Policy development for the reduction of pollution caused by traffic experiences from The Netherlands

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Abstract Road traffic is a diffuse source of heavy metals and oil that leads to pollution of verges and surface water in areas immediately surrounding roads. The Commission for Integrated Water Management (CIW) has drawn up a policy document addressing methods for managing this type of pollution. The document is based on results from numerous studies in The Netherlands targeting pollution caused by traffic. The Commission concludes that measures at the source are the only way to realise sustainable solutions. For example, attention should be devoted to the issue of zinc emissions from car tyres and crash barriers. The concept of controlled infiltration is recommended for combating pollution caused by spray and runoff from roads. This includes periodic chemical inspection of verge pollution and, where necessary, replacement of the verge’s top layer. The application of porous asphalt on highways in The Netherlands has also proven highly effective in limiting pollution caused by traffic, with far less pollution caused by spray from the highway and runoff as compared to traditional asphalt.

Keywords Asphalt infiltration; metals policy; runoff; traffic

Introduction

Car traffic is a typical diffuse source of pollution of soil, water and atmosphere. Fuel combustion is a diffuse source of atmospheric carbon dioxide, nitrogen oxides and PAHs. Runoff and spray from the abrasion of tyres and road surfaces, leakage of lubricants, corrosion of crash barriers and pollutants such as heavy metals and oil lead to diffuse pollution of the soil of the verges and surface water along roads. This type of pollution occurs everywhere, from narrow village roads and cities to highways.

One of the first publications in The Netherlands to target traffic as a diffuse source of water pollution was published in 1986 (CUWVO, 1986). In doing so, the authors roughly quantified pollution based mainly on emission factors derived from information in international literature. They illustrated the importance of tyre abrasion leading to zinc emissions and lead emissions resulting from combustion of leaded fuel. It was the starting point for various field studies that addressed diffuse pollution caused by traffic. The chemical composition of runoff and pollution by spray from national highways in The Netherlands paved with porous and traditional asphalt was measured (Road and Hydraulic Engineering Division, 1995). Similar studies were carried out along provincial roads (de Jonge et al., 1999; Project Teams Diffuse Sources, 2000). The pollution of the verges along highways and provincial roads was investigated (Road and Hydraulic Division, 1990, 1999; Project Teams Diffuse Sources, 2000). The effectiveness of measures limiting the emission of runoff was investigated and evaluated (Berbee et al., 1996, 1999; Gronmij, 1999). And studies were performed into the concentration of various pollutants in runoff collected at large traffic tunnels in The Netherlands (MTI, 1997). These studies and their analysis have considerably increased the body of knowledge concerning diffuse pollution caused by traffic in The Netherlands.

At the same time, the pollution caused by traffic during large (re)construction works at
highways and provincial roads was evaluated. The question arose as to whether it is necessary to apply measures that limit emission to protect the soil of verges, its underlying groundwater or the surface water into which polluted runoff is discharged. Answers indicate that not only technical problems are important but that legal issues must also be addressed.

These questions arose at several (re)construction works. For that reason, the CIW (Commission for Integral Water Management) in The Netherlands decided to prepare a general policy guideline on how to deal with pollution caused by traffic in The Netherlands. This guideline includes general recommendations for supporting and harmonising licensing of permits for discharging polluted runoff. The guideline was published recently (CIW, 2002). This paper provides an outline of the information provided on diffuse pollution by traffic, the general guidelines and the discussions that took place.

Methods
The working group that prepared the policy document on runoff was composed of experts from provinces, water boards and road authorities. They first made an inventory of all knowledge on pollution by runoff as described in reports and in literature. There appeared to be a lack of information about costs and the effectiveness of measures limiting emission. A separate study was performed to fill these gaps (Grontmij, 1999).

Results and discussion
Pollution caused by runoff
There are various pathways for pollution caused by traffic, including large-scale spread into the atmosphere, runoff and spray (see Figure 1). Well-known gaseous pollutants such as NO\textsubscript{X} and CO\textsubscript{2} are distributed widely into the atmosphere.

Table 1 provides an overview of the concentrations of pollutants found in runoff, as measured in various studies in The Netherlands. The concentrations of Zn, Cu and oil in runoff are far higher than in rainwater. The presence of zinc is explained by the abrasion of tyres. The presence of copper is probably caused by abrasion of brake lining (Milieudata, 1997). Oil leakage from vehicles is certainly responsible for its presence in runoff. Corrosion of zinc-coated crash barriers may also be a source and may be responsible for considerably higher zinc concentrations in runoff than the zinc concentrations mentioned in Table 1 (Berbee et al., 1996).

Highways in The Netherlands are generally made of porous asphalt, consisting of an upper layer of 5 cm of porous asphalt on impervious asphalt. Compared to traditional
asphalt this type of asphalt has benefits as to reduced generation of spray during rain, less noise and greater skid resistance. The runoff from porous asphalt contains far lower concentrations of pollutants (see Table 1). This is probably a result of the filtration of the solids in the runoff in the asphalt’s porous top layer. These solids and sand are transported to the unused hard shoulders by a type of pumping effect by the tyres. To avoid plugging, these hard shoulders have to be cleaned periodically using special equipment. Porous asphalt has a few disadvantages: its lifespan is somewhat less than traditional asphalt and it requires more salt in periods of black ice during wintertime. In the relatively mild maritime climate of The Netherlands however, these disadvantages are more or less accepted.

For traditional asphalt, a variation was expected in runoff quality from highways, provincial and municipal roads, because of its dependency on traffic intensity. However, a comparison of concentrations found as shown in Table 1 indicates that this is not the case. Polluted runoff from highways and province roads mostly infiltrates the soil of the verges. In some cases, it is collected in sewage systems and is discharged into surface water to prevent dangerous situations caused by water on the road surface.

Pollution by spray
Spray (dry and wet) is another pathway for pollutants into a road’s immediate surroundings. Table 2 provides an overview of the quantitative size of spray, derived from measurements of pollutant deposits on grass turf along five highways in The Netherlands.

Table 2 shows that the contribution of spray on traditional asphalt is greater than that for runoff. It is not surprising that on highways with porous asphalt, spray is of no significance at all. There are three explanations: the fast removal of rain by drainage through the pores, the lower concentrations of pollutants and the reduced amount of runoff (on average only 20%, Berbee, 1996). The reduced amount of runoff is a result of greater evaporation due to pores in the asphalt.

Soil and groundwater pollution
Both spray and runoff from roads lead to pollution of the verges. Heavy metal concentrations were determined as a function of depth and distance from the road in soil of verges of 40-year-old highways with traditional asphalt. In general, pollution was limited to a depth

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Concentration of pollutants in runoff from different types of asphalt roads (CIW, 2002)</th>
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</thead>
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<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Highways (asphalt type)</th>
<th>Provincial roads</th>
<th>Municipal road</th>
<th>Rain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Traditional</td>
<td>Porous</td>
<td>North and South-Holland</td>
<td>Gelderland</td>
</tr>
<tr>
<td>Suspended solids mg/L</td>
<td>187 (153–354)</td>
<td>17 (2–70)</td>
<td>49 (5–300)</td>
<td>90</td>
</tr>
<tr>
<td>NOx-N mg/L</td>
<td>0.5/0.9</td>
<td>1/2</td>
<td>13 (1–26)</td>
<td>0.9</td>
</tr>
<tr>
<td>N-Kj mg/L</td>
<td>1/2</td>
<td>1/2</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>COD mg/L</td>
<td>143/149</td>
<td>16/18</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>BOD mg/L</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>8.7 (4.1–16)</td>
</tr>
<tr>
<td>Cd µg/L</td>
<td>1 (1–5)</td>
<td>0.1 (0.1–1)</td>
<td>0.7 (0.1–6.5)</td>
<td>&lt;0.4 (&lt;0.4–0.52)</td>
</tr>
<tr>
<td>Cr µg/L</td>
<td>5 (3–26)</td>
<td>1 (0.4–3)</td>
<td>12 (1–47)</td>
<td>3.5 (&lt;2–14.8)</td>
</tr>
<tr>
<td>Cu µg/L</td>
<td>121 (11–163)</td>
<td>40 (14–107)</td>
<td>37 (2–160)</td>
<td>82 (22–84)</td>
</tr>
<tr>
<td>Ni µg/L</td>
<td>5 (4–15)</td>
<td>1 (1–9)</td>
<td>5 (1–21)</td>
<td>&lt;10 (&lt;10–&lt;10)</td>
</tr>
<tr>
<td>Pb µg/L</td>
<td>93 (51–195)</td>
<td>7 (2–34)</td>
<td>18 (5–110)</td>
<td>29 (&lt;10–100)</td>
</tr>
<tr>
<td>Zn µg/L</td>
<td>452 (225–530)</td>
<td>47 (18–133)</td>
<td>152 (22–700)</td>
<td>181 (111–313)</td>
</tr>
<tr>
<td>Oil mg/L</td>
<td>4 (3–8)</td>
<td>&lt;0.1 (&lt;0.1–0.2)</td>
<td>0.5 (0.025–2.7)</td>
<td>1.0 (0.55–1.2)</td>
</tr>
<tr>
<td>PAHs (VROM) µg/L</td>
<td>3.7/4.3</td>
<td>&lt;0.2/0.2</td>
<td>0.9 (0.0–5.3)</td>
<td>0.8 (0.43–1)</td>
</tr>
</tbody>
</table>

1 Most measurement occurred in the period 1990–2000. The table shows median values. In cases of limited numbers of observations, the actual data measured is shown. Values between brackets are minimum and maximum values.
of no more than 60 cm and was concentrated in the first few metres along the highway and in the first 5 cm of the verges. An illustration of the soil pollution is shown in Figure 2 (CIW, 2002).

In most cases, the concentrations of pollutants in the soil and ground water were below or close to the target values for soil in The Netherlands. A monitoring programme along a ten-year-old highway with porous asphalt (A58 Breda) did not reveal any accumulation of pollutants in the verges or groundwater. This is not surprising in view of the far lower pollution generated by this type of highway (see Table 2).

**Effectiveness of measures limiting emission**

In France and Britain, settling basins are occasionally used for removing pollutants in runoff (Middlesex Polytechnic, 1991). In The Netherlands, Berbee et al. (1996 and 1999) studied the settling properties of the solids in runoff of porous and traditional asphalt. Settling proved to be a very slow process. Calculations of effectiveness and costs of settling basins for treating runoff from province roads and highways were made (Grontmij, 1999) on the basis of settling properties measured previously (Berbee et al., 1996). The efficiency of removing heavy metals (Zn, Cu and Pb) was disappointingly low: around 40% for runoff from traditional asphalt roads and less than 20% for highways with porous asphalt (Grontmij, 1999; Berbee, 1999). The very low efficiency in the case of porous asphalt can be explained by the existing low concentrations of suspended solids in runoff from porous asphalt (see Table 1). The cost of settling basins is particularly high and amounts to (tens of) thousands of euros per kg of heavy metals removed. These costs are more than a factor of ten higher than those usually encountered in wastewater treatment (Berbee, 1999).
should also be noted that the use of settling facilities does not affect the soluble fraction of metals in the runoff or the more important pollution of the verges by spray.

Model calculations indicate that pollutants in runoff are removed very efficiently (some 90%) when runoff infiltrates either the soil itself or specially designed infiltration basins (Grontmij, 1999). Infiltration inevitably leads to pollution of the verges, although the results of monitoring programmes along old highways indicate that pollution of the verges remains limited to the top layer of the soil (see also Figure 2). These verges were not only exposed to polluted runoff but also to spray.

**Policy development**

The discussion on policy development took place within the working group of the CIW. All representatives were aware that traffic leads to more or less unavoidable pollution that has to be accepted in view of the current mobility conduct and desires of our society.

The importance of taking measures at the source received unanimous support. It is considered the only way to influence the issue of diffuse pollution. Measures that influence the pathways of pollutants only alter the compartment in which pollutants finally settle (atmosphere, soil or water) but do not effectively change the scope of the emissions.

An important point of discussion within the working group was the balance between pollution of either the soil–ground water system in the verges, or the surface water. The province representatives responsible for soil quality were especially concerned about the impact of infiltration on groundwater extracted close to roads and highways for the production of drinking water.

Within the working group, it was recognised that measures limiting emission through treatment of runoff do not affect the more important variable, pollution by spray. Infiltration of the runoff in the verges or in centralised infiltration basins results in pollution of the top layer of the soil close to the roads. The top layer of the soil however can be monitored by analyses and replaced if concentration limits in the soil are exceeded. In general the top layer is removed in any case during regular maintenance activities. In this respect, the use of porous asphalt on highways has clear benefits with respect to reduced pollution by both runoff and spray.

Introducing runoff directly into surface water would entail accepting diffuse pollution in a highly mobile compartment that cannot be controlled.

As a result, the working group finally chose the concept of controlled infiltration of runoff in the verges. The word controlled means that the chemical quality of the soil and groundwater has to be inspected periodically in order to prevent limits being reached. In very sensitive areas, routing runoff outside the area where it can be infiltrated may be considered. This choice of controlled infiltration agrees with current practice. Runoff is infiltrated along most roads outside villages and cities in The Netherlands.

**Conclusions**

The considerations of the working group led to the following conclusions and recommendations.

More attention should be devoted to limiting the emission of micro-pollutants at the source, for instance limiting Zn emissions from tyres and Cu emissions from brakes. This will require initiatives at the European Union level. On a national level, research and application for alternative zinc-coated crash barriers and portals are recommended. This type of measure is the only way to achieve more sustainable solutions. “End of pipe measures” only affect the pathway and do not provide real solutions.

Controlled infiltration of polluted runoff in the verges seems to be the best practical method of treating runoff. In this way, micro-pollutants such as metals, oil, PAHs are fixed.
in the top layer of the verges. Periodic analyses of the verges and groundwater are recommended. Results from existing monitoring programmes and model calculations show that the accumulation of pollutant levels proceeds very slowly. Inside cities and villages, diffuse sources other than runoff also play a role (corrosion of gutters, animal excreta, and so on). In these situations, tailored solutions for treatment of the runoff should be found (infiltration or treatment in a biological wastewater treatment plant).

Measures directed at purifying runoff have highly limited efficiency, are costly and do not solve the issue of pollution caused by spray. In view of the very low COD and N-Kj concentrations (Table 1) and the high flows of runoff from road surfaces, treatment in a sewage treatment plant is not recommended.

In the relatively mild maritime climate in The Netherlands, the application of porous asphalt on highways is feasible. Compared to traditional asphalt, it generates far lower emissions of micro-pollutants through spray and runoff. The pollutants and sand released from this type of road surface appears to concentrate in the hard shoulders. To prevent aquaplaning on the driving lanes, a clean up of these hard shoulders is required twice a year.

In vulnerable areas, the concept of controlled infiltration also seems to provide sufficient protection. In order to avoid risks, a more intensive chemical monitoring program of the verges could be considered. One option may be to route the runoff outside the sensitive area. This is not a solution for the pollution caused by spray. Only the use of baffle boards or hedges seems to offer a solution for limiting the spread of polluted spray.

As far as environmental issues in road (re)construction are concerned, road managers have to deal with a variety of authorities, water boards, municipalities and provinces. Different environmental effects (soil pollution, discharge into surface water, and so forth) are governed by several different Acts, giving rise to legal disputes. Producing a specific decree to simplify these matters is therefore also recommended.

References
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