End seminar

Mats Gustafsson, Ana Stojiljkovic, Michael Norman, Bruce Denby & Throstur Thorsteinsson

Göran Blomqvist, Ida Järlskog, Joakim Lundberg, Olle Eriksson, Sara Janhäll, Jennie Hurkmans, Sanna Silvergren, Max Elmgren, Christer Johansson, Kaarle Kupiainen, Sami Kulovouri, Aleksi Malinen, Roosa Ritola
Content

• Background to and overview of NorDust project
• Field tests conducted in Finland and Sweden
  • Vantaa
  • Stockholm
• Laboratory tests
  • Studded tyre tests with Vectra instrumented car
  • Studded tyre tests in VTI road simulator

• NORTRIP
  • model development
  • NORTRIP in Iceland
  • Applications of NORTRIP in Norway
Background

• The Nordic countries have similar air quality problems related to road dust
• Many years of national abatement strategies to reduce road dust, but little co-operation and differing ambitions and focus.
• NORTRIP project (Nordic ministers of councils project) brought together road dust researchers in the Nordic countries, focus on gather available data and knowledge to build an emission model that could handle processes affecting road dust generation and suspension.
• NorDust sprung out of NORTRIP, with the ambition to perform research for further understanding of the road dust system and needed to further improve the NORTRIP model.
• 3-year project (2015-2018), 593 000 €, 4 road authorities, 9 scientific partners
Main goals

• “The aim of the project is to improve the knowledge base of road dust formation and emission in Nordic conditions in order to better determine the most effective and efficient road dust mitigation strategies.”

• “…better informed decisions concerning road dust abatement and the consequences for health and legislation.”

• “…help the road authorities to better understand the processes around sanding/salting and removal from the road surface.” This will help to better plan and manage their winter road maintenance and save resources.”
Main activities

• Road dust
  • Vantaa campaign with semi-controlled conditions
  • Stockholm campaign in real-world conditions
  • Data sharing with national on-going projects
• Studded tyres
  • Test track study with instrumented car
  • Road simulator study
• NORTRIP model
  • Implementation of NORTRIP in Iceland
  • Model developments based on project input
Methods used

• Instrumented vehicles – Sniffer and Vectra
• Stationary air quality measurements
• Wet Dust Sampler
• Road simulator
• Traffic measurements at Vantaa
• Road surface measurements
Field tests
Vantaa campaign activities

- Tests performed during Vantaa campaign
  - Road dust suspension experiment
  - Sanding experiment
  - Crushing experiment
  - Cleaning experiment
  - Air quality measurements
Vantaa test area

- Asphalt surface
- Two tracks (O and I)
- O-track for dust suspension tests
- I-track for sanding and sweeping tests
- 6 personal cars performed over 1800 passes during 8 sets
- Measurements made during and in-between traffic sets
# Measurements at Vantaa

<table>
<thead>
<tr>
<th>Date</th>
<th>Traffic round</th>
<th>Traffic (passages)</th>
<th>Mean speed (km/h)</th>
<th>WDS-measurement</th>
<th>Note</th>
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<tr>
<td>2016-09-26</td>
<td>1</td>
<td>10</td>
<td>38</td>
<td>A1, B1, C1</td>
<td>Before any traffic</td>
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<tr>
<td></td>
<td>2</td>
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<td>39</td>
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<td></td>
<td>only Vectra, before meandering test</td>
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<tr>
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<td>41</td>
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<td></td>
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<td></td>
<td>6</td>
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<td>43</td>
<td></td>
<td>All cars, light drizzle</td>
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<tr>
<td></td>
<td>6</td>
<td>120</td>
<td>39</td>
<td></td>
<td>All cars</td>
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<tr>
<td>2016-09-29</td>
<td>6</td>
<td>200</td>
<td>44</td>
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<td></td>
<td>7</td>
<td>200</td>
<td>49</td>
<td>A7, B7, C7</td>
<td>Wet surface, rain</td>
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<td>2016-09-30</td>
<td>8</td>
<td>206</td>
<td>60</td>
<td>A8, B8, C8</td>
<td>All cars, wet surface, rain</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>200</td>
<td></td>
<td>A9, B9, C9</td>
<td>All cars</td>
</tr>
</tbody>
</table>
Traffic registration during campaign, speed
Traffic registration during campaign, position
Road dust suspension experiment

- Low amounts from the start, especially in B and C – little suspension from surface at speeds used.
- In A dust is successively lower until rain redistributes the dust to wheel tracks (A7-A9)
Suspension test Vectra

S2- Suspension test 27.9.2016

- Speed (km/h)
- PM10 concentration (µg/m³)
- Round/Vehicle passes

S2- Suspension test 27.9.2016

0
10
20
30
40
50
60
0
1000
2000
3000
4000
5000
6000
5
20
35
50
65
80
95
110
125
140
155
170
185
200
15
30
45
60
75
90
105
120
135
150
165
180
195
200
10h
15h
17h
18h

Vectra - Speed (km/h)
Vectra - PM10 concentration (µg/m³)
Round/Vehicle passes
S2- Suspension test 27.9.2016
Meandering test

- Suspension increases as Vectra vehicle leaves the wheeltracks and suspends dust accumulated outside the wheeltracks.
Cleaning experiment - setup

• Cleaning machines:
  ➢ CityCat 5006 (compact sweeper)
  ➢ BROCK “PIMU” (Scrubber with Captive Hydrology)

• Location: I-tracks

• Suspension emission measurements:
  ➢ Vectra instrumented car
  ➢ Three post-treatment measurements
  ➢ 5 passes within cleaned area and 5 passes outside of the cleaned area
Cleaning experiment, WDS results
Cleaning experiment – PM$_{10}$ emission reduction

- High emission level compared with the urban street standards
- Both machines decrease PM10 emissions on the day of the treatment (35%, CityCat 5006 and 54%, PIMU)
- The effect for the CitCat 5006 was limited to several hours
Sanding experiment - setup

• Mass of the applied sanding material: 150 g/m²
• Measurement vehicle: Vectra instrumented car
• Mobile measurements:
  ➢ Before the treatment - 10 passages
  ➢ 1st follow-up – 20 passages (5 cars)
  ➢ 2nd follow-up – 10 passages (5 cars)

• Material is applied on a dry street surface -> does not represent real-life application
Sanding experiment
Sanding experiment, sand leaving the tracks
Sanding experiment – PM$_{10}$ emission

- Higher mean emission level on the treated section of the I-track after the sand application
- Increase in the PM10 emission on both sections of the I-track
Crushing experiment

- Known sand amount
- Driving slowly to and forth
- Studded and non-studded winter tyre
- Sweeping and WDS-sampling after
Crushing results

• Fractions around 100-200 µm are reduced and around 10-20 µm increased in the WDS-samples.
• Slightly finer fractions are reduced and enriched for friction tyres
• Higher amounts of dust are reduced and enriched using studded tyres
Some conclusions from Vantaa field tests

- Site different from trafficked road regarding surface characteristics and dust load distribution
- Reduction in dust load and PM$_{10}$ suspension connected to traffic
- Meandering results in higher suspension from Vectra
- Sweeping reduces suspension of PM$_{10}$ but dust load is not obviously affected.
- Sand is removed fast from wheeltrack 50 % after 20 vehicles, then slower. Slower between wheeltracks. PM$_{10}$ suspension increases due to sanding.
- Within DL180, the crushing test reduces coarser particles (around 100 µm) and increases finer (around 10 µm).
Air Quality measurements, objectives

Vantaa

Measure single and multiple plumes from vehicles
Calculate EF
Vantaa setup
• Four PM-monitors
• One up-wind
• Three downwind
Vantaa: Goal calculate emission per passage

- Theory. Based on Etyemezian et al., 2003
- Measurements on different heights downwind
Detection of each individual plume

- Could the results be compared with the Vectra results?
Wind direction mostly wrong!

- Only short period with westerly winds nighttime
First 10 rounds on O-track

• Fast decreasing concentrations at the first tests
• Fast removal of dust
• Never the case in reality?
Day 2, Run 500-1000, O-track
Day 2, Run 520-1050, O-track

- No signal in old track
- High signal during meandering test
Day 2, Run 520-1050, O-track
Day 2, Run 520-1050, O-track

- When a lot of traffic can a signal be seen, but not for single traffic
Vantaa Day 3, New position

- Still after >700 passages can single peaks be seen
- Better wind direction
Some conclusions from Vantaa field tests, cont. (air quality)

- Mostly wrong wind direction
- Fast decreasing concentrations in beginning
- Much higher when driving off-track
- No signal from sanding
- Surprisingly not highest concentrations at lowest height
- If the cars were passing too often the plume was spread and the data got very noisy
- If the wind was not blowing perpendicular to the road track (or close to perpendicular) the increased concentration measured when a vehicle passing the measurement setup was increased at both upwind and downwind side
Stockholm campaign activities

• Tests performed during Stockholm campaign
  • E18 measurements
  • Mobile measurements in tunnel
  • Mobile measurements in street
  • Cleaning evaluation
  • Traffic dislocation
  • Air quality measurements
  • WDSII and III comparison
Road dust field tests, Stockholm, road dust transect on E18
Texture and dust load on E18
E18, Mobile measurements

• Measurement vehicle:
  ➢ Vectra instrumented car

• Measurement site:
  ➢ Three lanes, both directions
  ➢ Target speed 70 km/h
  ➢ 3 passages per lane
E18, Mobile measurements - results
Sweeping test, Fleminggatan Stockholm

- Increased dust load rather than decreased
Traffic dislocation test

• How does dislocated traffic affect dust load pattern?
Traffic dislocation test

• Area between wheeltracks "eroded" by traffic, but also reduced dust load in area outside the markings.
Air Quality measurements, objetives

Stockholm

Comparison of ambient concentrations to vehicle measurements
Measure and calculate EF for comparison between
Calculate emissions factors with NORTRIP model
Stockholm campaign

• AQ measurements at:
  • 3 streets (Hornsgatan, Fleminggatan and Sveavägen)
  • Södra länken tunnel
  • E18 Danderyd testsite (Trafikverket)

• Alla stations with PM10
Variation in PM10 concentrations

Hornsgatan > Sveavägen > Fleminggatan

5-10 times higher PM10 in tunnel compared to streets

Depends on WD, Large difference in NOx, only small difference in PM1
Variation in concentrations

E18

PM$_{10}$

PM$_{2.5}$

PM$_{1}$

NO$_X$

Wind speed and direction
Hornsgatan, cleaning

- Low concentrations as long as street is wet
- Equal concentrations afterwards compared to before
- No observed effect from cleaning in ambient PM10
Size distributions, March 2017
Effect from cleaning, dustbindning and speed?

• Hornsgatan, 40 times with vacuum cleaning and ? Times CMA, ~40 km/h
• Uppsala no cleaning and no dustbindning, ~40 km/h
• E18 highway, ~70-90 km/h

-More larger particles (>3 µm) in Uppsala than at Horngatan. That could be a result of the intense cleaning at Horngatan removing the larger particles.

At E18 were more smaller particles (<3 µm) found compared to the city streets. Could the higher speed be the reason for more smaller particles at E18?
Size distributions Hornsgatan

- 2017 intense cleaning with vacuum and dustbinding
- 2018 only dustbinding

More larger particles (>3 µm) were present in March 2018 compared to March 2017

Larger particles removed by the vacuum cleaning?
Hornsgatan, emission factors

- From measurements
- $EF_{PM10} = EF_{NOx} \frac{\Delta PM10}{\Delta NOx}$
- The subtraction of urban background is not perfect especially at nighttime

- From NORTTRIP modell
- Observed moisture
- Lower than observed and less variation
Some conclusions from Stockholm field tests

- Dust load on E18 highly variable, with high load between and low in wheeltracks.
- High macro texture relates to high dust load in E18.
- PM$_{10}$ suspension on E18 was highest in the bus lane.
- Sweeping test with a vacuum cleaner had no obvious effect.
- Traffic dislocation eroded dust load between wheel tracks, but was unconclusive due to simultaneously reduced dust load outside the test area.
Dust load sampling in Finland

• Measurement sites:
  ➢ Mäkelänkatu, Helsinki ("supersite", extensive air quality and weather monitoring)
  ➢ Mannerheiminkatu, Porvoo
Dust load sampling in Finland, results
Dust load - Stockholm and Helsinki, April 2017

- WDS III measurements in Stockholm and Helsinki
Sniffer measurements - Stockholm and Helsinki, April 2017

Blue bars – mean PM10 emission measured by Sniffer during the Stockholm campaign in April
Gray bar – PM10 emission measured by Sniffer in Mäkelänkatu, Helsinki
Controlled and laboratory tests
Studded tyre tests

• Test track and Vectra instrumented vehicle (7 studded tyres, 1 unstudded)
• Road simulator (6 studded tyres)
Use of studded tyres in Finland

- Share of studded tyres varies across the country
- Lowest in Uusimaa region (76%), highest in the north (96%) *(source www.if.fi)*
- In Helsinki metropolitan area small decrease
Studded tyre regulation

• New regulation regarding the number of studs on studded tyres and stud protrusion was introduced in Sweden and Finland in 2013
• Regulation allows 50 studs per meter rolling circumference and 1.2mm mean stud protrusion for the light duty vehicles
• Alternatively, tyres can be approved by passing so-called over-run test

• Aim of the measurements was to investigate new generation studded tyres from the PM10 emissions point of view
Measurement setup

• Test street: Vanha Porvoontie, Vantaa
• Measurement vehicle: Vectra instrumented car
  ➢ Target speed during measurements 50 km/h
  ➢ 3-5 passages per tyre
  ➢ Friction tyre used as reference tyre
• Measurement timing: low “summertime” suspension level measured with the reference non-studded tyre
• Two measurement campaigns
### New generation tyres

<table>
<thead>
<tr>
<th>Tyre</th>
<th>Number of studs</th>
<th>Manufactured</th>
<th>Stud protrusion before the tests *)</th>
<th>Vectra</th>
<th>Road Simulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nokia Hakkapeliitta 8</td>
<td>190</td>
<td>W24/2016</td>
<td>0,5825 mm</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Bridgestone Noranza 001</td>
<td>190</td>
<td>W17/2016</td>
<td>0,685 mm</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Continental Ice Contact 2</td>
<td>190</td>
<td>W37/2015</td>
<td>0,805 mm</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Hankook Winter I*Pike RS</td>
<td>170</td>
<td>W19/2016</td>
<td>1,1025 mm</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Pirelli Ice Zero</td>
<td>130</td>
<td>W33/2014</td>
<td>0,8725 mm</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Nokia Hakkapeliitta 7</td>
<td>128</td>
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<td>0,73 mm</td>
<td>X</td>
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<td>Michelin X ice North 3</td>
<td>96</td>
<td>W11/2016</td>
<td>0,45 mm</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Goodyear Ultra Grip**</td>
<td>130</td>
<td>W18/2013</td>
<td>0,873 mm</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

*) average of 20 studs

**) tested only in 2017

Picture: www.scason.fi/

Picture: NordFeu
PM\textsubscript{10} emission - median values

- Line markers: 4 results for each tyre (2 directions (north and south) x 2 sections (VPT2 and VPT3))
- Reference tyre: Nokia Hakkapeliitta R2, friction tyre
- Low suspension conditions
No clear evidence from the “on-road” tyre measurements that number of studs increases PM10 emission

Emissions may be affected by other factors as well, such as, stud protrusion, tyre tread and rubber characteristics

More data points are needed for better understanding
Studded tyre tests in road simulator

- Circular track
- 4 wheels (4 positions + excentric movement)
- Up to 70 km/h
- Climate control
- PM$_{10}$, size distributions
Experiment design

- Six tyre sets
- Statistically optimized sequence for tyre comparison
- Four tests a day
- Start and stop with same set
- 50 km/h constant speed
- Registration of tyre and environmental parameters (test not optimized for investigation of influence of these, though)
Results in road simulator, PM$_{10}$

- 190-studs tyre highest emissions, but also second lowest
- 96-studs tyre lowest emissions
Statistical analysis states that:

• Nokian Hakka 8 results in significantly higher PM$_{10}$ concentrations than all other tyres

• Michelin X-Ice North results in significantly lower PM$_{10}$ concentrations than all other tyres

• Other tyres in-between with some significant and some non-significant differences
Order in Vectra tests, $PM_{10}$

- 170-studs tyre highest emissions
- 130-studs tyre second highest emissions
- 96-studs tyre lowest emissions
Results in road simulator, PNC

- 130-studs tyre highest emissions
- 190-studs tyres high emissions
- 96-studs tyre lowest emissions
Statistical analysis states that:

• Pirelli Ice Zero results in significantly higher PN concentrations than all other tyres
• Michelin X-Ice North results in significantly lower PM$_{10}$ concentrations than all other tyres
• Other tyres in-between with some significant and some non-significant differences
Effect of tyre parameters on PM$_{10}$ in simulator
Comparison road simulator and Vectra
Comparison road simulator and Vectra

High emissions per tyre

Highest emission per stud and mm protrusion

Lowest emission per stud and mm protrusion
Conclusions from studded tyre tests

• New regulations on studded tyres influence road wear and PM$_{10}$ emissions
• Different tyre manufacturers have different strategies to reduce wear
• Number of studs does not alone affect PM$_{10}$ emission, but the lowest number in the test has the lowest emissions in all tests.
• A tyre with high emissions can still have low emissions per stud and protrusion mm, showing that there are several parameters that can contribute to reduced emissions, such as stud protrusion, placement of studs on the tyre surface, tyre tread and rubber characteristics
• More data is needed to draw firm conclusions
Conclusions in brief

The NorDust project has resulted in:

• The first common Nordic road dust research collaboration
• Increased knowledge on
  • road dust formation and dynamics
  • influence on PM10 emissions of new studded tyre types
  • road dust abatement efficiency and influencing factors
  • road dust sampling technique and methodology
• Input for improved NORTRIP emission modelling and extended model implementation and evaluation
Report coming soon!

Thanks for your attention!

Photos: Sami Kulovouri and Mats Gustafsson