Finland, it seems to be the most cost-effective, too.

Because of the lack of capacity, no willingness to pay –analysis was carried out in the study. Instead, indicative calculations were made concerning the groundwater value in the Lahti area and fuel and travel time savings concerning the road winter maintenance, but these estimations have not been utilized as decision making criteria.

There has been much discussion of the road winter maintenance in the newspapers in Finland. Proposals have also be made to end up the use of salt in important ground water areas or to prescribe it liable for a permit. One prerequisite for the social acceptability of the road winter maintenance is, however, that there are alternative measures to take care of it. Finally, it is a matter of political preferences to increase the research of them and to find out an alternative or a combination of alternatives optimal for the society.
Acknowledgements

This case study report has been prepared in the Finnish Environment Institute, SYKE by MSc Marja-Leena Kosola, an economist working as a researcher in the Research Programme for Environmental Policy and by MSc (hydrogeology) Juhani Gustafsson from the Water Resource Management Unit.

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The authors will also thank to the environmental and road authorities and experts of the valuable information they gave through the interviews carried out in spring 2006 for the purposes of the study.
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Strengthening of the capacity in selected METAP countries to assess the cost of environmental degradation in costal areas. Cost of environmental degradation in costal areas of Tunisia. Finnish Environment Institute SYKE, Soil and Water Ltd. Interim report. December 2005.


Other references

Statistics over the use of salt in Häme Road District 2004 -2005.
Statistics over the traffic accidents in winter time 2004 - 2005.
## Appendix 1

### Winter maintenance of roads:
**List of socio-economic indicators in 2002 price level**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- per kilometer of highways</td>
<td>600 €/km</td>
<td>Road administration</td>
</tr>
<tr>
<td>- per tonne of salt applied</td>
<td>370€/ton</td>
<td>Road administration</td>
</tr>
<tr>
<td>Material (road salts)</td>
<td>60€/ton</td>
<td>Road administration</td>
</tr>
</tbody>
</table>

**Salt application:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- equipments</td>
<td>35€/hour/vehicle</td>
<td>Road administration</td>
</tr>
<tr>
<td>- labour</td>
<td>50€/hour-worker</td>
<td>Road administration</td>
</tr>
</tbody>
</table>

**Bridges:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- reparations</td>
<td>880€/m²/year</td>
<td>Road administration</td>
</tr>
<tr>
<td>- protection</td>
<td>80€/m²</td>
<td>Road administration</td>
</tr>
</tbody>
</table>

**Garages (typical multi-level):**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>160€/m²</td>
<td>Road administration munici-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>palities</td>
</tr>
</tbody>
</table>

**Corrosion costs of underground utilities:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1850€/ton</td>
<td>Environment and road authori-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ties</td>
</tr>
</tbody>
</table>

**Vehicles:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- vehicle depreciation costs due to road salt corrosion</td>
<td>170€/vehicle/year</td>
<td>Environment and road authori-</td>
</tr>
<tr>
<td>- vehicle protection costs</td>
<td>370€/vehicle/year</td>
<td>Environment and road authori-</td>
</tr>
</tbody>
</table>

**Environment:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- water wells claim</td>
<td>6400 – 18500€ per well per year</td>
<td>Regional environment authori-</td>
</tr>
<tr>
<td>- surface water</td>
<td></td>
<td>ties</td>
</tr>
</tbody>
</table>

**Vegetation:**

<table>
<thead>
<tr>
<th>Economic evaluation</th>
<th>Economic indicator</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- trees</td>
<td>1000-500€/tree</td>
<td>Municipalities</td>
</tr>
<tr>
<td>- shrubs</td>
<td>130-30€/shr/km</td>
<td>Municipalities</td>
</tr>
<tr>
<td>- grass</td>
<td>440€/ha/year</td>
<td>Municipalities</td>
</tr>
<tr>
<td>- soil</td>
<td>550€/ha/</td>
<td>Environment authorities</td>
</tr>
</tbody>
</table>

---

37 Indicators indicative; to be discussed only
<table>
<thead>
<tr>
<th>Category</th>
<th>Unit</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>- biota</td>
<td></td>
<td>CV/WTP?</td>
<td></td>
</tr>
<tr>
<td>Fuel savings, %</td>
<td></td>
<td>Road auth.</td>
<td></td>
</tr>
<tr>
<td>Fuel efficiency, litres/100 km</td>
<td></td>
<td>Road auth.</td>
<td></td>
</tr>
<tr>
<td>Monetary value of fuel savings</td>
<td>2.20€/100 kms</td>
<td>Road auth.</td>
<td></td>
</tr>
<tr>
<td>Travel time saving</td>
<td>13 - 11€/for auto/bus travellers</td>
<td>Road auth.</td>
<td></td>
</tr>
<tr>
<td>Accident cost saving:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- per fatality</td>
<td>1850000€</td>
<td>Insurance companies</td>
<td></td>
</tr>
<tr>
<td>- per injury</td>
<td>33000€ 6600€</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction in liability claims</td>
<td></td>
<td></td>
<td>Environment and road authorities</td>
</tr>
<tr>
<td>Maintaining economic-activities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Reduction in production losses</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>- Reduction of losses in good shipments</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>- Cost of trucking activities during severe storms</td>
<td></td>
<td>Road administration, Field studies</td>
<td></td>
</tr>
<tr>
<td>- Reduction in wage losses (lateness to work)</td>
<td>40€/hr/worker</td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>- Wage loss due absenteeism from work</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>Access to social activities</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>- Emergency response time</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
<tr>
<td>- Possibilities to part. in social activities</td>
<td></td>
<td>Field studies</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2

Questionnaire

THE ASSESSMENT OF THE IMPACTS OF ROAD WINTER MAINTENANCE ALTERNATIVES IN THE LAHTI AQUIFER

Questionnaire

The use of salt in road winter maintenance easily increases NaCl – concentration in groundwater. In Finland, the use of salt was at its highest level in 1990's. Since then the purpose has been to decrease the use of the salt and, at the same time, environmental damages caused by the salting. This questionnaire is a part of a study, in which the economic impacts of the road winter maintenance in the Lahti region will be assessed. The questionnaire is a part of an EU-project, in which, applying the Water Framework Directive, threshold values for groundwater are investigated and their socio-economic effects are assessed.

Four alternatives are studied:

ALT0: Road salting on the level of 2005
ALT 1: The use of salt is decreased considerably till 2011
ALT 2: Road slopes to supplement road salting
ALT 3: The use of an alternative chemical

The purpose of this questionnaire is to find out the attitudes of principal stakeholders towards the road winter maintenance (Part I), and to collect basic data concerning the Lahti region necessary in the economic analysis (Part II). In Part III you may make supplementary comments concerning the road winter maintenance. The inquiries are made by phone. Connecting persons of the study are Marja-Leena Kosola, researcher in SYKE, tel (09) 4030 0341, e-mail marja-leena.kosola@ymparisto.fi and Juhani Gustafsson, senior researcher in SYKE, tel. (09) 4030 0442, e-mail juhani.gustafsson@ymparisto.fi.

Part I Road winter maintenance alternatives

Theme: Objectives to reduce the use of salt

The salt used in the road winter maintenance has, on the national level, reduced according to statistics 1990 – 2004.
a) Do you think that the objectives to reduce the use of salt has been reached in the Lahti region? What about on the public roads like on the Highway 12?

b) If the goals have not been reached, what do you think the reasons are?

Theme: The decrease of the use of salt till 2011.

The road network in Finland has been divided into specific winter maintenance classes. Into the highest maintenance class (Is) belong the roads which are kept totally without snow in the wintertime. Into the next maintenance class (I) belong the roads which most of the time are without any snow. In the third category (Ib) the maintenance of the road is of high quality, but no salt is used. The road surface may, depending of the road traffic and weather conditions, be partly bare, or there may lie some heaps of snow on the road.

Do you see that the use of salt should be reduced on the research area till 2011 despite of the fact that this makes the road conditions worse in wintertime? Choose the preferable alternative in Table 1.

### Table 1.

<table>
<thead>
<tr>
<th>Public roads</th>
<th>In the road quality classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Is -&gt; I (Change)</td>
</tr>
<tr>
<td></td>
<td>I -&gt; Ib (Change)</td>
</tr>
<tr>
<td></td>
<td>Is -&gt; Ib (Change)</td>
</tr>
<tr>
<td>To be accepted</td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td></td>
</tr>
<tr>
<td>Maybe</td>
<td></td>
</tr>
<tr>
<td>Without any doubt</td>
<td></td>
</tr>
</tbody>
</table>

How much the use of salt could be reduced per year in average? _______ tons/year

Comments
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Theme. Increasing the use of the road salting.

a) Do you think that the use of the road slopes should be increased till 2011?

b) For which public roads they should be built?

c) How many meters or kilometers they should be built in the case study region?

Theme. The use of calium formate in road winter maintenance.
a) Do you think that the use of calcium formate or some other chemical suitable for winter maintenance should be increased till 2011 on public roads?

b) On what parts of the roads the use of calcium formate or a corresponding chemical should be utilized?

c) How much (tons/year) it should be used?

Theme. The simultaneous use of road winter maintenance measures.

a) Do you think it is possible to use road slopes simultaneously with road salting?

b) Do you think it is suitable to use calcium formate simultaneously with road sloping?

c) Do you think that it would be possible to utilize road slopes instead of road salting?

d) Is it possible to replace the use of salt with calcium formate?

e) What would be the optimal combination of specific techniques like road salting, road slopes, calcium formate (in %)?

f) Does this demand ad hoc –consideration?

Part II. Impacts of road winter maintenance

Traffic safety

2.1 How many traffic accidents did happen in 2004 – 2005 in the Lahti region?

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident to death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident to injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal injuries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property damages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other damages like collisions with animals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

How many of these happened due to slippery winter conditions on the roads?

<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident to death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accident to injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal injuries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property damages</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• Other damages like accidents with animals _____ _____

Comments
_______________________________________________________
_______________________________________________________
_______________________________________________________

Environment

2.2 Has the use of salt in road winter maintenance caused damage to

a) groundwater; describe the quality (NaCl; other pollutants) and the quantity of the damage;

b) surface water; describe the quality and the quantity of the damage;

c) the wells in the region; describe the quality and the quantity of the damage;

d) damages to the soil; describe the quality and the quantity of the damage;

e) damages to the animals as collisions with elks; describe the quality and the quantity of the damage;

f) damages to the costal fishery; aquatic vegetation; micro-organisms; describe the quality and the quantity of the damage;

g) damages to the road side vegetation like trees, bushes or grass; describe the quality and the quantity of the damage;

h) other damages; describe the quality and the quantity of the damage;

Infrastructure and the stock of vehicles

2.3 Road salting causes corrosive damages in metal constructions like bridges, parking halls and garages and in the underground drinking water and sewage network. According to a Canadian research about 1.5% of the metal construction of bridges and about 1% of floor surfaces of the parking halls and garages made of metal presume yearly maintenance because of the corrosion damages due to road salting. How much is it necessary in the case study region to yearly remediate or maintain

• metal constructions of bridges, m2
• metal floor surfaces in parking halls, m2
• metal floor surfaces in garages, m2
• underground drinking water and sewage network, m
2.4 Road salting causes damages for the vehicle stock, too

a) How large are these damages (e.g., how many vehicles per year have to be protected against corrosion)?

b) How many vehicles are there in the study region damaged by corrosion?

Traffic fluency

2.5 The Finnish Road Administration has proved in its studies concerning the road winter maintenance (Rönnholm et al.) that the use of the petroleum of a car on a slippery, snowy and uneven road surface is about 15 % higher compared to the consumption on dry, bare and even road surface. How much and in what way would you estimate the specific road winter maintenance alternatives to influence the fuel consumption of the road users in the case study area in average? Compare with a hypothetical situation with no road salting.

<table>
<thead>
<tr>
<th></th>
<th>Increases</th>
<th>Decreases</th>
<th>How much</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALT0: Road salting on the level of 2005</td>
<td></td>
<td></td>
<td>ltr/100 km</td>
</tr>
<tr>
<td>ALT 1: The use of salt is decreased Considerably till 2011</td>
<td></td>
<td></td>
<td>ltr/100 km</td>
</tr>
<tr>
<td>ALT 2: Road slopes to supplement road salting.</td>
<td></td>
<td></td>
<td>ltr/100 km</td>
</tr>
<tr>
<td>ALT 3: The use of an alternative chemical.</td>
<td></td>
<td></td>
<td>ltr/100 km</td>
</tr>
</tbody>
</table>

2.6 The Finnish Road Administration has proved in its studies concerning travel time (Kalenoja and Mäntynen 1993) that the use of salt would increase travel times about 1 – 5 %. How much would you estimate that the road winter maintenance influence a road user's average travel time in the study area? Compare with a situation of no road salting.

<table>
<thead>
<tr>
<th></th>
<th>Increases</th>
<th>Decreases</th>
<th>How much</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALT0: Road salting on the level of 2005</td>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>ALT 1: The use of salt is decreased considerably till 2011</td>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>ALT 2: Road slopes to supplement road salting</td>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>ALT 3: The use of an alternative chemical.</td>
<td></td>
<td></td>
<td>min</td>
</tr>
</tbody>
</table>

2.7 How large was the stock of vehicles in the case study area in 2004 – 2005? What about the amount of traffic? (M road-kms)?
2004 2005

Stock of vehicles (amount of vehicles)
- Personal cars
- Trams, lorries
- Motor cycles, mopeds
- Other vehicles

Traffic amount (Mroad-kms)
- Traffic amount

2.8 According to the Action Plan of 2007 – 2011 of the Finnish Road Administration the amount of traffic increases about 15 % till 2011 on the national level. How would you estimate the traffic amount to change in the study region on the same period?

Grows more □  Grows less □

III Comments

__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________
__________________________________________________________________________________________

Stakeholders interviewed

Häme Road District
Häme Regional Environmental Center
City of Lahti
LV Lahti Water Ltd.
Finnish Road Enterprise
Finnish Road Administration (Central Administration)