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REDUST LIFE09 ENV/FI/000579
Action 4

Winter maintenance strategy with feasible additional measures
Final report

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1. Introduction – REDUST project and purpose of the Deliverable

Objectives of the REDUST (EU LIFE+) project were to **find best winter maintenance practices** in the fields of traction control, dust suppressing and street cleaning and accelerate their implementation to **reduce levels of respirable PM_{10} street dust in urban areas**.

The project aimed at efficient reduction of respirable PM_{10} street dust levels by **demonstrating the emission reduction potential and air quality benefits of the different practices** used in relation to winter traffic in Finland. During winter such practices included traction control (winter tyres, street sanding and salting) and snow plowing. Later on in the spring dust suppression and street cleaning were applied to reduce emissions from the street environment to the air. Based on the demonstration tests most efficient maintenance measures were selected for the strategy development. The associated costs of the improved measures were estimated and compared with the costs of the current state street maintenance. Where and when applicable improved measures were introduced in the REDUST cities and tested in practice during the project. Finally the project goal was to **develop and implement a strategy** to reduce levels of respirable PM_{10} street dust by means of better winter maintenance practices in urban areas in Finland.

The REDUST project was divided into six Actions:

Action 1: Demonstrations of best practices to reduce PM_{10} street dust by means of winter maintenance
- Action 1.1 Traction control practices (winter tyres, traction sanding)
- Action 1.2 Dust binding practices (dust binding solutions, dispersion techniques)
- Action 1.3 Street cleaning practices (mechanical & vacuum sweepers, street scrubbers, combinations)

Action 2: Emission estimations and mitigation potential of the practices

Action 3: Total PM_{10} emissions, reduction potential and cost estimations of the measures to support the strategy development

Action 4: Development and implementation of the feasible winter maintenance strategy to reduce street dust emissions compared with current state

Action 5: Communication and dissemination

Action 6: Project Management & Audit

The strategy development in Action 4 of the REDUST project aimed at finding the best set of practices to be used in urban areas to reduce harmful levels of respirable street dust. "Optimized street dust mitigation strategy" was developed utilizing the results of the demonstration testing and measurements in Actions 1 and 2. In Action 3 of the project, air quality benefits and costs of the optimized methods were estimated and compared with other practices (e.g. "business as usual strategy" or some lower ambition level strategy) to further support the development of a feasible strategy.

The three REDUST cities; Espoo, Helsinki and Vantaa have earlier documented the organization of each city's own winter maintenance and spring cleaning practices. These documents include information about the equipment and personnel, as well as about the methods used for the winter/spring traction control and maintenance. In addition, the methods that aim at reducing respirable street dust in springtime are described. These documents are summarized in Annex 1. In Table 1 current methods with some additional measures to reduce the formation and accumulation of street dust are compiled. The methods and practices currently used in traction control and dust mitigation in the cities are based on long experience and are well established. Also the methods and equipment in different cities are in general quite similar. Background information from different cities provided valuable information for the strategy development work.

The purpose of this paper is to (1) present the necessary components of a good strategy, (2) to describe the best tools to achieve successful strategy in street dust mitigation in different cities and (3) to review the strategy development work throughout the REDUST project.

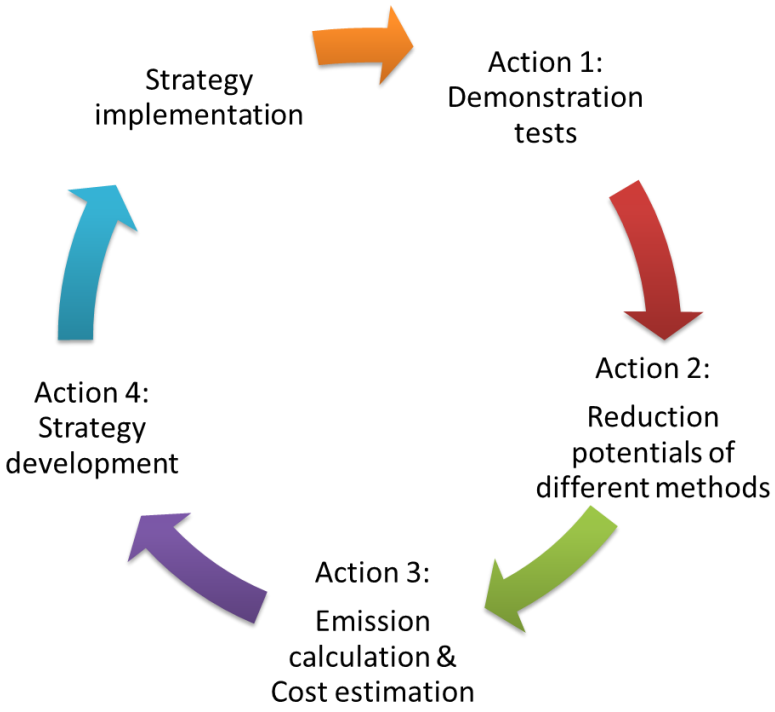

Figure 1. Project flow chart.

The Action 4 strategy development has been an iterative process that continued throughout the project. Actions 1-4 were carried out each year (Figure 1). The strategy incorporated new practices as soon as their efficiencies in reducing respirable street dust had been demonstrated. The implementation of the strategy work has been documented annually and this report will review the process. Findings of the REDUST project have been communicated to participant cities

through project meetings and yearly street dust seminars. REDUST has had an effect on winter maintenance strategies in participant cities already before the publication of the final reports.

Table 1. Different measures to reduce PM_{10} street dust emissions. In the REDUST project, the street dust effects of different winter tyres, sanding materials, dust binding and cleaning methods were studied.

Reduction of dust formation and accumulation on streets in winter
Winter tyres - less studded tyres and more studless friction tyres - shorter time period for the use of winter tyres - development of less dust forming studded tyres
Winter sanding - wear-resistant stone materials without fine grains (< 1-2mm removed) - targeted spreading only to problematic sites and times - use of de-icing salts instead of sand when possible
Pavement and street properties - wear-resistant and smooth pavements - easy-to-clean street environments
Traffic flow characteristics - less traffic - lower driving speeds
Constructions sites - prevention of dust-dispersion
Snow plowing and removal of snow from street environment - removal of dust containing snow from busy street environments
Co-operation and communication with different stakeholders - sanding, salting and plowing of street lanes, sidewalks, cycle paths and tram rails - co-operation with public organisations, companies and citizens
Reduction of dust emission from streets in spring
Dust binding - optimisation of spreading area (targeting), solution composition and timing based on street dustiness and weather conditions - early starting time in spring
Cleaning of streets - efficient cleaning techniques, combinations and procedures - early timing in spring and repetition later - development of more efficient techniques and their combinations
Co-operation and communication with different stakeholders - fluent cleaning of street lanes, sidewalks, cycle paths and tram rails - co-operation with public organisations, companies and citizens

2. Background information for strategy development

Background information concerning winter and spring maintenance as well as dust mitigation strategies was collected from the REDUST cities in the beginning of the REDUST project in 2011 (Annex 1). For many parts cities use similar methods in their winter and spring maintenance work, but for instance the characteristic street environments and available resources determine some city-specific arrangements. This chapter summarizes the relevant background information from Espoo, Helsinki and Vantaa.

2.1 Maintenance responsibilities and operational environment

The Finnish legislation (669/1978, Laki kadun ja eräiden yleisten alueiden kunnossa- ja puhtaanapidosta) requires the municipalities and real estate owners to keep the streets in a condition required for the needs of traffic. This comprises also winter maintenance actions needed to achieve this purpose, such as traction control and traction sand removal. Street cleaning actions in turn aim to keep the streets clean and in satisfactory condition from public health perspective. The distribution of maintenance responsibilities between cities and real estate owners vary somewhat between cities and also between different districts of the same city, when decisions relating to arrangements of maintenance have been taken locally.

These responsibilities originating from the legislation can be seen as major motivation to organize the winter maintenance and street cleaning actions by the municipalities in Finland. However, the legislation gives relatively much freedom for the municipalities themselves to decide how the operations are organized and there are several ways to arrange them. Therefore strategic considerations are essential to achieve good outcome for traffic safety, health and environment.

The need for strategic approach applies also to actions to reduce effects of PM_{10} road dust in street environments, which can be considered also to be motivated by, i.e. the legislation's notion that the street environment should be kept on a clean level that is satisfactory from public health perspective. A core aim of the REDUST project has been to develop and implement a feasible winter maintenance strategy to reduce PM_{10} street dust emissions. To achieve this task the project has systematically created in several project Actions the required knowledge base to support the development of the strategy. During the course of the project the beneficiary cities have already begun the implementation of the strategic actions to mitigate street dust. This paper reports the strategy development and its current state. Different actors are invited to use this report as a benchmark and continue their strategy work along the lines outlined in the REDUST project and this report.

Every city has their own urban characteristics which are reflected in the strategy work, and together with budget considerations they explain some of the different choices of equipment and material used in the maintenance work. Some key characteristics and organization of the maintenance work is presented in Figure 2.

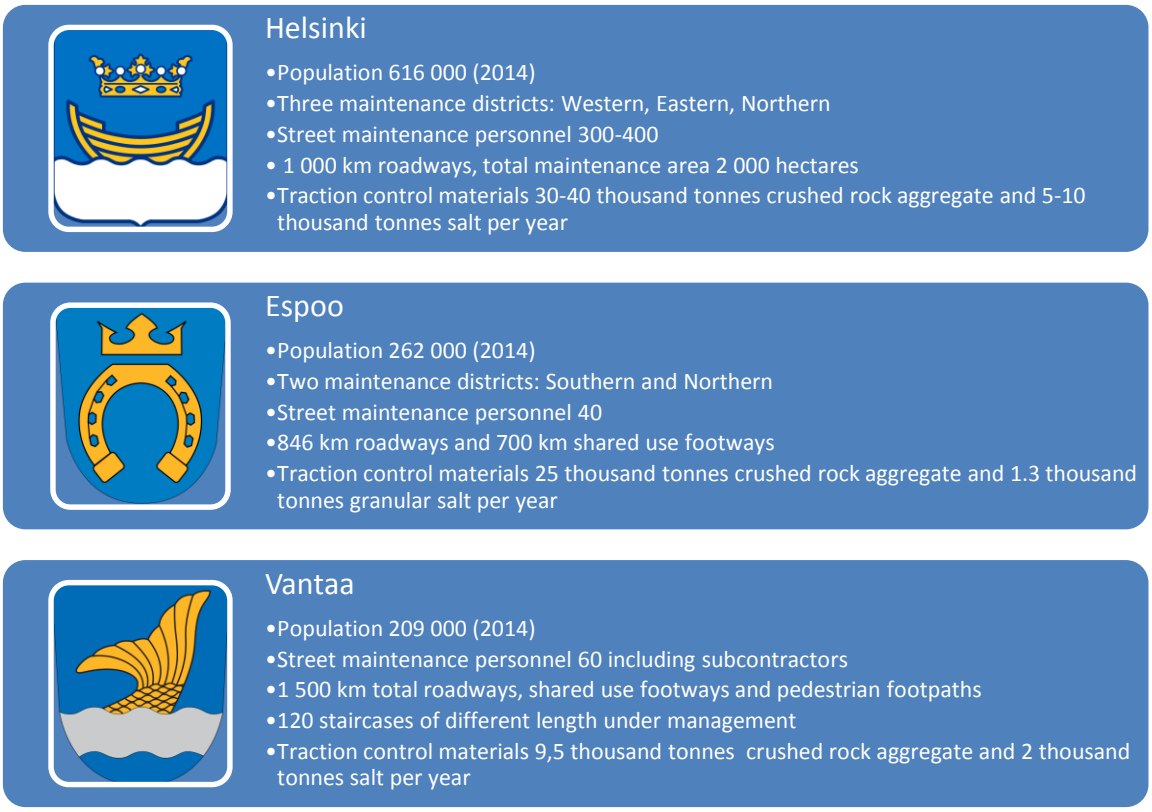

Figure 2. Key figures of the winter maintenance environment in the REDUST cities.

2.2 Air quality measurements and action plans

Helsinki Region Environmental Services Authority (HSY) is responsible for air quality monitoring in the four cities (Helsinki, Espoo, Vantaa and Kauniainen) that form the Helsinki metropolitan area. HSY also informs the authorities and public about air quality in the area and gives instructions of the ways to reduce exposure in situations of poor air quality. The cities are responsible for measures to improve air quality in their respective areas. Altogether 11 air quality monitoring stations are located in the area in different types of environments. Several gaseous and particulate pollutants are measured. Results are updated every hour and the up-to-date information about air quality is available on HSY website www.hsy.fi/en. The street maintenance organizations of the Helsinki metropolitan area follow air quality monitoring information provided by HSY and may commence maintenance actions such as dust binding when necessary.

Occasionally the concentrations of air pollutants rise to exceptionally high and harmful levels in the Helsinki metropolitan area. Regarding these air pollution episodes, local authorities have drawn up an action plan: *Short-term action plan for a sudden deterioration of air quality in the Helsinki metropolitan area*. The plan includes information for the authorities; how to proceed in these types of situations to reduce resident exposure to air pollutants. The four pollutants addressed in the plan are: respirable particles (PM_{10}), a cause of concern especially in the

springtime due to street dust, nitrogen dioxide (NO_2) from traffic exhaust, fine particles ($PM_{2,5}$) and ozone (O_3).

Street dust causes high concentrations of respirable particles (PM_{10}) close to traffic areas, especially during dry spring days. Worst PM_{10} problems typically emerge in busy street canyons at city centres, where buildings prevent the dilution of pollutants. HSY utilizes the results of PM_{10} air quality measurements to inform the public and the authorities about poor air quality and exceedances of the daily limit value for PM_{10}, to estimate the need for dust binding during acute dust episodes, to evaluate the effectiveness of dust mitigations measures and to monitor long-term annual PM_{10} trends.

The cities take actions to reduce street dust concentrations by e.g. treating street surfaces with calcium chloride ($CaCl_2$) solution (typically 5-10 mass-%), which binds water and with it the dust to the street surface, thus mitigating street dust emissions from the street surfaces. Dust binding has become an important part of the maintenance procedures to reduce street dust concentrations especially in Helsinki, where there are several street canyon locations with high traffic volumes and the highest risk of exceeding the PM_{10} daily limit value (50 µg/m^3). Feasibility of dust binding as an acute tool against high street dust emissions is based on the method's characteristic quick reaction time and fast execution. Other maintenance actions against street dust require more time for planning and are slower to implement.

3.1 Objectives

Both long and short-term objectives to guide the work need to be identified and set. The objectives should ideally be demanding enough to facilitate progress, but still be realistic and reachable. Street maintenance authorities or other relevant stakeholder, sometimes for example the authority ordering the work, should draw up a long-term strategy to reduce the levels of respirable street dust in urban areas. Demanding objectives should be set for a longer time span and in order to achieve these objectives, more detailed short-term operational targets that guide the work along the way could be set.

The long-term overall strategic objective should be to reduce PM_{10} street dust concentrations and emissions by means of winter and spring maintenance methods. Short-term operational objectives could be related for instance to the PM_{10} daily limit values (number of exceedance days) in the following spring, or year, or directly to the different maintenance measures.

Current objectives and approaches in the REDUST cities

In the REDUST cities work to mitigate street dust emissions has been continuing for a long time, although comprehensive strategies against street dust have not been made. In 2012 the Helsinki City Council passed an environmental policy document, which among other environmental protection areas will direct the objectives for street dust prevention in the coming years (Table 2). Previously the Helsinki air protection action plan (2008) listed 13 measure proposals to improve street dust situation during years 2008-2016. In shorter timespan, the prevention of street dust by maintenance actions in Helsinki is mainly guided by the qualitative or other targets of Helsinki Public Works Departments and Stara, which acts as the City of Helsinki construction and maintenance contractor.

Table 2. Long- and mid-term objectives for air quality set in the environmental policy document accepted by the Helsinki City Council in 2012.

Environment policy sets objectives for street dust prevention in Helsinki

In Helsinki the city council has passed an environmental policy -document, which will direct objectives in the essential sections of environmental protection. The environmental policy defines long-term goals to year 2050 and mid-term goals to year 2020.

In the field of air quality the following goals relate to street dust:
Long-term (2050)

- Number of respirable particle (PM_{10}) daily-limit value exceedances has at least halved from the current permitted maximum level (35 per year), and is under 18 per year. The exceedances clearly caused by long-range transport of particles are not taken into account.

Mid-term (2020)

- The limit values of air quality have not been exceeded after year 2015. Concentrations of air pollutants have continued decline after this.
- The air quality target values and national guideline values are not exceeded

The Espoo Air Protection Action Plan for 2008-2016 sets a general objective to reduce street dust via efficient sand removal, choice of sanding materials and dust binding in order to shorten the spring dust period. The Espoo Technical Services Department has not formulated long-term objectives specifically for street dust emissions or PM_{10} (T. Korjus, personal communication, 17.11.2014). However, in the operational model document "*Espoon Toimintamalli katupölyn ehkäisemiseksi" (2011)* several short-term objectives related to street dust prevention are listed (Table A1 in Annex 1). Of the different maintenance methods, at the moment the main mean to mitigate street dust in Espoo is optimized street cleaning.

The Vantaa Air Protection Action Plan for 2008-2016 specifies three main actions via which to reduce the levels of street dust in the city: (1) by improving the efficiency of maintenance equipment (2) by improving the quality of sanding materials and (3) seeking alternatives for traction control. The operational model document "*Vantaan toimintamalli katupölyn ehkäisemiseksi" (2011)* describes the organization of spring and winter maintenance in Vantaa and lists some means that guide the current work in the Technical Services Department, and some building blocks for a future strategy. One example is that sufficient amount of working hours is allocated for the spring period to ensure efficient cleaning operations. Tools that have been employed this far include the street scrubber (PIMU) cleaning method, that has been systematically used in Vantaa already for several years. Lastly the latest research results and information about street dust is communicated to the people working with the street maintenance for example by arranging Street Dust Seminars specifically aimed for employees and contractors of the maintenance organizations (latest in spring 2014).

3.2 Follow up

Keeping track of the air quality and street dust measurement results is essential in order to evaluate the success of street dust mitigation work. Alternative indicators for the follow up can be for example the springtime (15 March – 15 May) PM_{10} concentration in the nearest HSY air quality monitoring station and/or the number of days when the daily limit value has been exceeded (during spring period/whole year). City or even street specific PM_{10} results (measured from the street surface) are available from the mobile street dust measurement vehicles.

During street dust research projects preceding the REDUST project a step-wise index was designed together with the street maintenance experts to help demonstrating the PM_{10} emission results (Kupiainen et al. 2009). The index provides a standard measure to compare the PM_{10} emission levels measured by mobile street dust measurement van Sniffer. Furthermore, presenting the results as index colors improves the visualization and readability of the results (Table 3). The aim of the index is to guide and help the work done by air quality and street maintenance managers to achieve better air quality in the springtime.

Table 3. The index provides a standard measure to compare the PM_{10} emission levels measured by mobile street dust measurement van Sniffer. Index also indicates whether cleaning or other activities are still needed, or if the street surface is already clean.

Index value	Index color	Conc. (µg/m³)	Definition
0-15		0-300	Wet or clean street surface.
15-50		300-1000	Summertime clean street surface.
50-100		1000-2000	Street surface after springtime cleanings.
100-275		2000-5500	Actions required.
275-400		5500-8000	Actions required.
400-600		8000-1200	Actions required.
>600		>12000	Actions required.

The air quality results in the HSY measurement stations are currently followed up by the maintenance personnel in the cities. For instance in Vantaa a normal procedure in spring time dust period would be to check the air quality results first thing in the morning, and follow the situation even a couple of times during the shift or work day. Results are then used to support the decision making concerning the needed maintenance methods (E. Tammisto, personal communication, 18.11.2014).

Although at the Helsinki metropolitan area the maintenance organizations have relatively good access to air quality data through HSY air quality monitoring network, there is still a significant need to develop practical methods to evaluate PM_{10} street dust emissions in different street environments. Measurements with methods such as mobile laboratory Sniffer are theoretically

available anywhere, but practical solution to guide maintenance work in real time would require further development. In smaller cities air quality monitoring networks are limited or may not exist at all, but problems with street dust may still be significant. This creates further need for a simple and preferably mobile PM_{10} measurement solution, which might for example be integrated into vehicles operated by the public authorities in different cities.

3.3 Resources

Sufficient amount of resources need to be allocated for the work in order to successfully prevent the formation and emissions of street dust. Weather conditions can cause significant yearly variation to the need of maintenance methods and thus to the costs. In order to ensure sufficient budget and resources for the spring maintenance one option would be to have completely separate budgets for winter and spring maintenance instead of having a fixed quota for the whole year.

When old equipment is replaced or new equipment purchased, the best available technology should be considered. In recent years some old cleaning equipment has been replaced with more efficient PIMU street scrubbers, but most often the case is that the cities use older and new technology side by side. Efficient use of different technologies requires a plan according to which the most efficient technique is available at the right place at the right time (as an example, using PIMU scrubber in busy street canyons). In larger cities it may be possible to improve availability of machinery by creating more flexible models of rotation for example between different maintenance districts.

Machinery which is used for dust binding purposes is typically integrated into either street washing trucks or traction sanding trucks (skip loader truck), which have good availability for most maintenance organizations as they have multiple setups and purposes. Specialized street cleaning equipment such as PIMU street scrubber have a specific end function and seasonal demand. This creates challenges for the availability of the machinery during the street dust season. It would be beneficial for the street dust mitigation if municipal maintenance organizations and private maintenance contractors developed more co-operation and contracting models to increase the share of modern street scrubbers and similar advanced equipment in street dust mitigation work.

Co-operation between different stakeholders and authorities is generally very important in the field of street dust mitigation. Co-operation and information exchange should even extend over the neighboring cities or neighboring maintenance areas, especially where more comprehensive strategy is pursued. It is important that the maintenance organizations keep following up on latest research and participate in research projects to gain the latest knowledge about effective measures also in the future.

(3) Ways to measure the progress towards the objectives: Relevant methods to follow up the progress towards achieving the objectives need to also be in place. The choice of methods in this case depends on the objectives and for example quantitative objectives should be directly linked with the way to measure them. In case of an air quality related objective, the method should be linked with the air quality measurements in the area. If there is no air quality measurement station nearby one option would be to set the objective to refer to a load or emission level of street dust, which could be followed up for example with mobile street dust measurement vehicles or methods that measure street dust load. Right tools (both operational and other) that fit the location need to carefully be selected.

The most advanced version of the *optimized street dust mitigation strategy* was implemented in the Helsinki City Centre. Most of the factors needed for a successful street maintenance strategy were already in place, the objectives, means to follow up the results, relevant stakeholders were involved and resources available. The optimized street maintenance strategy incorporated two main street maintenance tools, these were (1) optimized street cleaning with PIMU scrubber and (2) more frequent dust binding with faster reaction time. In addition to more efficient street cleaning and frequent dust binding, other strategic tools that have been applied in the Helsinki City Centre include using sanding materials without fine grain size, improved cooperation with the companies responsible for dusty construction works, improved cooperation with the bodies responsible for maintenance of sidewalks, lower speed limits in the city centre (30-40 km/h, traffic safety) and lighter studs in winter tyres in Finland (less abrasion of pavements).

Available PM_{10} measurements from the Helsinki City Centre indicate declining trends in both ambient air concentrations as well as street surface emissions several years in a row. The effect of variable weather between different years cannot be fully excluded, but the overall situation regarding street dust in the Helsinki City Centre can be estimated to have improved. This in turn suggests that the strategy in Helsinki City Centre has been successful and the area is well on the way to reaching the objectives. Experiences in the Helsinki City Centre operations can serve as examples when the optimized street dust mitigation strategy is developed in other areas. Despite the positive development observed in the air quality during recent years, street dust still causes health hazards and reduced comfort of living in the busy traffic environments of Helsinki. The daily limit value for PM_{10} particles has not been exceeded after year 2006 in Helsinki, but the risk of exceedance might still exist in the busiest street canyons. Therefore focus must be maintained in work against street dust to secure the air quality gains of recent years and to improve air quality even further.

Sources and more information

Finnish Environment Institute: Migration of alternative de-icing chemicals in aquifers (MIDAS project). http://syke.fi/projects/midas

Gustafsson, M., Blomqvist, G., Jonsson, P., Ferm, M. 2010. Effekter av dammbindning av belagda vägar. (Effects of dust binding of paved roads; in Swedish with an abstract in English). VTI rapport 666. 65 p

Hafner et al. 2012. CMA+ Instruction Manual 1.1. for the reduction of fine-dust (PM) pollution through the application of a liquid “fine-dust glue” (Calcium-Magnesium-Acetate). Klagenfurt 2012.

Kupiainen, K., Pirjola, L., Viinanen, J., Stojiljkovic, A., Malinen, A. 2009. Katupölyn päästöt ja torjunta. KAPU-hankkeen loppuraportti. (Street dust emission and prevention. Final Report of KAPU-project; in Finnish with an abstract in English). Publications by City of Helsinki Environment Centre 13/2009. 102 p.

Kupiainen, K., Niemi, J., Ritola, R., Stojiljkovic, A. 2012. Hiukkasten koostumus ja lähteet Mannerheimintiellä PM_{10}-raja-arvon ylityspäivinä 2010. (Composition and sources of particles in Mannerheimintie during exceedance days of PM_{10} limit value in 2010.) HSY publications 3/2012. 24 p.

Kupiainen, K., Pirjola, L., Ritola, R., Stojiljkovic, A., Malinen, A. 2013. Talvirenkaiden pölypäästöt ja eri katupölylähteiden osuudet kadunvarrella kerätyissä hiukkasnäytteissä. (Emissions of road dust by winter tyres and the contributions of different road dust sources in road side particle samples; in Finnish with an abstract in English). HSY publications 3/2013. 26 p.

REDUST Action 1 and 2 final report – Demonstration tests, main results and conclusions

REDUST Action 3 final report – PM_{10} dust emission estimates for current measures and estimation of emission reductions due to additional measures

REDUST final reports available at http://www.ymk-projektit.fi/redust/en

Toiskallio, K., Kuukka-Ruotsalainen, V., Alppivuori, K. 2013. Improving air quality by increased use of friction tires – without compromising traffic safety. The final report of the STUD research programme 2011-2013. (summary report in English). Publications by City of Helsinki Public Works Department. 18 p. summary report. http://www.nasta.fi/english

Annex 1. Descriptions of the current state maintenance methods

Equipment and materials used for street maintenance in Finland

Finnish municipalities use several types and combinations of vehicles and equipment in winter maintenance operations, such as trucks, tractors, wheel loaders, front-end loaders, skid loaders**,** vans and pickup cars. Vehicles are equipped with special snow removal accessories, such as snowplows, different types of blades, vessels and containers, automatic gritters, salt spreaders and sweepers. In addition the vans and pickup trucks are equipped with tools needed for the manual work; shovels, snow scrapers, gritters, de-icing and sanding materials. Vehicles that are used for sand removal or dust binding are usually trucks or tractors equipped with several types of brushes, vacuum sweepers and captive hydrology street cleaning components. The necessary maintenance equipment is partly owned by the cities themselves and partly by subcontractors and private sector operators.

The traction control materials used by the municipalities include traction sand (sand in this context used as a general term for different stone materials used) or salt (mostly NaCl). Traction sand materials include crushed or non-crushed rock aggregates that can be sieved (wet or dry sieved) in order to exclude fine dust. Crushed, wet-sieved materials are currently considered materials with least dust formation and emission. Salt is dispersed in solution with water or in granular form depending on the weather conditions. Both sanding and salting materials are often used as mixtures, e.g. granular salt and crushed stone aggregates mixed or crushed stone aggregate moistened with brine solution. Some cities in Finland use brine solution, usually $CaCl_2$, also as dust suppressant. It is commonly used on unpaved gravel roads, but more and more also to reduce dust emissions from paved streets especially in spring time.

The amounts of different materials needed for traction control vary between the cities and between years mostly because of weather conditions. To give some reference, figures (per year) describing the amounts of salt and crushed stone aggregates used for traction control purposes from different cities are presented (Figure 2).

Winter maintenance

Winter maintenance and quality assurance in Helsinki and Vantaa are in principal handled according to the guidelines published in *Alueurakointi, Yleinen tehtäväluettelo 2003* (publication by the Association of Finnish Local and Regional Authorities). In Helsinki some supplementary guidelines are also given. However the guidelines are directive and the needed measures are always considered case by case. City of Espoo has composed a manual of its own: *Katuylläpito, Alueurakointi, Yleinen tehtäväluettelo 2011* according to which the winter maintenance and quality assurance is organized.

Plowing

Plowing is done when necessary, which means that snow is removed and transferred away from the street environment at latest when the amount of snow either disturbs traffic or normal maintenance procedures, or presents a threat to surrounding vegetation. Sometimes plowing is also done in order to be prepared for subsequent snow fall, and to speed up the melting of snow piles in springtime.

During a continuous snow fall salt or a mixture of stone aggregate and salt can be applied to the street surfaces with the purpose of being able to detach the packed snow completely from the pavement surface with plows.

Traction control

In the Helsinki metropolitan area streets have been classified into three groups that specifies the priority level for maintenance actions based on traffic amounts and importance in the street network. This classification determines to some extent how traction control is conducted.

Mainly crushed stone aggregate and salt (NaCl) are applied for traction control, sometimes cities might use gravel or sand in areas where it is suitable. In paved driveways the traction control material is usually wet sieved or sieved crushed stone aggregate, salt, brine or a mixture of stone aggregate and salt. The material is selected based on the location, weather, road conditions and forecasts. In Vantaa for the class I and II streets crushed stone aggregates is mainly used on the bus stops and crossroads, in case the weather does not allow the use of salt (temperatures below zero). On class III streets only sanding is used. On pedestrian and shared use pathways the traction materials used are sieved crushed stone aggregate or sand. According to the Helsinki city authorities the amount of material applied to driveways vary between 60-110 g/m^2, depending on the weather and local conditions. Usually some salt is added to the mixture before applying it in order to prevent clogging.

Salt is usually used as moistened or as a brine solution. In most streets salt or brine solution are used in the beginning of the winter or in spring, but in some locations with high traffic amounts salt is preferred throughout the winter. The amount of salt that is applied on the street varies between 5-60 g/m^2 (minimum for a dry condition, maximum for a wet, snow fall condition).

When temperatures are close to zero, it is possible to keep the streets free of ice with using nothing more than salt; vehicles passing by spread the salt and break down the ice layer on the surface of the road. Melt water is spread and evaporates efficiently from the street surface due to the traffic flow. In case the temperature is 5-10 degrees below zero, mixture of crushed stone aggregate and salt is often applied in the busiest truck and bus routes. In case the temperature is close to zero and cooling, salt is spread before sand.

Traction materials are purchased yearly based on tenders. Following quality requirements have been specified in the procurement documents for salt (example from Espoo): Salt should consist 97%-wt of NaCl (dry); anti-clogging substance (potassium or sodium ferrocyanide) should not exceed 150 ppm (0.015 %); maximum grain size should be 5 mm and the amount of fine dust

(<0.125 mm) should not exceed 5 %. Concerning sanding materials, only washed and sieved materials can be applied (on driveways). On pedestrian and shared use footways dry sieved (non-washed) material is also allowed. Current requirements for the grain size of the material are 1 to 5.6 mm for driveways and 3 to 5.6 mm in pedestrian areas.

In Vantaa so-called “safety sand” (size distribution 1-6mm) has been used in pedestrian areas. Safety sand differs from the conventional sanding material in that the gravel is not crushed, and thus the grains are not so sharp. Sharp grains of crushed stone aggregate have been claimed to break bicycle tyres on pedestrian areas in Finland during winter and spring.

Although the crushed stone aggregate is wet sieved, measured grain size distributions show that some leftovers of finer material are possible. Recent measured grain size distributions have contained in average 0.7 mass-% material in the sieve <63µm (min-max 0.4%-0.9%, SD 0.3). Traction sand used in Espoo in the winter spring period 2012-2013 was analyzed in a laboratory to get the grain size distribution of the material. Results are presented in Figure A1. Material contained in average 0.5 mass-% material in the smallest fraction (sieve size <63µm). Material smaller than 63 µm can be considered suspendable dust.

Sieve size (mm)	Percent passing (%)
0.063	0.5
0.125	0.7
0.25	1.0
0.5	1.7
1	4.7
2	20.8
4	62.7
8	100.0
16	100.0
31.5	100.0
63	100.0
90	100.0
125	100.0
150	100.0
180	100.0
250	100.0

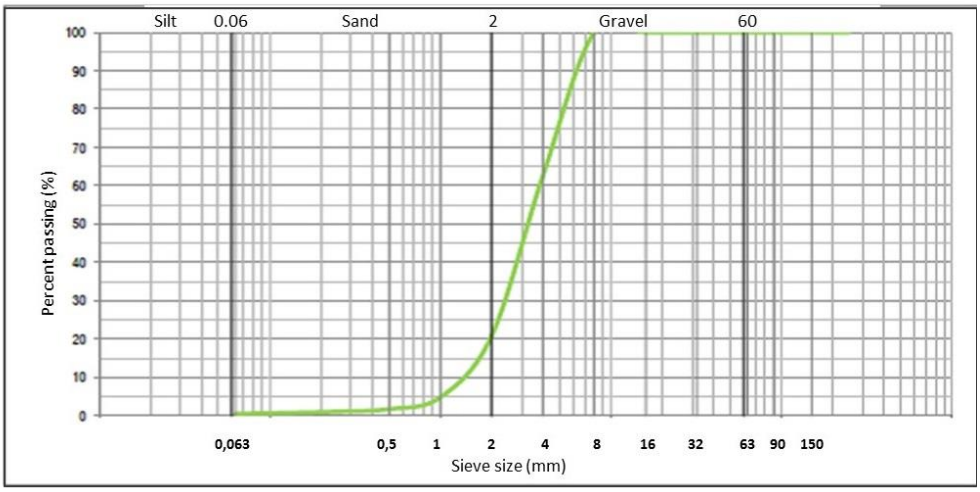

Figure A1. Grain size distribution curve for traction sand (1-5.6 mm). Results show that the material contained in average 0.5 mass-% material in the sieve <63µm.

Spring cleaning

Spring cleaning in Helsinki metropolitan area is typically initiated when weather forecasts show low probability for snowfall and sub-zero temperatures. The municipalities and real estate owners charged with maintenance responsibilities have the right to decide themselves the timing of the cleaning operations.

Most of the equipment require the use of water. In such case the timing of the work has to be optimized with weather conditions (above zero temperatures) to prevent freezing of the street surfaces and proper operation of the equipment. For example temperatures close to zero might cause the nozzles of the suction sweepers to freeze thus preventing the cleaning. During heavy rain fall it is not practical to use suction sweepers since the amount of water collected from the streets make the tanks fill up too fast. Such factors bring natural variation to the timing of the spring cleanings. For example during years 2006-2010 the starting time of the spring cleanings in Espoo, Helsinki and Vantaa varied between week 12/2007 to week 15/2006.

Espoo

The primary means of combating street dust in the spring is optimized street cleaning. Espoo has mainly given up dust binding (with calcium chloride), because it is perceived to complicate spring cleaning by accumulating on the road surface and together with the road surface dust layer forming a hard layer which is difficult to remove with the current street cleaning equipment / technology. Removing this thin hard layer is perceived to slow down or prevent the progression of the street cleaning in the spring. Thus Calcium chloride to be used only as if the washes are not appropriate.

Cleaning begins when the road conditions allow; in case there are still wide stretches of ice on the sides of the road, it is more feasible to start the cleaning from the pedestrian areas. Due to the need of pre-moistening, the cleaning will not begin if the temperature is below zero. Occasionally $CaCl_2$ solution or pine soap is used to prevent freezing. However, since $CaCl_2$ is corrosive scrubbers suffer from the use of $CaCl_2$, and it can only be used in special equipment.

From the driveways the material (leftover sand, debris, coarse dust) is collected with suction sweepers or with mechanical sweepers. Mechanical sweepers are used when the material has to be collected either straight to lorries or to temporary deposits. In some areas the sand is swept straight into the surrounding terrain. Additional moisturizing equipment is used in case the machines own sprinkling system does not prevent dust emissions from the equipment's operation efficiently enough. Edges of the roads and other structures are washed latest when all the coarse material is removed. The work is finalized with suction sweepers or scrubbers, depending on the available resources. Bus stops and terminals are washed once usually in the beginning of the cleaning period.

The removal of the traction sanding materials from the pedestrian and shared-use footways is done with mechanical sweepers and the material is collected either straight to lorries or in temporary deposits similarly as for driveways. Sand can be swept straight into the surrounding terrain in some areas. Staircases and other structures in pedestrian areas are washed manually. The cleaning of pedestrian and shared-use footways is finished with sweepers and/or scrubbers. Sand removal from the urban park- and green areas is done in cooperation with the Street and Park Division, and the aim is to coordinate the timing of the operations to start simultaneously. This is particularly important in situations when the collected sand has to be temporarily moved from the green areas to street areas where the cleaning has already taken place.

Helsinki

In the central area of the city, individual properties are responsible for the cleaning of the sidewalks. In suburban areas and in the district of Etu-Töölö the city is responsible for these. Properties are allowed to sweep the traction sand from the sidewalk onto the side of the driveways – not on the tram rails - after which the city will clean it off at the same time with street cleaning. However, after the city has completed the street cleaning operations, private properties are no longer allowed to sweep sand onto the driveway. To assure good coordination, it is planned that the maintenance of all streets including the sidewalks will in the future become the city's responsibility.

The removal of remaining sand and gravel from the streets is started as early as possible, as soon as the weather conditions allow. Sand removal begins with brushing the pedestrian areas and shared-use footways. From the driveways coarse crushed stone aggregate and similar materials are removed with mechanical brushes, after that a vacuum sweeper removes the finer material. In the final stage the surface is washed with high pressure water. After the coarse material is collected, the street ought to be clean from sand/gravel, and after the high pressure washing, free from dust. From 2013 on one PIMU (street scrubber with high pressure washing and subsequent suction of the sludge) has also been used in the street cleaning in Helsinki City Centre area with the aim of increase the removal of finer dust including PM_{10}.

Vantaa

In Vantaa the first areas to be cleaned are the central pedestrian areas and shared-use footways. After that the order follows the classification of the streets. During the first weeks of the cleaning (mainly in class I and II streets), the work is done in longer shifts than usual (Mon-Thu 12 hours/day). Tunnels and some other challenging locations are cleaned during weekends and nighttime only.

Cleaning is finished with scrubbers that combine high pressure washing and subsequent suction (PIMU). The operation with the scrubbers begins from the central areas of the city and move forward to all mechanically swept streets and areas. It usually takes around one month before the cleaning proceeds to class III streets. The cleaning order of the class III streets is different every year. Altogether the removal of the sand/gravel takes usually 6 to 8 weeks depending on the spring. Aim is to finish all cleaning by mid-June. The quality assurance procedure for the cleaning includes visual inspections and following the air quality index from the HSY's measuring stations.

In case of sudden changes in the weather in spring, sanding may be required in some areas after the cleaning operations have already taken place. This is not a problem in roadways, where sand can be applied only to the places where it is important (bus stops, crossroads). However usually, after the cleaning operations have been initiated, only salt is used for traction control in each of the cities.

Dust binding practices

The main method to mitigate acute dust episodes in the Helsinki metropolitan area is dust binding. Typically the cities use 5-10 % calcium chloride solution ($CaCl_2$) as a dust binder, but other substances, such as potassium formate, have also been tested. Pine soap is sometimes used to decrease the surface tension of the water during street cleaning. Dust binding is carried out year round when and if the weather and road conditions require. The need for dust binding is estimated by street maintenance personnel based on air quality monitoring results as well as on weather and air quality forecasts. Furthermore, visual observations are utilized to obtain a view on the dryness and dustiness of different street sections.

In springtime dust binding is carried out proactively and systematically, before and during the sand removal. Sand is removed from the street environment as early as possible to prevent unnecessary accumulation of dust. Dust binding may be carried out for a selected streets or city areas. In most cases, dust binding solution is only spread on the street edges with special spreading equipment designed for the purpose. Dust binding is repeated when necessary.

The operation practices depend very much on the situation, e.g. location, street surface conditions at the time of the operation. The demonstration tests in the REDUST project were conducted mostly with 10 mass-% $CaCl_2$-solution. A typical truck can take up 8 m^3 of solution. The driver is able to adjust both the flow and pressure, the typical working pressure is 1.5 kpm/cm^2. Typical spreading amounts in the Helsinki City Centre may vary from 60 g/m^2 (targeted spreading, no visible dust or dirt layer) even up to 100 g/m^2 (whole lane treatment, significant dirt layer that sucks up the dispersant) of 10%-mass solution. (S. Ilvonen, personal communication, November 7 2014).

Procurement and R&D

Whenever old equipment is replaced or new equipment purchased, the best available technology is considered. At the same time more efficient methods and procedures are developed to enhance the current street cleaning and sand removal methods.

Cities also participate actively in studies related to street dust mitigation, and aim at utilizing the research results. For the time being dust binding is used in Helsinki and Vantaa but not in Espoo.

Table A1. Espoo – Street dust prevention. Methods to reach the objectives
• as a traction sanding material only crushed and sieved stone material is used • plowed snow will be removed from the street environment in order to also remove the potentially dusty material together with it to the snow deposits • Sand/grit removal is started as early as possible in the spring, taking into account the weather and weather forecast. • Proactive street dust prevention in the main arterial roads is enhanced by starting the cleaning from the driveways and moving on to bike and pedestrian lanes, where the sanding material does not cause as high dust emissions to the air. • Sand removal equipment are changed into more efficient ones as they become available with the renewal of the maintenance fleet. At the same time more efficient methods in sand removal and street cleaning are developed in order to enhance the use of the equipment. • Private sector owned and operated PIMU scrubber will be tested • Active participation in street dust research programs and utilizing the results • Development of the silo in Olari. The silo was expanded in 2010 and the capacity to prepare and store $CaCl_2$ solution grew significantly. The preparedness to perform dust binding is now good, in case for some reason the street cleaning would not be possible.