Environmental aspects of road de-icing technologies

B.Jelisejevs, M.sc.ing, researcher, Riga Technical University
V. Urbanovichs, M.b.a., chairman, SJSC ”Roads of Central Region”

Abstract

This article contains analytical information about environmental impact of de-icing technologies, with particular focus on present methods accepted for routine maintenance of Latvian state road network. There is a general comparison between the existing methods (prewetted salt and abrasives) and alternative technologies (other inorganic and organic chemicals, deicing liquids) from the ecological point of view. The ways of soil, air and water pollution with these materials as well as impact's severity and lasting effects are discussed.

Unfortunately, most of environmental impacts have subjective qualitative nor measurable criteria, which make more difficult cost/benefit analysis of competent ice control methods. The only objective judgement may be concerning reversibility of these impacts and financial evaluation of possible mitigative measures. De-icing activities may have various direct and indirect disclosures on the environment. They are exactly connected with climatic conditions, which from the one side they reflect frequency of the needed ice control measures and from the other hand they provide a dissolving substance (atmospheric precipitation) for the counteraction of chemical pollution. It is clear, that any action with use of automotive equipment and emission of technological materials to the surrounding have an effect on it, but till this moment that is not advised from the level of ecosystems, which impedes a creation of discrete models for the support of decision making in technological aspects of ice control.

State of the art in this field mainly conceives reactive experience concerning road salting as the mostly used ice control measure, so it is still in information gathering and knowledge acquisition stage (monitoring of discovered evident ecological problems and attempts to mitigate them). Therefore, optimization of ice control technique considering environmental aspects, is a relevant challenge for road maintenance sector.

This paper is partly based on the results of the research “Evaluation of alternative chemicals for deicing of Riga main streets” 2003. Up today, there is no particular monitoring data concerning environmental impact of road deicing measures in Latvia, because their background is under the margins of official econorms. That is because road salting as ice control basis was implemented since 1996., so, its accumulative effect still is not fully appreciated, but may appear in future.

The main conclusion is that road salt is harm for roadside vegetation, but it's homogenous background and specific weight in overall pollution to environment (especially in urban areas) is not significant or unpriced. However, it is distinctive in several places due to local geological features (well's pollution) or sensitive roadside vegetation. The utilization of organic or abrasive materials as a direct alternative of salt is not absolutely harmless, they have only different mechanism of environmental impacts and these technologies are more expensive too. Salt is deemed as basic de-icing chemical for Latvian roads due to functional, climatic and financial considerations. Until there is a compromise between a service level of winter roads and byeffects of its providing, the real potential for mitigation environmental harm of salt is in a complex of decreasing measures for annual salt consumption in certain maintenance area, including: implementation of anti-icing strategy, improvements in logistic and storage of de-icers, reduction of salt spreading for road sections in notably sensitive territories. The factor of deicing salt, of course, should be taken into account for roadside green works, requiring special soil treatment and expansion of salt-tolerant vegetation, where it is urgent.

Introduction

Ice control on winter roads is important part of road routine maintenance program in snowy regions. It is necessary to maintain effective mobility in road network, namely to maintain traffic uninterrupted, fluent and safe, but it has also negative byeffects (corrosive and environmental impacts). It is clear, that any action with use of automotive equipment and emission of technological materials to the surrounding have effects on it, which are divided into primary and secondary impacts. Abrasives, corresponding on their origin, are a sources of additional dust in air, but concerning de-icing reagents, their primary effect on environment is: affecting of soil and ground water, in which increase concentrations of corresponding chemical elements (inorganic materials) or increasing of nutritious substance and biochemical oxygen demand as well as gas emissions (organic materials). These principals initiate secondary impacts, which cover flora and biota and initiate changes in existing environmental balance.

State of the art in this field mainly conceives reactive experience concerning road salting as the mostly used ice control measure, so it still is in knowledge acquisition stage (monitoring of discovered evident ecological problems and attempts to mitigate them). Almost all environmental impacts have subjective qualitative nor financial evaluation, which make more difficult comparative analysis of competent ice control methods. The only objective judgement may concern reversibility, principal severity of these impacts and fiscal evaluation of possible mitigative measures. Up to now, environmental aspects of ice control are not advised from the level of ecosystems, which impedes a creation of unified expert systems for the support of decision making in de-icing technologies, therefore optimization of ice control technique considering environmental aspects is a relevant challenge for road maintenance sector.

Up today, there is no particular monitoring data concerning environmental impact of road deicing measures in Latvia and analysis of common environmental data don't indicate their influence, because their background is under the margins of official econorms as well as no widely spread effects noticed. That is because road salting as ice control basis was implemented since 1996., so, its accumulative effect still is not appreciated, but may appear in future. However, it'll be incorrect to disclaim advanced ecological loading of road salting on roadside area and particularly on its vegetation. In this case, it is essential to define correct tasks to be achieved, concerning environmental impact of modern ice control. Hereby, roadside greenery has to be spruce and without serious damages for visual perception, but it is impractical to raise strict qualitative requirements for that.

Environmental approach to ice control

There are many different technologies of de-icing, based on utilization of abrasives and chemicals, which are comparatively characterized by the following means:

- functional properties (including compliance with climatic conditions, lasting effect, provided pavement grip value, melting properties of chemicals);
- expenses (including all associated direct expenses to provide certain service level of a road by a certain technology);
- byeffects (corrosive, environmental impacts).

The two first factors are technically objective and well-known, therefore they are prior for road authorities in decision making process, but collateral effects in their turn are not so clear and discrete, so they are usually are underestimated. From the economical point of view, the effectiveness of road de-icing may be defined though cost/benefit analysis (table 1.). Indirect costs are not simultaneous and their consequences are not visible in short time perspective, therefore they have to be considered on a life cycle basis. It follows, that environmental impact of ice control measures depends to the indirect society costs and its amount is unclear for overall fiscal valuation. Some of environmental impacts are irreversible, and have only qualitative indicators of changes. Therefore, the analysis of de-icers can be based on principal comparison by a mechanism of impacts, taking into account possible corrective measures (soil treatment, replacement of damaged trees and shrubs etc.).

Table 1.

Breakdown of costs and benefits of ice control measures, using de-icers

COSTS	BENEFITS
Direct (technological): • Material cost • Equipment cost • Labour cost	Direct (to road user): • Fuel savings • Travel time savings • Minimize probability of road accidents
Indirect (to society): • Cost to infrastructure • Cost to vehicles • **Cost to the Environment**	Indirect (to society): • Reduction in macroeconomic losses due to higher traffic safety • Maintain the economic activity • Maintain access to social activities and emergent needs

Road de-icing is not only a position of costs, it has also some indirect environmental benefits. Driving in bare road conditions allows savings in fuel up to 33% as compared to when roads are snowy/icy, therefore combustion's emissions of vehicles (CO_x, NO_x, stable organic compositions and other) are accordingly less at the same level of traffic. High level of accessibility on roads under advanced ice control increases the effect of emergent actions, which lead to mitigation of common environmental hazards.

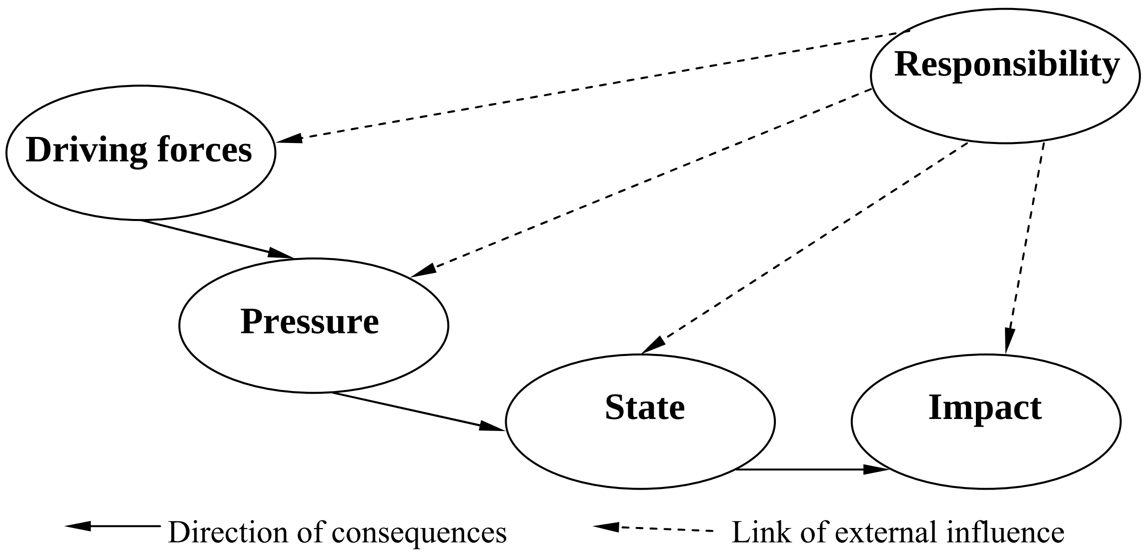


Figure 1. DPSIR model for environmental decision making

Principally, ice control's influence on the environment and possibilities to regulate that can be described by a DPSIR model, so, it is a system of 5 interconnected elements (fig.1.), in which:

- Driving forces (D) – social needs (effective and safe mobility) of road de-icing, which are technically reflected in a standard of winter road maintenance;
- Pressure (P) – exposure to environment of de-icing materials;

- State (S) – primary influence (changes in natural balance of soil, air and water) as a result of de-icing activities;
- Impact (I) – condition of several elements of environment (subjects of flora and biota) under the primary influence of de-icing measures, further secondary influence (problems on the level of ecosystems), which leads to essential changes in environment;
- Responsibility (R) - awareness of the interaction between environment and road de-icing to manage that accordingly to ecologic consideration.

Road authorities in collaboration with ecological institutions and society (via NGO) have a responsibility to regulate this process on all stages through: setting of environmental requirements, changes in existing ice control's approach and implementation of countermeasures. In any case, that negotiation leads to acceptable compromise between: desirable service level of a road, available financing and environmental concern. The guidelines for this process must be set up from the point of view of sustainability, namely, high level of mobility must not degrade the environment.

Technologies of road de-icing

International experience shows that bare pavement policy is the most adequate for heavy trafficked motorways, but local roads are enough to be passable in winter. The providing of required road conditions need snow cleaning activities and corresponding de-icing measures. There is a description of de-icing technologies, specified for Latvian state roads (table 2.). These methods are widely spread and well experienced throughout the world and they are considered as more adequate for securing effective and safe traffic in Latvian road network by climatic and financial means.

The absolutely different approach to de-icing with spreading of materials on a pavement is a strategy of spiked tires without intensive use of de-icers, but due to many reasons (loss in mobility, pavement wear, climatic considerations) it can't be disputed as comparable to the use of de-icers. Other principal alternatives, as road heating or special counter-icing pavements also can't be massive alternative at the moment.

Table 2.

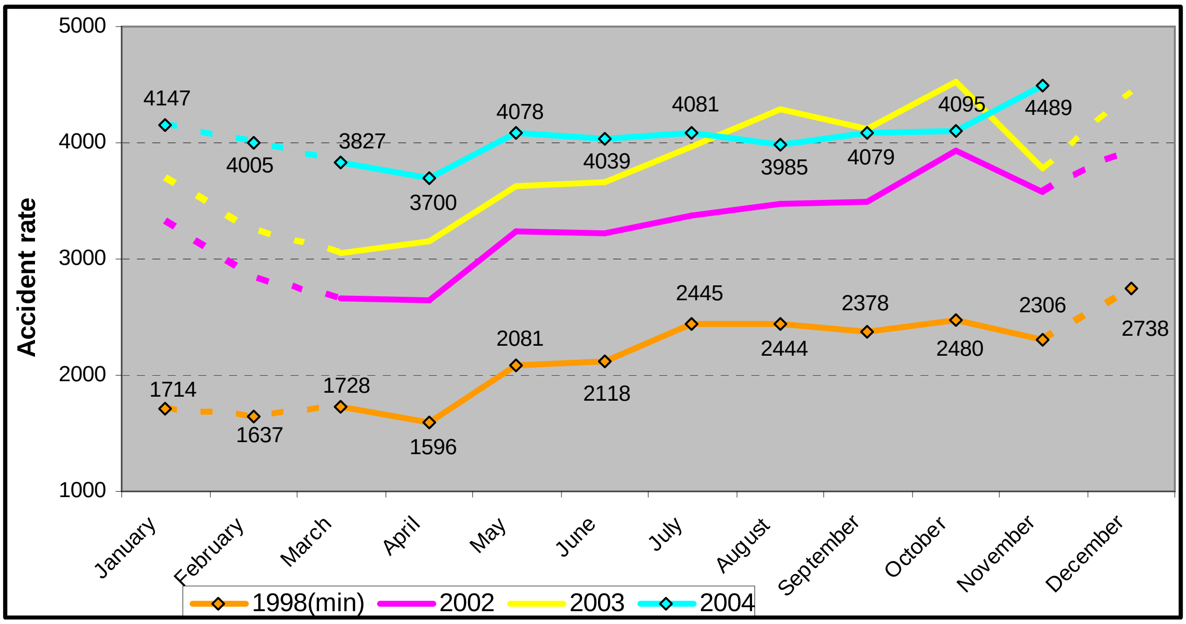
De-icing technologies specified for Latvian state road network

De-icing technology (by used material)	Consumption of materials at a single treatment, $g./m.^2$	Effective in climatic conditions
sand/salt mixture (9/1)	190 – 320	$-6^0C > t > -10^0C$, continued precipitations
sand or crushed aggregate	320	$t < -10^0C$
Prewetted salt (NaCl)	5 – 30	$t > -10^0C$, black ice, freezing rain, frost, snow
Solution (NaCl, $CaCl_2$)*	15	$t > -3^0C$, black ice, frost
Ice grinding **	--------	$t < -8^0C$, snowpack on the road

Remarks:
* - de-icing with liquids is specified, but not really experienced in Latvia;
** - ice grinding is in very limited use on local roads due to unstable winter conditions.

De-icing with prewetted salt and sand/salt mixture using modern universal equipment with programmed parameters of spreading are more wide used technologies of ice control on Latvian roads. The using of salt is more preferable from the economic point of view, than abrasives. De-icing with sand/salt mixture is 2,2 times more expensive and 10 times more material consumptive than ice control with prewetted salt. It also need additional works after winter season (road band and drainage should be cleaned from deposits). By the functional mean, abrasives provides only up to 40% grip improvement of icy road, when snow melting chemicals bring this indicator nearer to 100% (bare pavement), therefore salt spreading is a major measure of ice control on primary Latvian roads, but abrasives are mainly used at low temperatures (when salt spreading is not effective) and for spot treatment (crossings, curves, high embankments) on local roads.

As shown on Figure 2., despite of remarkably more hazardous driving conditions during winter, traffic accident rate in this period is not higher than annual average rate. Statistic of traffic safety on Latvian roads in a period of 2002. – 2004. shows: average monthly amount of traffic accidents is 3707 (100%), while in winter it is 3642 (98,2%). That is partly related to traffic deactivation in winter, but also indicates considerably high level of routine maintenance on winter roads, which can’t be sacrificed to manage related collateral aspects and impacts of ice control.



Remark:
dotted line describes annual period under ice control measures.

Figure 2. Statistic of overall traffic accidents on Latvian roads

Since conventional de-icing with abrasives and snow melting chemicals can’t be ceased or replaced with equivalent measures and the present level of service is undesirable to decrease, the main attention is to be paid for more optimal de-icing with known materials.

Mechanism of influence of de-icers on environment

Abrasives contribute air contamination with dust particles (environmental problems: human health – allergic reactions, vegetation – photosynthesis and worse quality of top soil), depending on origin of the material, but they don’t change existing chemical balance in environment. The precise share of dust emission in air through the de-icing is unknown, because of many other sources of these particles (wear of pavement and tires, industrial sources and so on). Natural or sieved sand only are abrasives for road de-icing in Latvia. Sand particles don’t tend to brake into smaller ones (unlike crushed aggregate), therefore dust from that can be reduced, through elemintaing (wet seiving) of small (less 1mm) particles. Accordingly to national econorms safe contents of suspended particles (PM_{10} indicator) in air is 49µg/m^3 and outside big cities and industrial centers along motorways that is under the recommended margin. However, for instance, in the centre of Riga it is excessive

(PM_{10}=60µg/m^3). Spreading of abrasives has about 10 times higher material consumption, therefore spreaders mileage and emissions of their engines as well as dust particles from corresponding wear of tires and pavement are accordingly higher, than for salt spreading. Further, abrasives are out of the detailed study.

De-icing chemicals have more advanced environmental impact than abrasives, therefore they need in-depth study. For effective melting of ice road salt (NaCl, sodium chloride) or another reagents need to be exposured on pavements in amounts, exceeding ecological norms. After reacting with ice, there appear water solutions of chemicals with high beginning concentration of substance (20 - 35%), that consequently decreases as a result of natural dilution with water from surrounding. De-icing chemicals have two basic arrival paths to environment due to slopes of road surface:

- solutions by direct ways arrive to watercourses (runoff from bridges and drainage systems);
- solutions arrive to roadside soil (dependent on type of reagents, they may to crystallize and form deposits or continue vertical filtration in liquid form).

The first path is limited due to few such occurencies throughout the whole road network. The background of chemicals is difficult to control in mainly crossed watercourses, where de-icers are diluted with permanently flowing water (rivers, brooklets), but at the same time, limitation and localization of these objects let to implement specific measures to decrease or avoid direct runoff of de-icers to watercourses.

De-icing chemicals reach roadside soil by transitional way (in sequence of decreasing a share in whole process and increasing of transitional distance) as follows: a runoff of melted ice, a result of lateral movement of polluted snow from the pavement, splash of liquids / movement of suspended drops of liquids in air. Therefore, considering linear character of roads, contents of de-icers in roadside soil decrease with increasing of range from the pavement and distinctively polluted with de-icers are narrow strips of roadside soils (5-10m.), which usually have no means of agricultural or forestry utilization and are parts of road band.

Inorganic commercial de-icers are represented by chlorides (NaCl, $CaCl_2$, $MgCl_2$, KCl), which exist in nature in different compositions and are characterized as relatively passive chemicals. These substances don’t form volatile matter, therefore they don’t affect air quality in any action at natural conditions. Their content in soil and groundwater of specific area depends on natural level of mineralization, level of pollution and accumulative/dilutive process affected by geologic features and water circuit. Chlorides make dissociated solutions in contact with water, namely break down into cations Na^+, K^+, Mg^{2+}, Ca^{2+} and anion Cl^-, and in this form they are catched by organisms (here it means roadside vegetation as directly and hardly affected environmental subjects by de-icing). Metals of cations are needed for growth, but chlorine is not involved in biologic processes and serves as ballast element, which has a trend to accumulate. If its content increase and exceed acceptable margins (which are individual and oscillate in wide range, depending on organism’s origin), metabolism get slower and toxic reactions may occur. Substances, which natural form is solid, aim to restore it, forming deposits (NaCl, KCl), affecting chemical content and density of soil. Chlorides, existing in liquid or hydrate forms ($CaCl_2$, $MgCl_2$) have less direct impact on roadside ecosystem, because of more intensive migration of solutions inside the soil. Soil monitoring showed that if the use of chlorides is interrupted, their specific weight constantly decrease, so this kind of pollution is reversible.

Concerning perspectives of organic de-icers, advised alternatives to road salt are chemicals from groups of acetates and formiates ($[CaMg_2(C_2H_3O_2)]_6$ CMA, $KC_2H_3O_2$ KAc, $NaCH_2O_2$ NaFo), which are positioned as more friendly to environment, than chlorides. These chemicals also break in water into cation and anion and have common principal mechanism of action: when substance is diluted in water and come out of pavement, combined organic anions $C_2H_3O_2^-$ (actates) and $CH_2O_2^-$ (formiates) are not stable and biodegrade, influenced by bacteria. That means realizing of H_2O and CO_2 and this process require BOD (biochemical oxygen demand) 0,5-1,0 g. from the surrounding for 1g. of the chemical. Decomposition time of complex organic anions in soil varies, accordingly to various external factors (temperature, humidity etc.) and may reach some months. Laboratory tests showed, that after 5 weeks until the application, 70% of acetae's anion broke down, when for formiate this indicator is 82%. Namely, soil and water are affected in more delicate way concerning its chemical content and with temporary influence, but excessive nutrition and gas emissions from the other part are negative ecological factors.

Additives of de-icing chemicals (inhibitors of corrosion, anti caking agents etc.) are out of sope of this paper, because they have far less environmental concern, comparatively to de-icers ones, which is a subject of special study. Similar approach is fair for combined commercial de-icing products under original trademarks (mixtures of principal chemicals), which have environmental impacts equivalent to impacts of their components, nor something absolutely individual.

Environmental impacts of de-icing chemicals

Concerning environmental impact of chemical de-icers, main attention is to be paid to their different impacts on air, water and soil as well as particular emphasis is on road side vegetation as hardly affected environmental sector. Impact on human's health and biota is a more complicated derivation of these principal impacts and needs more detailed studies.

Impact on soil (in aspect of roadside vegetation)

Vegetation (trees, shrubs, grass) in road band and neighbouring areas is of high esthetique meaning and fulfills many other functions: protection of soil from erosion, screening of traffic emissions and noise. Monitoring of tree's greenery in Riga along the streets (not really correspondive for motorways outside cities) concluded: remarkably affected by salt are nearest to pavement separately placed trees, due to localization of road salt deposits. Salt effects soil thus: it becomes denser; decreases its permeability; increases its perceptivity for water; its pH level meet changes towards alkaline state. This has the following negative consequences on vegetation: decreases access of water and oxygen to roots, which slower growing process, with simultaneous absorption of chlorine in cells. If chloride's background is stable, toxic level can be reached after several years, which can be observable as damaged leaves and anticipatory falling of foliage. As a result, there is a decreasing in freeze resistance and immunity of trees, which in a complex with other aggressive factors of road leads to slower growing and shorter lifetime of roadside's trees.

Some de-icing products ($CaCl_2$, KCl, nitrogen contained Urea) are widely presented as harmless for vegetation and improving agents of soil quality. This is a controversial point, because of mentioned effects are reached at targeted annual agricultural dosage (25-60g./m^2), while due to ice control in roadside it can reach (100-300g./m^2), so toxic reactions on vegetation are similar to salt usage have to be initiated, while consumption of these materials can't be decreased (ice melting capacity is equivalent or less than for salt).

Acetates and formiates have no long lasting impact on vegetation and are advisable for use near the sensitive greenery, although the process of their decomposition is not fully known. Some disputed facts need to be taken into account: depending on external factors, decomposition may occur in soil, subtracting oxygen from the herbage; soils, affected by organic chemicals, demonstrate a decrease of NO_3-N and PO_4-P vitamins.

It's to be noted, that in winter vegetation is in a sleep mode and absorbs minimum water and respectively pollutants, but annual growing process begin in April/March, so chlorine's content in soil in this period mainly affects greenery, therefore salt spreading in the end of ice control's season is to be as prudent as possible.

Impact on water resources

The mechanism of contamination of surface and ground water with de-icing chemicals is evident, but impacts of de-icers on water courses are localized and mainly depend on parameters of natural water exchange in their. Big practical meaning is for awareness about how de-icers affect resources of drinking water. Potential objects for this impact are individual wells near the salted motorways, but up to now no concrete information (also complaints from inhabitants) gained about that. Concerning cities with centralized water supplement, it can not be problem, because of professional water treatment, however, for instance, water in river Daugava in taking place for water supplement for Riga city characterized with the following parameters: Na^{+} - 4 mg/l. (sanitary norm - 200 mg/l.), Cl^{-} - 4mg/l (norm - 250 mg./l.), therefore, it doesn't initiate ecological problem and impact of road salt here must not be overestimated. Available monitoring data, concerning condition of Latvian watercourses didn't shows excessive background of road salt there, but potentially the problem may occur in closed to salted roads small watercourses without natural water circuit (ponds, lakes).

Acetates and formiates as organic matter, in their turn are suppliers of excessive nutrition and consume relevant amount of oxygen, which accelerates eutrophication of watercourses, therefore their massive implementation with prescribed discharge of melt water in watercourses is doubtful.

Impact on air

Road salt as well as other chlorides don't influence air quality, although in certain climatic conditions (fog, high air humidity) drops (spray) of their solutions may be suspended in air as a transitional way to soil or vegetation. Formation of salt dust as a wearing product of previously salted dry pavement is not estimated, but hypothesis can be made about its absence, because of hygroscopic nature of salt (trend to absorb water and become heavy for continuous suspension in air). There is so-called technical salt used for road de-icing in Latvia, which by supplement standard holds up to 1% of insoluble mineral impurities (similarly to abrasives contribute dust formation).

Decomposition of organic de-icers connected with realizing of CO_2, which is greenhouse gas, having global impact on environment, moreover in urban areas it can be problem for human health. For example, in the centre of Riga its content is 58 $\mu g./m^3$ but normatively acceptable level is under 40 $\mu g./m^3$. Acetates in liquid form emit volatile compositions (ethers), which by themselves aren't toxic, but has a distinctive smell and may initiate human's allergic reactions.

Solving environmental problems of ice control

As shown above, environmental aspects of different de-icing technologies (by material) are characterized with many complicated factors, which can not be unequivocally evaluated for discrete comparative analysis, therefore objective is only principal comparison (table.3). The utilization of organic or abrasive materials as a direct alternative of salt for treatment of pavements is not absolutely harmless, they have only different mechanism of environmental impacts and these technologies are more expensive too.

Salt is deemed as basic de-icing chemical for Latvian roads due to functional, climatic and financial considerations. Until there is a compromise between a service level of winter roads and byeffects of its providing, the real potential for mitigation environmental harm of salt is in a complex of decreasing measures for annual salt consumption in certain maintenance area. The decrease in cumulative ecological loading of de-icers [C_{ov}] is possible to be performed through the minimizing of their emissions to environment:

- from the treated surfaces (pavements, paths); - [C_{pa}]
- from the dumping grounds of snow; - [C_{lo}]
- in the process of logistics and storage of de-icers. - [C_{lo}]

This process can be expressed as a target function of minimization annual consumption of de-icers to specific indicator of treated roads (km of lane or m^2):

$$f = C_{ov} = \sum C_{pa} + \sum C_{lo} = \blacktriangleright \text{ min. (1)},$$

Concerning localized objects the target is reached with corresponding technical improvements of technological infrastructure (warehouses, maintenance bases). For example, SJSC "Roads of Central Region" implemented a program of improvement storage and handling of de-icers, by which all chemicals are handled in closed storage space with solid impermeable floor, and the same principle now in progress, concerning abrasives and sand/salt mixture. Despite of needed investment, this measure is also cost effective for contractor, because let to maintain de-icers in acceptable conditions all the time and to do job better.

For treated areas in their turn, amount of applied salt to reach specified level of service mainly depends on weather conditions, but possibilities for its minimisation is widening of technological range to meet the needs with minimal amount of de-icers: preventive measures and application of de-icing liquids, namely that means gradual transition from de-icing to anti-icing policy in road maintenance. Now, preventive actions are enforced mainly in obvious situations, but its implementation as a basis of ice control in Latvia need many activities else. Anti-icing policy is not easy to implement, because this is step outside the present universal approach towards more individual approach. Decrease in quantity of de-icing at the same level of service need more precise weather forecast, but liquids need to be stored and applied differently from the solids. At the same time, existing technologies can be replaced with liquids only in about 50% of hazardous road conditions. So, regardless of anticipated savings of de-icers, overall direct expenses are expected to be higher, due to increasing organisational efforts.

Figure 3. shows principal data of salt consumption in annual de-icing measures on state roads (cumulative amount, including salt's part in sand/salt mixtures). Up to 1995. road de-icing were based mainly on use of abrasives, that explains minimal salt consumption, but use of prewetted salt was gradually implemented in the next several years. Since 1999. new road winter maintenance technical regulations were established, which claimed bare pavement policy on primary roads and accelerated salt usage. Accordingly to all maintained pavements, average annual salt exposure was approximately 650gr./m^2 in 2003., which is equaled to 3-35 de-icing activities for this period (depending on level of service of a road). Despite of uneven weather in last winters, optimal annual salt consumption for marked maintenance area should be stabilized at the level of already practically achieved 12 – 14 thous. tons per year. The index of winter severity as an indicator of performance evaluation, further can be modernized to contain a procedure for determination of adequate salting.

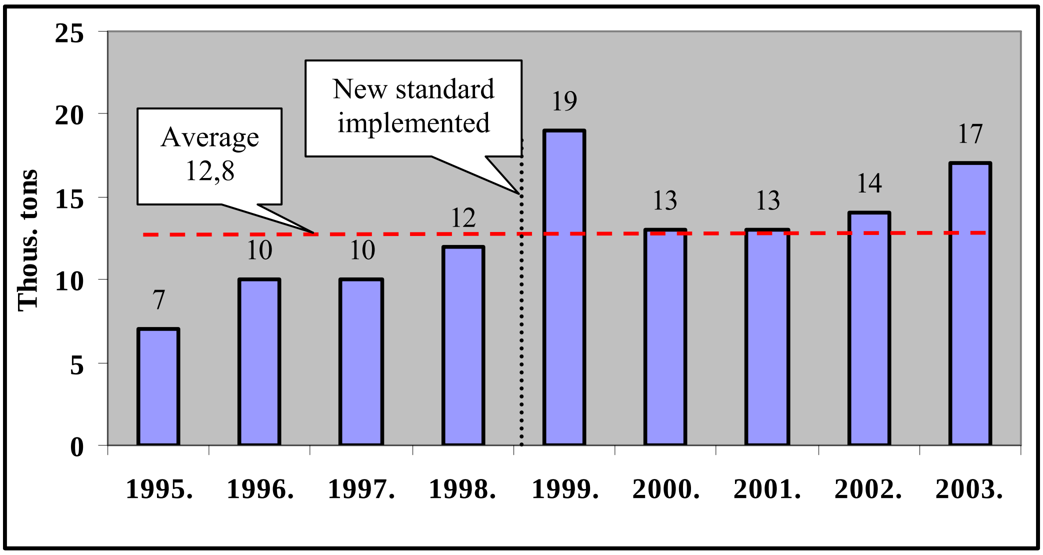


Figure 3. Annual road salt consumption in Central Region of Latvia

Comparison of de-icing materials from principal environmental point of view showed in table 3.

Table 3.

Overall environmental considerations of de-icers

Area	Environmental impacts		
	Chlorides	**Organic chemicals**	**Abrasives**
Air	Practically don't affect	Realize CO_2, emit a specific smell	Relevant source of dust
Soil	Tend to accumulate and change natural chemical balance	Short-term effect due to decomposition, smartly affect existing chemical background	Form deposits
Water	Increase concentrations of corresponding ions	Absorb oxygen, contribute eutrophication of water courses	Don't affect
Roadside vegetation	Repress growth at high concentration	Practically don't affect	Practically don't affect
Overall impression	Impact on roadside vegetation	Can contribute problems of water courses, worse air quality	Worse air quality
Conclusion	Need to be restricted near the sensitive vegetation	Can not be advised as absolutely better alternative for salt	Effective on local roads, pathways and pavements at adverse weather conditions

The factor of de-icing salt, of course, need to be taken into accounts for green works in roadside, requiring special soil treatment and expansion of salt-tolerant vegetation, where it is urgent, as counter measures of soil's contamination. Chemicals are accumulated in soil during de-icing season (November - March) and washed out by ground waters and precipitations in another annual period. Soil contaminated by salt can be restored by treatment with gypsum. Anent planting beds of greenery near the streets in urban areas, additional irrigation and loosening of topsoil in Spring are desirable. The factor of sensitiveness of species to chemicals and overall pollution must not be ignored in process of replacement of damaged trees. For instance, Riga municipality recently was faced with a problem of adaptation of new roadside greenery, which was represented by distinctively sensitive specie (lime -tree). Implementation of more salt toleranted species (oak, cherry-tree, poplar etc.) in that case let to minimize visual damage and growing problems of roadside vegetation.

References

1. Blomqvist G., De-icing salt and roadside environment strategies for impact analysis.// Tech. report on XIth PIARC winter congress, Sapporo, Japan, 2002.
2. Jeļisejevs B., Alternative methods of de-icing on highways.// ”Motrways” – Rīga 2001.g., III. – 31.-34.p. (in Latvian).
3. Road salts – Canadian environmental protection act. – Ottawa, 1999.
4. Backman L., Enviromental effects of chemical de-icing.// Tech. report on IXth PIARC winter congress, Seefeld, Austria, 1994.
5. Jelisejevs B., Environmental assesment of de-icing chemicals in Riga.// Scientific proceedings of RTU – 2003.g.
6. Nysten T., Helssten P., Migration of alternative de-icing chemicals in shallow aquifers.// Tech. report on XIth PIARC winter congress, Sapporo, Japan, 2002.

7. Ketcham S., Fleege J. Manual of Practice for an effective Anti-icing Program. – Virginia: FHWA, 1996.
8. Jelisejevs B., The modified technical regulation for road routine maintenance.// Scientific proceedings of RTU – 2004.g.
9. Gustafsson M., Non-exhaust particles in the road enviroment.// Tech. report on XIth PIARC winter congress, Sapporo, Japan, 2002.
10. Survey of Riga's environment in 2001. – Riga, 2002. (in Latvian).
11. Karaban G., Ratinov V., Road de-icing, using chemicals. – Moscow, 1976. (in Russian).

Environmental aspects of de-icing technologies

B.Jelisejevs, researcher
Riga Technical University

V.Urbanovichs, chairman
JSC “Roads of Central Region”

De-icers are evaluated by:

- **Functional properties (objective)**
- **Direct expenses (objective)**
- **Byeffects (some are unpriced)**

Breakdown of costs and benefits

COSTS	BENEFITS
Direct (technological): • Material cost • Equipment cost • Labour cost	**Direct (to road user):** • Fuel savings • Travel time savings • Minimize probability of road accidents
Indirect (to society): • Cost to infrastructure • Cost to vehicles • **Cost to the Environment**	**Indirect (to society):** • Reduction in macroeconomic losses due to higher traffic safety • Maintain the economic activity • Maintain access to social activities and emergent needs

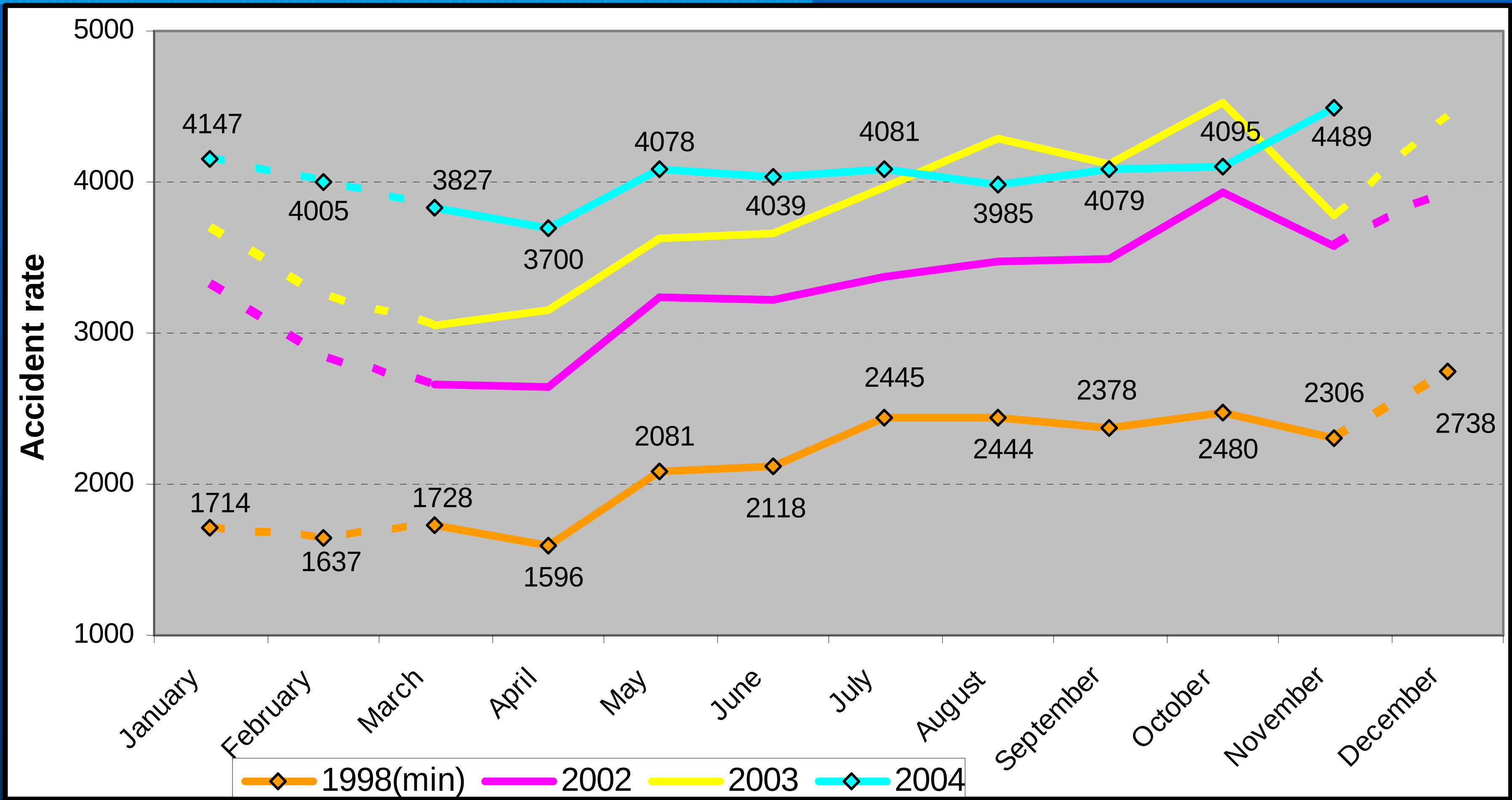
Environmental concern of de-icing by DPSIR model

- **Driving forces (D) – social needs for effective and safe mobility**
- **Pressure (P) – exposure of de-icers**
- **State (S) – primary influence (changes in natural balance)**
- **Impact (I) – condition of several environmental subjects**
- **Responsibility (R) – management of ecologic consideration**

Principles of environmental approach to road de-icing

- **Collaboration between road authorities, ecologic institutions and NGO**
- **Acceptable compromise between desirable service level, environmental concern and financing**
- **Sustainability (high mobility must not degrade the environment)**

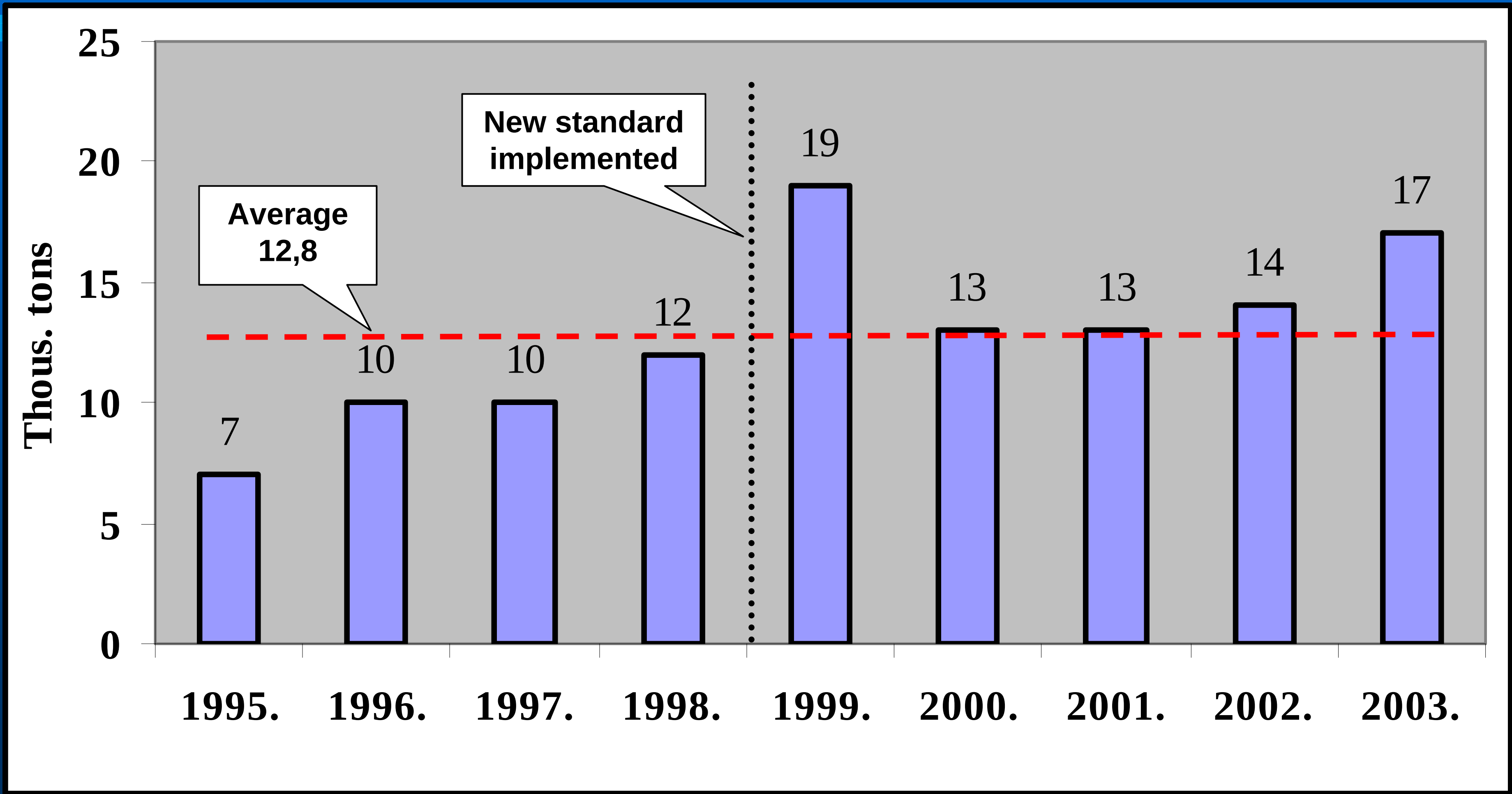
Accident rate on Latvian roads



De-icing technologies, specified for Latvian state road network

De-icing technology (by used material)	Consumption of materials at a single treatment, g./m.^{2}	Effective in climatic conditions
sand/salt mixture (9/1)	190 – 320	$-6^0C > t > -10^0C$, continued precipitations
sand or crushed aggregate	320	$t < -10^0C$
Prewetted salt (NaCl)	5 – 30	$t > -10^0C$, black ice, freezing rain, frost, snow
Solution (NaCl, $CaCl_2$)	15	$t > -3^0C$, black ice, frost
Ice grinding	--------	$t < -8^0C$, snowpack on the road

Annual consumption of road salt in Central Region of Latvia



Problems

- **Greenery in road band (especially for urban areas)**
- **Potential localized problems with sauce water (well’s pollution)**
- **Large - scale ecological risks still are not identified (due to short time of massive salting, since 1996.)**

Principal alternatives

- **Inorganic de-icers (NaCl, $CaCl_2$, $MgCl_2$, KCl)**
- **Organic de-icers (CMA, KaC, NaFo)**
- **Abrasives (sand, crushed aggregate, mixtures)**
- **Passive measures (studded tyres, speed limits etc.)**

Overall consideration of de-icers

Area	Environmental impacts		
	Chlorides	**Organic chemicals**	**Abrasives**
Air	Practically don't affect	Realize CO_2, emit a specific smell	Relevant source of dust
Soil	Tend to accumulate and change natural chemical balance	Short-term effect due to decomposition	Form deposits
Water	Increase concentrations of corresponding ions	Absorb oxygen, contribute eutrophication of water courses	Don't affect
Roadside vegetation	Repress growth at high concentration	Practically don't affect	Practically don't affect
Overall impression	Impact on roadside vegetation	Can contribute problems of water courses, worse air quality	Worse air quality
Conclusion	Need to be restricted near the sensitive vegetation	Can not be advised as absolutely better alternative for salt	Effective on local roads, pathways and pavements at adverse weather conditions

Solutions

- Decreasing of road service level in winter (inacceptable)
- Minimization of annual salt consumption at present or even higher service level
- Special road greenery oriented measures

THANK YOU !!!