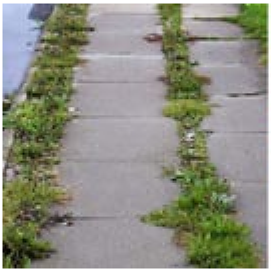
DIAS report

Conference on Policies on Pesticide Use by Local and Regional Authorities

25th April 2006

Wageningen UR, Wageningen, The Netherlands

Sonja Graugaard, Kirsten Jensen,
Bo Melander, Corné Kempenaar (Editors)




North East South West
INTERREG IIIC
PROJECT PART-FINANCED
BY THE EUROPEAN UNION
CleanRegion

DIAS report no. 126 • December 2006

Ministry of Food, Agriculture and Fisheries
Danish Institute of Agricultural Sciences

DIAS report Plant production no. 126 • December 2006

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Department of Integrated Pest Management
Danish Institute of Agricultural Sciences
Forsøgsvej 1
DK-4200 Slagelse

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Print: www.digisource.dk
ISBN 87-91949-04-1
ISSN 1397-9884

CleanRegion

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Organizing committee
Corné Kempenaar
Joop Spijker
Cees Niemeijer

PROJECT PART-FINANCED
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Preface

The new INTERREG IIIC operation "Regional Collaboration for Minimising Pesticide Emissions in the Environment", in short "CleanRegion" was launched in early spring 2005. The project links research institutes and local and regional authorities in Denmark, Finland, Germany, Latvia, the Netherlands, Sweden and the United Kingdom. Together they want to minimize the use of herbicides for weed control in urban areas and thus reduce the risk of pesticides leaching to the ground water.

At the moment, European discussion is strongly focused on the use of pesticides in Europe, and on the risk they pose to human health and to the environment. The sustainable use of pesticides is one of seven key environmental issues to be tackled in the Sixth Community Environment Action Programme (EAP), 2001-2010[1]. Besides other negative effects, pesticides contribute to increased water pollution and with this to growing pressure on natural resources - one of the unsustainable trends addressed by the currently reviewed Gothenburg Strategy.

The municipalities and cities involved in CleanRegion spend extensive time and money on weed control on hard surfaces, such as pavements, parking places and squares. Spraying with herbicides has been the predominant method for weed control for many years. However, pesticide use on hard surfaces has been severely restricted in some countries, e.g. in Denmark and Germany, or in specific municipalities in Sweden. And taking the pesticide policy of the EU into account, it is expected that other EU countries will follow this path in the years to come. Alternative, more environmentally friendly methods for weed control such as flaming, brushing, mowing and steaming are already in use. But the methods are very costly compared with herbicide spraying, and the scientific knowledge of the public authorities for optimising control on different types of surfaces is still limited.

The project partners will survey weed species and weed abundance in the cities and regions involved. Various weed control methods, mainly non-chemical, and management strategies will be tested. Based on the results of these tests, practical guidelines for weed control on hard surfaces are formulated, which will then be disseminated to other municipalities and cities in Europe. These will help to develop new strategies for weed control, which are environmentally friendly and at the same time economically sustainable.

Besides weed surveying and test of strategies, CleanRegion also contains a component with the aim to exchange information and experience among the participants on the different policies on pesticide use implemented in their regions. Most of this information was presented at a one-day conference held on 25th April 2006 at Wageningen University in The Netherlands. This proceeding contains summaries of the main content given in each talk.

Further information can be obtained from the Project Manager Mr. Bo Melander, Danish Institute of Agricultural Sciences, bo.melander@agrsci.dk

[1] For more information: http://europa.eu.int/yourvoice/forms/dispatch?form=399

Inventory of policies on pesticide use by local and regional authorities in the 7 project countries (DE, DK, FI, LV, NL, SE, UK)

P. Kristoffersen & A. M. Rask
Danish Centre for Forest, Landscape and Planning, The Royal Veterinary and Agricultural University, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark

Summary

A comprehensive overview of the regulation of use of pesticides for weed control in urban areas, including the actual pesticide use, was carried out with a questionnaire addressed to the CleanRegion steering committee members in the seven project countries. The aim was to test the differences in political interest and public debate on the topic: "use of pesticides on public urban areas". The questionnaire included questions regarding the historical development in the political interest, national, regional and local regulations within each country and questions on the amounts of pesticides used on paved areas contra total use of pesticides. A comparative analysis of the answers revealed major differences on political interest, regulations and availability of statistics on pesticide use.

Introduction

The use of pesticides for weed control exerts a major threat to the environment including drinking water resources all over the world, (Albrechtsen *et al.*, 2001; Barbash *et al.*, 2001; Kolpin *et al.*, 1998). In Denmark, the drinking water supply is primarily based on ground water (Stockmarr *et al.*, 2000), and these resources are in danger of being polluted by percolation of pesticides into the lower aquifers. In a large number of wells, the authorities have already detected concentrations of pesticide residues exceeding the Danish drinking water limit of 0.1 µg/l (Spliid *et al.*, 1998; Stockmarr *et al.*, 2000). The relevant legislation in force within the European Union is the Council Directive concerning the placing of plant protection products on the market (EEC, 1991). This legislation is the only regulation of the use of pesticides for weed control regarding the member states of the European Union. The directive recognises that plant protection products may involve risks and hazards to humans, animals and the environment, if not properly tested and authorised. Other regulations both statutory and voluntary may exist within each member state.

This paper presents the results of a survey on political interest and regulations of pesticide use on non-cropland in the seven project countries. In the following, the definition "non-cropland" or urban areas will be referred to as describing areas like roads, pavements, squares, parks, gardens, sports grounds, golf courses, cemeteries, etc.

Results and discussion

Policies

In Denmark, Sweden, Germany and The Netherlands the subject "use of pesticides on urban areas" has received great attention in recent decades (Table 1). This interest has mainly arisen due to public awareness of the environmental consequences of using pesticides. In The Netherlands, concentrations of diuron above 1.0 μg/l was found in 1993 in the river Meuse, which is used for drinking water. Diuron was mainly used by public authorities on paved areas. As a consequence political interest increased, and since 1995 all policy papers on the topic pesticides have paragraphs on the use in urban areas. In Sweden, the political interest started in the 1970's after a massive debate about the use of Agent Orange in forestry and along railways. Aerial spraying was totally banned in 1977. The debate went on because the Swedish Agricultural University found chemical residues in watercourses, and the government then decided that the use of herbicides should be halved by 1990. In Denmark, the debate resulted in a political hearing in the Danish Parliament about pesticide use in general, and an inventory of public pesticide use was started in 1995. It was decided in 1998 to phase out the use of pesticides on public areas by 1st January 2003 at the latest.

In Germany, the debate has ceased and is instead focused on neglected maintenance of public areas.

Table 1. Political interest and regulation on pesticide use in the seven project countries.

Country	Political interest	Regulations on urban areas	Statistics on pesticide use on urban areas
Denmark	Strong	Very strict	Yes
Sweden	Strong	Strict/Very strict	No
The Netherlands	Strong	Strict	Yes
United Kingdom	Moderate	Strict/ moderate	No
Germany	Moderate	Strict (varying between federal states)	No
Finland	Almost none	No specific regulations	No (rough estimate given)
Latvia	Weak	No specific regulations	No

In the United Kingdom, there has been some debate and political interest on pesticide use on public areas, whereas the debate has been weak or non-existing (Table 1) in Latvia and Finland.

Reflected by the political interest, use of alternative control methods, research and technological innovation is very high in Denmark, Sweden and The Netherlands compared with the other countries (Table 2).

Table 2. Interests in and activities on alternatives to chemical control in the seven project countries.

Country	Use of alternatives	Research into alternatives	Technological innovation
Denmark	Common	Strong	High
Sweden	Common	Moderate	Moderate
The Netherlands	Common	Strong	High
United Kingdom	None	Weak	Weak
Germany	Some	Some	Moderate
Finland	None	None	None
Latvia	None	None	None

Regulations

The level of regulations in the project countries is in all cases reflected by the political interest and public debate. As a consequence Denmark, Sweden, Germany and The Netherlands are among the countries with the strictest regulations. In Germany the debate has ceased and is instead focused on neglected maintenance of public areas. In United Kingdom, the regulation is strict/moderate, whereas Finland and Latvia do not have specific regulations regarding the use of pesticides on public areas.

Use of pesticides

Statistics on the use of pesticides on public areas were not available in five of seven countries (Table 3). Information on total amounts of pesticides (cropland and non-cropland) was collected from all countries apart from Latvia and (partially) United Kingdom. The variations in total pesticide use is partly due to differences in land area, cultivation intensity and population density, but is probably also somewhat influenced by the regulations in each country. This issue needs further investigations.

Table 3. Available statistics on the use of pesticides in the seven project countries. a.i. is active ingredients.

Country	Land area (sq km)	Population	Urban areas (t a.i. year^{-1})	Total use (t a.i. year^{-1})
Denmark	43,070	5,387,000	6.3 (2002 data)	2,087 (2004 data)
Sweden	411,620	8,878,000	No specific info on urban areas	1,075 (data from 2004)
The Netherlands	33,920	16,407,000	40.042 (CBS 2001)	Rough estimate: 1,500-2,500
United Kingdom	241,600	59,247,000	No specific info on urban areas	No info on total herbicide use
Germany	349,520	81,904,000	No specific info on urban areas	15,113 (data from 2004)
Finland	304,610	5,215,000	Rough estimate: 10 (glyphosate)	About 1,180 (data from 2004)
Latvia	64,589	2,290,000	No specific info on urban areas	No info available

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Dutch policy regarding pesticide use on hard surfaces

W. van Zeventer
Dutch Ministry of Transport, Public Works and Water Management, Directorate General Water, P.O. Box 20906, NL-2500 EX Den Haag, The Netherlands

For further information please contact the author.

Handling the risk of drinking water pollution by pesticides

J. Verheijden

Dutch Waterworks RIWA (Association of River Waterworks), Postbus 57212, NL 1040 BC Amsterdam, The Netherlands

Most people do not realize what is all behind the tap when they pour a glass of water or take a shower. It is all obvious and that is good[2]

Apart from logical functions of the river Meuse, such as navigation, cooling water, irrigation water, recreation, fishing, and the like, this typical river has an important role as raw material for the production of drinking water. About 6 million people and industries consume or use drinking water from the river Meuse. With respect to the extent of the flow of this "rain" river - and thus a restricted capacity during dry seasons - this can be considered as a huge volume of water. To give an indication: Brussels, Antwerp, Rotterdam, The Hague and the south-western part of The Netherlands are to a large extent dependent on Meuse water. The alternative of ground water does not exist in these areas because of brackish quality.

The water companies have invested billions of Euros in 'high technology" purification plants, storage basins, pipelines and other infrastructure. Until today they succeed in providing liable and tasty drinking water to their clients. But, these companies are "under attack"! During the past decades successively there exist the point sources of polluters - often industrial emissions located along the border of the river - which have been cured now.

There were also the communal drains of cities and urbanized areas without the treatment of sewage water. Investment plans are being realized now to improve the communal drain by building sewage treatment plants and collector systems, so it is expected that by the year 2010 the Meuse waterwill improve by lower content of bacterias and vira. Finally there are the diffuse polluters. As the word already indicates: very difficult to catch.

More and more pharmaceuticals and/or endocrine disruptors form a diffuse polluter. After treatment by humans these medicines end up in the sewage water. Even modern sewage water treatment plants do not form a barrier against these parameters and thus they are included in the effluent. Nowadays the concentrations of these medicines in the river Meuse are still very low. But they need attention. Studies are being carried out to prevent or diminish the discharge to surface water.

More of high concerns are for example pesticides used in agriculture and for example herbicides used on paved terrain or streets.

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[2] This presentation reckons with the fact that the conference attracts a broad audience as well as stakeholders, local communities and governmental policy makers. The subject is actually an invitation to all these parties and users of chemical products in household or on pavements as well as in agriculture to adapt their use to, what we call, sustainable use.

These biocides easily flow off with rain and reach the surface water. During the past years we measure increasing concentrations of the, sometimes even unknown, chemicals.
The water companies are concerned about this risk of drinking water pollution. They start from the principle that these stuffs do not belong in their raw material, but also with respect to the (toxic-) ecological effects. They cannot warrant that they always are able to eliminate these during the purification process.

Therefore, together they try to adjust this contamination of the river water with diffuse polluters. In co-operation with scientific institutes, universities, producers, users and governmental bodies, certified methods for the use of pesticides and/or herbicides have been developed and proved sustainable.

Now users of these chemicals, those are amongst others municipalities, farmers and private persons, are to be convinced to implement and apply these methods.

In order to give an idea of what actually was necessary to create a reliable provision of drinking water in the south-western part of the Netherlands; downstream of the river Meuse
more than 8 million people live in the Meuse basin. The river is not only a major waterway, but is also used for the discharge of cooling water from nuclear power plants and of domestic, industrial and agricultural sewage. The sewage treatment is still insufficient, especially in Belgium. Therefore, the water quality of the Meuse must be monitored carefully at all times. Every year hundreds of water samples are taken from the river for analysis in sophisticated laboratories.

The National Reserve The Brabantse Biesbosch hides three artificial reservoirs. They were built by the Water Storage Company Brabantse Biesbosch, or WBB. Since 1973 WBB supplies high-quality water – taken from the river Meuse - for the production of drinking water and industrial water in the south-western part of the Netherlands. Each second more than 5,500 litres of naturally purified water is pumped to the customers of WBB, 24 hours a day, year in, year out. The water intake of the reservoirs is guarded by biomonitors (daphnia and algae toximeter). If excessive pollution is detected, the water intake stops automatically.

The Meuse water is pumped into the first storage reservoir able to cope with ten weeks of drought or bad river water quality. The next two reservoirs are process reservoirs ensuring a minimum retention time for self-purification of the water.

The Berenplaat waterworks of the Water Supply Company Europoort treat about 100 billion litres of Biesbosch water each year and supply drinking water to households and industries in the Rotterdam region.

WBB can supply up to 230 billion litres per year. This capacity may increase in the future, if the river Meuse gets cleaner.

In 1993, the water intake had to be stopped for seven weeks because the Meuse was contaminated with the herbicide diuron. Water production was not disrupted, however, thanks to the large storage of water.

Beyond WBB at the Biesbosch other important withdrawals from the river Meuse are taken upstream by the water companies of the conglomerations of The Hague, Antwerp and Brussels. In order to overcome shortages of raw material for the production of drinking water, large volumes of purified water are stored by means of deep infiltration in the dunes along the coast line of Holland. The other water companies have small storage of Meuse water only and have to change source during dry periods with insufficient flow in the Meuse.

River water quality

The water quality developments in the Meuse are checked (by RIWA-Meuse) very carefully on a weekly basis very carefully. No intake stop will end before the river water meets the strict quality standards again.

The most important standard is the directive of the European Commission 75/440/EEC of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the Member States. Later, 23rd October 2000 the Water Frame Work Directive (200/60/EC) enforced these standards by the aim of article 7, sub 3, which says: "Member States shall ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water".

Biology and chemistry are equally important water quality aspects. The biological processes in the reservoirs have a strong impact on water quality. Some fish species feed on water fleas for instance, which is bad for water quality because the water fleas feed on nuisance algae in the water. The entire aquatic foodweb: bacteria, algae, invertebrates and fish is being monitored.

Meuse water quality in 2015 satisfactory?

Based on the Article 5 analysis published by the IMC in 2005 a prognosis will be given whether Meuse water quality in 2015 is compatible with the set of goals that have to be achieved under the EU Water Framework Directive. It seems likely that good chemical (ecotoxicological) status may be achieved if adequate pollution control measures are taken in the next decade. On the other hand, it is very doubtful that Meuse water quality in 2015 will be entirely satisfactory to the Belgian and Dutch drinking water companies which supply more than 6 million people with purified Meuse water. A particular problem for these companies is the excessive load of herbicides in the river that today necessitates very advanced and expensive water treatment technology.

RIWA-Meuse . . . your drinking water guardian

RIWA-Meuse was founded in 2001. Prior to 2001 the interests of the drinking water companies using Meuse water as their source of drinking water were represented by RIWA. RIWA also acted on behalf of the drinking water companies, which used the Rhine and the Scheldt as their source for the production of drinking water. As an independent organisation, RIWA-Meuse is now able to fully concentrate on the problems connected with Meuse water.
RIWA was founded in 1951 as an international association with members in the Netherlands and Belgium. RIWA’s responsibilities comprised the Meuse, Rhine and Scheldt river basins. This is an area in which 27 million people depend on these three rivers for their drinking water. For over 50 years it has been the aim of RIWA — which continues to function as an umbrella organisation — to foster ecologically sound rivers and other catchment areas as a source for drinking water companies to produce impeccable and reliable drinking water by means of natural processes.

In order to assess the quality of river water, RIWA had a permanent monitoring network at their disposal. In addition large-scale monitoring campaigns were carried out on an occasional basis. Specific substances causing pollution were registered. All research data pertaining to the factors affecting the quality of water were published in specific reports and annual reports.

RIWA used to target national, regional and local authorities, European institutions, international river commissions, industry and agriculture. Its members were kept informed about new developments on relevant themes and policies by means of symposia, congresses and award giving ceremonies.

RIWA-Meuse intends to continue its efforts along the same lines, but will now be able to focus on the problems connected with producing drinking water of excellent quality from Meuse water as raw material for drinking water.

Weed control in the public area: combining environmental and economical targets

C. Kempenaar[1] & R.J. Saft[2]
[1]*Wageningen UR - Plant Research International, P.O. Box 16, NL 6700 AA Wageningen, The Netherlands*
[2]*IVAM UvA bv, P.O. Box 18180, NL 1001 ZB Amsterdam, The Netherlands*

Summary

Chemical weed control on pavements has the lowest direct costs of weed control compared to available non-chemical methods. However, side effects of herbicides on pavements (e.g. run-off to surface water) can be large when herbicides are used without special precautions. In this paper, data are shown of costs and side effects of different weed control methods on pavements under Dutch conditions. An Environmental Life-Cycle Assessment shows that the environmental effect of a herbicide control system to a large extent depends on the amount of herbicide run-off. In this paper, also data of an actor participative project on sustainable weed control on pavements are presented. The objective of the project was to develop a management system that gives a substantial reduction of herbicide run-off while maintaining good level of control at acceptable costs. Surface water, efficacy and cost monitoring in this SWEEP-project showed that the environmental and economical targets could be achieved. It shows that knowledge of costs, efficacy and side effects of weed control methods can be translated into management guidelines that support managers to implement more sustainable weed control.

Introduction

After World War II, the use of synthetic pesticides per area of cultivated land has increased enormously, mainly because of the economic advantages that pesticides offered. With time, side effects of pesticide use became evident. As a result, most countries introduced pesticide laws, enforcing science-based risk evaluations of admitted pesticides and banning of noxious pesticides. Pesticide regulation, integrated management concepts and certification (e.g. environmental labels) have reduced side effects of pesticides during the past 20 years, but further reductions are still needed. On the other hand, non-chemical management also has side effects. It is today still difficult for managers to find a sustainable balance between the economics and the side effects of their management. This paper is on finding this balance for weed control on pavements.

For comparison of environmental or toxicological effects of pesticides, systems like environmental yard stick and pesticide exposure risk index have been developed (e.g. Venderbosch *et al.*, 2004). These systems allow a science-based choice of pesticides with smallest side effects. For comparison of environmental effects of different control methods (pesticides versus mechanical control), instruments such as Environmental Impact Assessment, Life Cycle Assessment (LCA), Environmental Risk Assessment, Multi-criteria Analysis and Cost Benefit Analysis are available. These instruments vary considerably in objectives, scope, simplicity and data intensity. However all instruments have in common that they provide an integrated approach to environmental assessment. This is increasingly recognised as an important technique for managing the environmental impacts of human actions. It may be defined as the interdisciplinary process of identification, analysis and appraisal of all the relevant natural and human processes, which affect the quality of the environment and environmental resources.

In this paper, results of recent studies on costs and side effects of weed control on pavements are summarized. Firstly, data of two desks studies on costs and side effects (LCA) are presented. Secondly, results of an actor-participative project on sustainable weed control on pavements in municipalities in the Netherlands are presented. Finally, some concluding remarks are made.

Weeds and weed control on pavements

It is the nature of plants to colonise the bare soil of the pavements. Conditions that favour plant growth are pavements with large gaps, little wear, extensive rain and day temperatures between 20 and 30°C. Plants become weeds when they adversely affect the functionality, safety, longevity or aesthetic value of pavements. As a result, managers of pavements have to apply weed control when such adverse effects are expected.

Currently, mechanical (brushing, sweeping, mowing, hand weeding), thermal (flaming, hot water) and chemical (herbicides) weed control methods are applied on pavements (e.g. Kortenhoff *et al.*, 2001). In 2001, four out of five municipalities in the Netherlands used herbicides to control weeds on pavements (Ekkes *et al.*, 2002; Kempenaar & Spijker, 2004). On industrial sites, herbicide use on pavements is probably even higher. Many other countries in the EU have a similar situation, but there are also differences due to regulations or tradition (see paper on policies in different EU countries in this proceeding).

An important side effect of herbicide use on pavements is emission to surface and soil waters, where they may adversely affect ecology and drinking water production. Concentrations of herbicides that are used on pavements sometimes exceed the drinking water threshold of 0.1 μg/l in rivers in the Netherlands. This affects a large proportion of the drinking water production in the country. Today, glyphosate is the most used herbicide on pavements in the Netherlands. The maximum permissible concentration (MPC) of glyphosate in surface water is 77 μg per litre (e.g. Withagen *et al.*, 2004). The physical chemical properties of glyphosate (high solubility in water, high sorption to soil particles) make the compound very sensitive to surface run-off while it hardly leaches to ground water (Luijendijk *et al.*, 2003; Ramwell & Hollis, 2003; Beltman *et al.*, 2001). In risk evaluation studies of Saft & Staats (2005, 2002), a run-off factor for standard practice herbicide use on pavements of 50% is used.

Desk studies on costs and environmental effects

Costs of weed control

In 2005, costs of weed control systems on pavements in municipalities were studied (Syncera, 2005). The systems are named after the main control method applied during a season: brushing, flaming, hot water and herbicide weed control (selective application technology is obligatory). The methods are applied in different frequencies to keep weed growth on pavements below a certain specification. Table 1 contains both frequencies and costs per year for different systems and two specifications of acceptable weed growth (the level of weed growth not to be exceeded). The figures in Table 1 reflect the current practical situation in the Netherlands.

Table 1. Frequencies of application per year and costs per m^2 per year of important weed control methods in the Netherlands (2005 price level).

System	Threshold weed growth specification			
	*Little weed growth**		*Very little weed growth**	
	Frequency	Costs (€ m^{-2})	Frequency	Costs (€ m^{-2})
1. Brushing	3	0.19 – 0.38	3.5 - 5	0.20 – 0.40
2. Flaming	Not applicable		5	0.15 – 0.35
3. Hot water	2.5	0.22 – 0.32	3 - 4	0.30 – 0.40
4. Herbicides	2	0.05 – 0.08	2.5	0.07 – 0.10

*Little weed growth means less than 25% of bare soil in the pavement is covered by weeds, very few weeds taller than 5 cm and no clumbs of weeds; very little weed growth means less than 5% of bare soil is covered by weeds, no weeds taller than 5 cm and no clumbs of weeds (after scale of Eco Consult, English translation of scale in Kempenaar *et al.*, 2006).

A few studies also address the issue of the external costs, for instance the abatement costs made by drinking water companies to remove herbicides and other impurities from their resource water. The external costs can have a significant influence on the integrated cost level. However, so far a sound allocation of costs has been hampered by major uncertainties.

Life Cycle Assessment

Environmental Life Cycle Assessment (LCA) provides a framework for identifying and evaluating environmental burdens associated with the life cycles of materials and services in a "cradle-to-grave" approach. LCA is a technique for assessing all the inputs and outputs of a product, process or service (Life Cycle Inventory); assessing the associated wastes, human health and ecological burdens (Impact Assessment); and interpreting and communicating the results of the assessment (Life Cycle Interpretation) throughout the life cycle of the products or processes under review. The term "life cycle" refers to the major activities in the course of the product's life-span from its manufacture, use, maintenance and final disposal; including the raw material acquisition required to manufacture the product. When one has to decide between two alternatives, LCA can help decision-makers compare all major environmental impacts caused by both products, processes or services. This ability to track and document shifts in environmental impacts can help decision makers and managers fully characterize the environmental trade-offs associated with product or process alternatives. It was this ability to show trade-offs that initiated the LCA studies for chemical weed control versus non-chemical weed control in 2002 and 2005.

In the LCA study, a number of work packages have been described that are able to fulfill the functional unit of controlling 1,000 m^2 of municipal pavement to a level of very little weed growth. These work packages are described in Table 2.

Table 2. Defined work packages (wp) for the LCA.

System	Frequency	Specification
1. Brushing	3.5	brusher machine 1,200 m^2/h, diesel fuel, waste to composting, partial weed control with glyphosate, 50% herbicide run-off
2. Flaming	5	flaming unit 1,200 m^2/h, LPG fuel
3. Hot water	3	hot water unit, 1.872 m^2/h, diesel fuel
4. Herbicides	2.5	sensor controlled application, 2,500 m^2/h, petrol fuel, glyphosate dose 0,43 kg a.s./ha per application, 50% run-off
5a SWEEP* high	2.5	see description below, 25% run-off
5b SWEEP* low	2.5	see description below, 3% run-off

* Explained in the next section

The results of the LCA study were presented as a number of impact category scores. A higher score means a higher (potential) impact on ecosystems and human health. Figure 2 gives an outline of the impact scores per category. The values on the y-axis are unitless and used only for relative comparison.

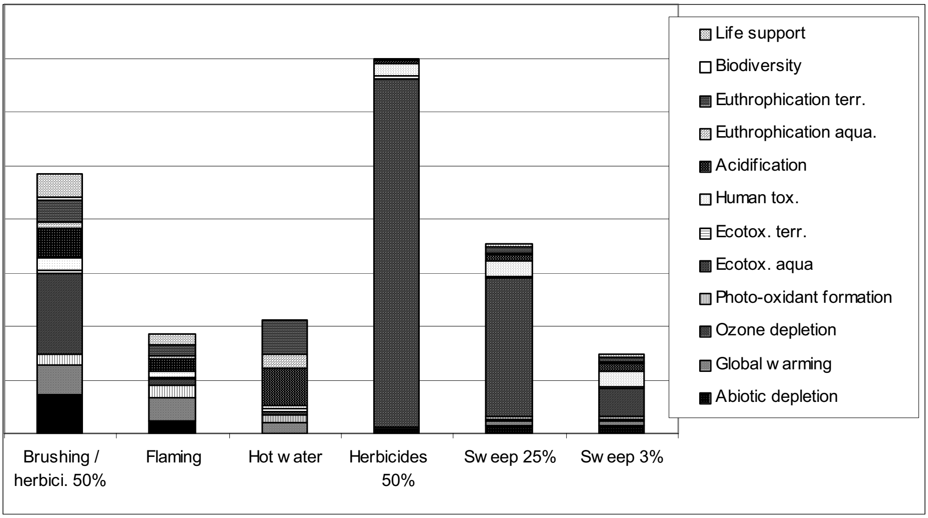

Figure 2. Impact scores from the LCA weed control on pavements (explanation of wp in Table 2).

From these results we learned that the use of herbicides has a major impact on the total score. The final emission of glyphosate caused by direct and indirect emissions (i.e. after sewage water treatment) is assigned to the impact category of aquatic ecotoxicity. The brushing work package has a less favourable score due to the relatively high fuel consumption and the additional use of herbicides in less accessible areas. Flaming, hot water and SWEEP have similar scores, although the latter is influenced by the run-off fraction.

For policy makers and managers this information has proved useful in supporting their decision making. Certainly, however, additional input is needed in the decision making process as the LCA tool does not take into consideration site specific circumstances or local impacts e.g. on the local surface water quality or the local air quality.

Combining environmental and economic targets in SWEEP project

The aim of the project was to develop a new concept of hard surface weed management that provides cost-effective and environmentally sound weed control. In the actor participative project, it was studied from 2002–2004 if herbicide use and emission could be reduced to a level that surface water criteria are met while costs, efficacy and ease of weed control remained acceptable for the majority of hard surface managers. The new management concept was tested in interaction with municipalities, weed control contractors, water boards and other stakeholders. The core of the concept is emission reducing measures. A summary of the measures is given below (for details, see www.dob-verhardingen.nl under shortlists (in Dutch and English)):

1. No herbicide use if the pavement is within 10 km upstream of surface water that is used for drinking water production.
2. No herbicide use on 1-m wide zones of pavements bordering surface waters.
3. No herbicide spraying when weather forecasts are favourable for run-off (probability of rain > 40 % and > 1 mm).
4. Restricted herbicide use near gully pots.
5. Best practices have to be applied (e.g. weed sensors for selective spraying).

Other elements of the concept are professional organization with maximum weed growth specifications, stimulation of weed prevention, monitoring of herbicide use and certification. Information on weed prevention is provided in a handbook (Kempenaar, 2004, version 1). The name of the new concept is SWEEP, Sustainable WEEd control on Pavements (DOB in Dutch).

Observations in SWEEP managed test areas

The SWEEP concept was tested in management units in urban areas of nine municipalities in the Netherlands in 2002-2004. The units were residential quarters (areas) of 5–25 ha with about 30% paved area to be managed. The following observations were done in the management units:

- Type and frequency of weed control methods applied, and herbicide use
- Herbicide run-off (glyphosate, AMPA, MCPA, glufosinate ammonium) to sewage water, sewage water purification facilities and surface water. Point sampling and flow rate proportional sampling was done.
- Efficacy of weed control (weed infestation was estimated on 20 random positions in the quarter on 3 - 5 dates per season.
- Costs of weed control per quarter per m^2.

For details, see reports on www.dob-verhardingen.nl and Kempenaar *et al.*, 2006.

Run-off, efficacy and costs

Table 3 summarizes the results of the observations in the test quarters. In one test quarter, the manager decided not to use herbicides because there were many canals in the quarter. He applied a combination of flaming, sweeping and brushing. In the other quarters, generally two times per year herbicides were applied under the SWEEP restrictions. The new concept gave on average a surface water concentration of 0.8 µg glyphosate per l at the discharge points of sewage water to surface water shortly after rain fall (worse case moment) (see Figure 3A). The 90-percentile was seen 1.3 µg per l. The ecological threshold (MPC) was not exceeded, but the 0.1 µg per l threshold was in at least 33 out of 137 samples (precise number cannot be given because detection limit was 0.5 µg per l). However, all test quarters were located more than 10 km away from surface waters that are to be protected waters according to the register of surface waters used for drinking water production. In some reference quarters in 2003 and 2004 with standard practice chemical weed control, the average glyphosate concentration at discharge points was 7.8 µg per l (see Figure 3A) (Van Zeeland *et al.*, 2005).

Regression analysis of the emission data showed that rain fall, the amount of herbicide used and the places within the quarters where the herbicides were sprayed determined the emission to a large extent. Flow rate proportional sampling showed an emission factor of on average 2% (see figure 3B) and a worst-case factor of 5.7%. These figures were used to define SWEEP low in the LCA.

The managers of the pavements in the test quarters were satisfied about the level of control they obtained during the seasons. Combining chemical and non chemical weed control methods required more efforts from them, but was manageable. The costs of weed control (0.05 – 0.15 € per m^2) increased 20-30% depending on quarter and management specific conditions (compare costs in Table 3 with those in Table 1). It remains to be seen if this is acceptable for the majority of hard surface managers in the Netherlands.

Table 3. Weed control parameters in test quarters of 9 municipalities in 2002, 2003 and 2004 under the SWEEP concept of weed management.

Parameter	Result
Herbicide reduction in test quarters compared with previous years	11% to 66%
Control methods on areas where herbicide could not be used in the test quarters	Flaming, hand mowing, brushing, sweeping
Surface water quality: Mean concentration of glyphosate in surface water at discharge points shortly after rain (137 samples)	0.8 µg/l
Efficacy of weed control	Moderate to good
Costs of weed control per year	0.05–0.15 € per m^2

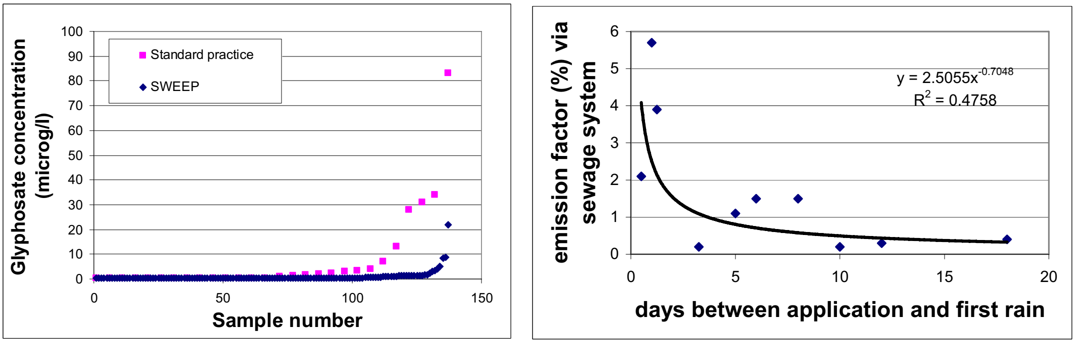

Figure 3. Glyphosate in surface water at discharge points in samples taken at moments of rain events after herbicide application on pavements (A, left), and relation between rain fall in test quarters and emission via the sewage water system (B, right) in study areas in 2002, 2003 and 2004.

Concluding remarks

Scientific knowledge of costs and side effects of pesticides and other control methods are essential to be able to combine environmental and economic targets in management practices. Cost and LCA studies on weed control on pavements provide useful information to promote more sustainable management practices. What the optimal trade off between targets is differs from country to country and site to site and because of differences in regulations, needs, tradition and environmental sensitivity, at national and local levels. SWEEP allows restricted herbicide spraying if the ecological standard of the herbicide applies for the surface water near the pavements, but no herbicide spraying when the drinking water standard applies. Also, personal considerations play a role. Alternative non-chemical methods on pavements are preferred, if highest priority is given to keep all surface waters free from residues of pesticides.

Herbicide use on pavements should be reduced to meet surface water quality criteria. The SWEEP system under Dutch conditions reduced herbicide run-off in the order of 90% compared with standard practice herbicide weed control on pavements (Figure 3A), while costs of weed control increased by 20–30% and the level of weed control remained good. Non- chemical methods are integrated with herbicide weed control in SWEEP. Herbicide weed control is not allowed in SWEEP when a pavement is close (10 km upstream) to surface water where the 0.1 µg/l criterion applies. SWEEP is a practical example of how knowledge on costs and side effects can be translated into guidelines for managers who want to combine economic and ecological targets in their management of pavements.

The EU Water Framework Directive (WFD) orders the local authorities at basin level to reach a 'good quality' of the water by the end of 2015. Herbicide use under SWEEP concept and non-chemical weed control methods can help to reach this objective. However, as the current market shares of both the SWEEP concept and non-chemical weed control methods are relatively small in the Netherlands, additional efforts are inevitable for a further reduction of the application of herbicides.

Acknowledgements

The cost and LCA studies were commissioned by the Institute for Inland Water Management and Waste Water Treatment and VEWIN in the frame of the OVO project. The actor participative project was commissioned by the water purification board ZHEW (now WSHD), VEWIN and Monsanto, and was financially supported by the Dutch Ministries of Agriculture, Nature & Food, Traffic & Water Works, and Environment, and by the EU life program.

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Approach of legislation and stimulation by Water Board Vallei & Eem

W. Doorn & F. van Baardwijk
Water Board Vallei & Eem, Postbus 330, NL 3830 AJ Leusden, The Netherlands

Summary

To reduce the pollution of surface waters, the Water Board can set limits to the concentration or amount of substances in the discharge waters. An immediate ban on the use or the discharge of weed control pesticides is not possible.

In order to start a process to reduce the emissions, the discharge permits given to municipalities for the combined sewer overflow and for the connection of the sewer to the purification plant were used. In these permits, an obligation was included to set up a plan to reduce diffuse pollutants, especially focused on heavy metals from constructing materials and pesticides from hard surfaces weed control.

To support the process of planning, the Governing Board of both Municipality and Water Board were involved. Furthermore, a workshop, sponsored by the Water Board, with all the necessary disciplines within the municipality started the internal discussion.

Within one year, 80% of the municipalities have carried out the workshop, continued the internal discussion and have almost completed the Plan of Reduction.

For the follow up an environmental certification process can be supported as well as regional exchange of knowledge.

Introduction

Many municipalities still use chemical weed control on hard surfaces. The only pesticide possible, according to national legislation, is glyphosate. This pesticide should be used in a selective way to minimise the amount used.

Unfortunately, a large amount of the glyphosate used is being flushed into the water system (Merkelbach R.C.M. *et al.*, 1999).

This may cause a problem in the receiving water body, but it certainly causes a problem in the preparation of drinking water taken from surface water (R. Faasen, 2005).

The goal of both water board and municipality is to reduce the amount of pesticides emitted to water. The best way to do so is prevention. There are a lot of alternative methods. In order to give the municipalities an overview of these methods as well as the organisational and planning requirements to change to non-chemical weed control, a manual has been generated (Spijker J. *et al.*, 2002).

Nevertheless, there are still municipalities using chemical weed control.

Besides these, there is a group of municipalities that are "chemical" free, often since several years. In this group, there is a yearly struggle to stay chemical free. This is because of the cost of the alternative control methods, which are higher than chemical treatment.

So every year during the budget discussions, chemical or non-chemical weed control is an item of which the outcome cannot be predicted (because often it is a political choice instead of a technical choice).

Water Board Vallei & Eem is a regional water authority trying to reduce water pollution, among other tasks.

The Water Board in cooperation with other water boards and three provinces tried to convince the municipalities not to use chemical weed control e.g. by the Manual (Spijker, J. *et al.*, 2002). The responses were poor; so another way was necessary.

According to the Pollution of Surface Waters Act, discharge of pollutants is forbidden, unless a permit is provided.

For the discharge of combined sewer overflow and rainwater and for the connection of the sewer system to the wastewater purification plant, the Municipality needs a permit. So, in the discussion about these licences, the issue of weed control related to water pollution was introduced as part of the need for emission reduction from non-point sources; the so-called diffuse pollution.

The leading principle in granting licences is pollution prevention. An immediate ban on chemical weed control is not possible: only the discharge of pollutants can be restricted. An immediate stop of the discharge, however, is not possible either, because of the major impact on the municipality's activities and budget.

After tough discussions, the permits now contain an obligation to set up a plan to reduce diffuse pollutants, especially focused on heavy metals from constructing materials and pesticides from hard surfaces weed control. The plan must be set up in accordance with the demands of the Water Board and must be available within a given limited period of time.

Stimulation

At the moment, most of the municipalities are not able to handle the subject of diffuse pollution. There is a great lack of knowledge. There are several causes.

One of them is the contact. Water Boards and municipalities were dealing with one another on the subject of sewerage and spatial scheduling. But diffuse pollution is an environmental subject, it reaches to more divisions than water only. But most of the municipalities keep the contact at the old, trusted situation.

Another cause is the width of the subject. People who are working on traffic or house construction are not aware of the possible consequences to water of the materials they are dealing with. They lack technical knowledge.

Because of these causes, municipalities asked for a blueprint of a plan. Instead of giving it, it would be better to help them establishing a plan. So they were offered a half-day workshop, to be attended by employees from divisions like construction, urban development, public maintenance, communication (very important!), traffic and so on.

During the workshop, it is explained what diffuse pollution is about, supported by images showing different situations from their own town or village. After that, there is a discussion about their ambition and view on diffuse pollution and which points to prioritize. At the end, a treatment for one or two sources on diffuse pollution is worked out. That will also be the basis for the whole plan.

Of course, weed control and heavy metals are always main subject in the workshops!

So the workshop contains an explanation of what diffuse pollution is about, people working on several subjects are informed about the specific problems and possibilities to solve them, and a start is made to establish the plan.

Note: the Water Board paid for the workshop!

Results

In our region, there are fifteen relevant municipalities, lying totally in our management area. There is also about five municipalities that lie partly in our area, they do not count in this project.

Twelve of them accepted the offer, one is so small that there was no need for a workshop (they said so), one is still to come and one is subject to discussion. The first workshop was in April 2005.

Up till now, two plans have been finished, (that means accounted for by the city councils) and there are three drafts. All the others are working on it.

As to be expected, the main targets are weed control (when they still use chemical means) and lixiviats of heavy metals from construction material. The latter subject is most observed when the municipality acts as a constituent. Also communication is an important subject to civilians as well as to professional building companies (developers, construction ventures). One important aspect is the internal communication: municipalities concluded there has to be more consultation between the divisions: urban development and public maintenance!

In one of the drafts, communication is the main target. But that is also the draft in which alternatives for chemical weed control have been compared with one another very well.

For the municipalities that are using chemical weed control, all plans (final and drafts) are aiming for alternative methods for chemical weed control, at least by 2010.

One of the most important results: it is their own plan, instead of rules put up by the Water board! The municipalities think about diffuse pollution themselves. That also means there is another ally to prevent diffuse pollution.

Follow-up

The described process provides plans of all the municipalities in the region of Water Board Vallei & Eem. We will review all the plans and inform the municipalities about the content of the plans of their colleagues; some kind of a benchmark.

Furthermore, a network for the municipalities will be set up for the exchange of knowledge on non-chemical weed control. The provinces in co-operation with the Water Board carry this out. There are still developments on the techniques for non-chemical weed control, and pilots are carried out every now and than. So for the technicians of the municipalities, it is essential to be well informed. The network provides and distributes the latest information.

Thirdly, we stimulate and cofinance the certification of the non-chemical weed control by municipalities. Environmental care systems can be certified by SMK. SMK is the organisation that controls the Dutch version of Ecolabel.

There are three levels of certification:
Bronze: which reflect a minimisation of chemical weed control on hard surfaces.
Silver: an overall minimisation of chemical weed control.
Gold: no chemical weed control at all and other environmental issues are also taken care of.

Certification is a useful tool to stimulate enthusiasm of both the Board and the people of a municipality. Last but not least, it may prevent an easy return to the use of chemicals.

Conclusions

Water Board Vallei & Eem used the discharge permits to put the issue of chemical weed control by municipalities on the agenda.

Besides the obligations, it was necessary to support the municipalities to start the planning process. This was done by a workshop in which all relevant disciplines were present.

The approach works out very well, according to the results so far.

The results indicate a move forwards in non-chemical weed control. This is a slow process, which may result in sustainable weed control methods, certified by an eco-label.

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Regional policy on herbicide use on pavements by Water Board Zuiderzeeland, the Netherlands

J. Meijerink
Water Board Zuiderzeeland, P.O. Box 229, NL 8200 AE Lelystad, The Netherlands

Water board Zuiderzeeland

Water board Zuiderzeeland is responsible for safety, water quantity and water quality management in the province Flevoland and small parts of the provinces Friesland and Overijssel in the Netherlands. The province of Flevoland is a relatively young region and from origin a former inland sea. In the sixties the first people, mainly farmers, moved to this part of the country that was planned to be an agricultural area. In the past decades the agricultural function changed more and more to a partly urban function. The use of pesticides for weed control on pavements becomes therefore more important due to the growth of the urban area.

The city of Almere, which first inhabitants were housed in 1976, does now count about 175,000 inhabitants and is still growing to become as large as the city of Utrecht. Because of its age, Almere has a sewer system that is almost completely separated. This means that the sewer system is separated in a dry weather sewer and a rainwater sewer. Wastewater from industries and households is discharged to an urban wastewater treatment plant, and rainwater coming from roads and pavements is directly discharged to surface water. The older cities and villages in Flevoland have only separated sewer systems in new housing estates.

Policy on weed control up to 2005

Preventing weed control using chemicals causes emissions of chemicals to surface water. In the year 2000, Water Board Zuiderzeeland formulated the policy that the use of pesticides for weed control on pavements was banded as from 2004. Because of the high cost of non-chemical weed control, the local authorities requested the water board to differentiate this policy and to investigate the possibilities of sustainable weed control on pavements (SWEEP).

Research in regular and sustainable weed control 2003 - 2004

In 2003 and 2004, weed control using sustainable weed control methods was investigated and compared with regular chemical weed control. Eight different districts in the municipalties in

Flevoland were selected for this study. Three of these districts were used as reference sites (regular chemical weed control). In the other districts, sustainable weed control was used for removing weeds on hard surfaces. The average concentration of glyphosate and AMPA were determined in rain water sewers and surface water in 2003 and 2004. The results are summarized in the table below:

Table 1. Glyphosate and AMPA contents in drains and surface waters

Municipal	**District**	**Weed control method**	**Year**	**Average concentration in** drain (µg/l)		surface water (µg/l)	
				Glyphosate	AMPA	Glyphosate	AMPA
Lelystad	Galjoen	Regular	2004	13.1	1.4	3.5	0.5
Lelystad	Waterwijk-West	Regular	2004	0.2	0.4	0.2	0.3
Dronten	De Landmaten	Regular	2004	34.3	2.3	29.8	2.0
Lelystad	Galjoen	Regular	2003	2.3	1.5	0.0	0.4
Lelystad	Waterwijk-West	Regular	2003	0.0	0.3	0.0	0.1
Dronten	De Landmaten	Regular	2003	17.4	1.9	9.4	1.5
Lelystad	Punter	SWEEP	2004	8.1	0.8	2.2	1.2
Lelystad	Waterwijk-Oost	SWEEP	2004	0.4	0.3	1.3	0.6
Dronten	Kamille	SWEEP	2004	12.0	1.1	6.4	1.1
Urk	Kreil	SWEEP	2004	7.3	1.3	0.2	0.5
Urk	Pyramideweg	SWEEP	2004	8.1	1.9	0.1	0.3
Lelystad	Punter	SWEEP	2003	1.5	0.7	0.5	0.9
Lelystad	Waterwijk-Oost	SWEEP	2003	0.2	1.2	0.0	0.9
Urk	Kreil	SWEEP	2003	12.0	2.2	0.2	0.3
Urk	Pyramideweg	SWEEP	2003	3.2	0.3	0.0	0.4
		Average regular		11.0	1.3	6.9	0.8
		Average SWEEP		5.7	1.1	1.3	0.7

The results in the table above show that there is a wide range in concentrations. This is mainly a result of the weather situation in the research period. Weather predictions are not always reliable. From this point of view, the difference between regular and sustainable weed control seems not to be clear. Maximum concentrations due to regular weed control, however, are higher than maximum concentrations due to sustainable weed control. Moreover, the average concentrations show a clear difference between regular chemical weed control and sustainable weed control. Looking at the results, sustainable weed control can minimize the emissions of pesticides to the sewer system and surface water.

There is, however, discussion about the compliance of the guidelines of sustainable weed control. The research performed by the water board has made it clear that the guidelines of sustainable weed control are not always carefully applied. It is therefore important that the application of sustainable weed control has some form of guarantee. For the water board, this means that the guideline of sustainable weed control has to be incorporated into a surface water pollution permit in order to minimise the emissions of glyphosate and AMPA to surface water. The permit makes it possible to supervise the application of the guidelines.

Policy water board Zuiderzeeland as from 2005

In 2005, the water board changed its policy from non-chemical weed control to sustainable weed control. Local authorities are only allowed to use pesticides for weed control having a water pollution permit. In this permit, it is written that weed control is only allowed using the method of sustainable weed control. The prescriptions of sustainable weed control are incorporated in the permit. This makes it possible for the water board to perform its own legal enforcement.

Global content of the permit

The global content of the permit is as follows:

- weed removal is only permitted, if using sustainable weed control;
- the use of pesticides is not allowed if the probability of rain exceeds 40% in the coming two days;
- the use of pesticides is not allowed if the wind velocity exceeds 8 m/s (4 Beaufort);
- discharge of waste water coming from rinsing machines to surface water is not allowed;
- the dose in spray water must not exceed 360 g glyphosate ha^{-1};
- the maximum amount of glyphosate applied per year must not exceed 720 gr glyphosate/ha;
- the use of pesticides is not allowed within 1 metre of drains or surface water;
- the use of pesticides on dikes or wet vegetation is not allowed;
- regular sweeping is part of preventing weed growth;
- amongst this, a yearly maintenance plan is demanded, in which the local authorities mention how weed control will be performed the coming year.

Acetic acid for weed control on hard surface areas

D. Hansson, S.-E. Svensson, J. E. Mattsson, J.-E. Englund & H. Schroeder
Swedish University of Agricultural Sciences, Department of Landscape Management and Horticultural Technology, P.O. Box 66, SE–230 53 Alnarp, Sweden

Introduction

There is currently a focus on research and development of alternatives such as flaming and brush weeding to chemical weed control methods on hard surface areas. One important reason is the growing awareness of the disadvantages of herbicides and public resistance to them. Residues from herbicides have been found in surface water and in some cases even in well water (Sandberg *et al*., 1996; Smith *et al*., 1999). The Swedish National Road Administration and most Swedish municipalities have decided not to use herbicides on urban hard surface areas. The use of herbicides on railroad embankments is also restricted.

In a survey carried out in 2004 on 30 selected representative municipal authority managers, 70% of these authorities had a ban on the use of glyphosate products. Half of those questioned were permitted to use acetic acid, while 20% were restricted to non-chemical methods. Weeds are regarded by most municipal authority managers as a moderate to very severe problem, and the majority consider that the problem has increased during the past 3-5 years. Weeds have become more difficult to control as a result of:

- Bans on chemical control methods
- Hard surfaces being incorrectly designed from a weed prevention perspective
- Reduced resources for cleaning hard surfaces due to cutbacks and increasing areas to maintain
- Poor maintenance of hard surfaces
- Increasing costs of non-chemical control compared with chemical control
- Abolition of the use of salt on roads in winter

Weeds impair the function of hard surface areas and shorten their lifetime and thereby cause substantial increases in expenditure for the authorities responsible. Weeds make the surface unattractive and more difficult to clean. Furthermore, weeds can cause serious accidents, if they obscure signs, signal lamps, etc. or make the railway tracks slippery. These problems are pronounced on railway embankments (Hansson *et al.*, 1995).

Weeds can be prevented on hard surface areas by changing the design of the surface, and by selecting suitable materials and construction techniques. However, the conversion of surfaces takes a long time and incurs high investment costs. To maintain large existing hard surface areas, there is a need for suitable alternatives to herbicides that are acceptable for weed control on such areas. These can be mechanical, thermal or based on natural substances with a low environmental impact.

The natural substance acetic acid was proposed as an alternative by some Swedish municipalities and the chemical industry in the beginning of the 1990s. A method for weed control on urban hard surfaces with acetic acid was developed and evaluated at the Swedish University of Agricultural Sciences in Alnarp. Important tasks were to find appropriate doses and concentrations, to test the method in real situations and to evaluate the effects on the environment and working conditions. Acetic acid was approved for use on hard surface areas in 1995 by the Swedish National Chemicals Inspectorate and is now an established method of weed control.

Materials and methods

Two types of experiments were carried out:

- Field experiment on the test weed *Sinapis alba* L. (white mustard)
- Experiments on hard surface areas with naturally developed weeds

In the experiments the response to treatment was generally assessed in two ways:

- Field experiment. Number of surviving plants at LD90, i.e. the dose needed to reduce the number of weeds by 90%
- Experiments on hard surface areas. Weed cover at ED90, i.e. the dose needed to reduce the weed cover by 90%

The response of the weed control effect was analysed using a dose-response analysis according to a method used and developed by Streibig *et al.* (1993) for herbicides and modified by Hansson & Mattsson (2002) to describe the effects of hot-water weed control.

Results and discussion

In one field experiment it was found that 6% and 24% acetic acid had the desired control effect on the test weed *Sinapis alba* L. For the same amount of active ingredient, the 6% concentration was more effective than the 24%.

Studies of weed control in two cities in southern Sweden on seven hard surface areas with heavy infestation of naturally occurring weeds showed that when 12% acetic acid was used, 0.21 L m^{-2} (spray volume rate) was required to reduce the weed cover by 90% (Figure 1).

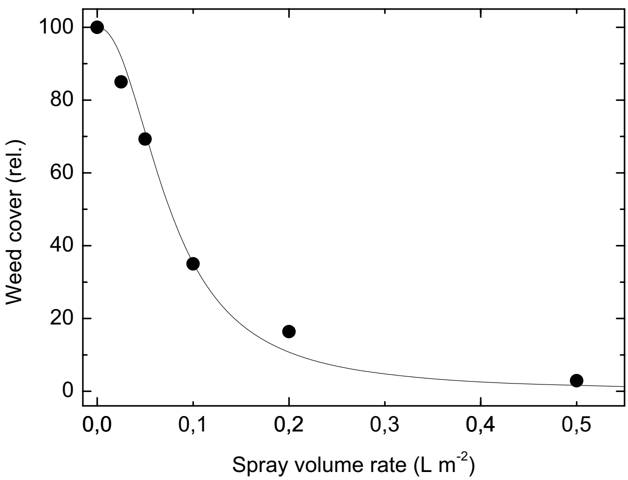

Figure 1. Effect of one treatment with 12% acetic acid (spray volume rate) on relative weed cover of naturally occurring weeds on hard surface areas in Gothenburg and Lund. The points are average values of the class mid-marks for the observed values (n=7), adjusted for the estimated block effect. Parameter estimates: ED_{50} = 0.076 L m^{-2}, ED_{90} = 0.208 L m^{-2}.

The effects of a 12% solution of acetic acid in weed control were investigated at 2 sites in southern Sweden (Skåne) over a period of 2 years. One site was a disused railway embankment in Ingelsträde (Höganäs municipality) and the other a macadam-covered gravel embankment (Alnarp). No weed control had been carried out at either site for some years prior to the experiments. The main aim of this investigation was to obtain background information about the weed control effect in rehabilitation situations on areas with heavy weed infestation level. The investigation showed that use of 12% acetic acid was a suitable method for maintaining and rehabilitating weed control on gravel embankments. However, the acetic acid did not provide a lasting weed control effect. During a full season, maintenance weed control required 3-5 treatments with approximately 0.25 litres of 12% acetic acid per m^2, depending on the weed pressure in the gravel embankment. When the treatment involved larger doses (approximately 0.4 litres of 12% acetic acid per m^2) repeated throughout the entire growing season, the method was also suitable for rehabilitating weed control and allowed even an established weed flora to be controlled on gravel embankments.

An acetic acid concentration of 12% was regarded as an acceptable concentration in terms of working environment. Lower concentrations of acetic acid would mean a decreased risk associated with use of the acid. However, too low a concentration would mean an increased risk for strain injuries because of the higher spray volume rates when using e.g. knapsack sprayers.

The effects on the environment and working conditions were evaluated. Working conditions were satisfactory with the use of prescribed protective clothing, i.e. protective gauntlets (gloves). It was also shown to be important to avoid the acid coming in contact with eyes. In a practical and theoretical hazard assessment, no damage was noted on the hard surfaces studied. Acetic acid can cause a change in pH and leaching of nutrients and heavy metals. The risk of leaching was shown to be higher in coarse soils, especially when they were saturated with water. However, the pH in the treated soil recovered within two days. The toxic effects on water organisms were moderate. Practical experiences showed no damage to surrounding vegetation.

Summary of conclusions from the user's point of view

- Most Swedish municipalities have decided not to use herbicides on urban hard surface areas. In some cases, this ban also extends to the use of acetic acid.
- Acetic acid causes odour problems. A number of complaints were received about the vinegary odour after treatment.
- When acetic acid is used for weed control, relatively large liquid volumes are required, which can cause logistical problems, etc.
- Compared with glyphosate, acetic acid is not an economically profitable alternative for the control of vegetatively propagated weeds. However, acetic acid is an interesting alternative to thermal and mechanical methods.

Future studies

In future research, it would be interesting to optimise the method, e.g. by adding a wetting agent or a leaf wax hydrolysing agent to see whether it is possible to decrease the dose of acetic acid.

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How pesticides used on hard surfaces end up in drinking water

W.H.J. Beltman[1], C. Kempenaar[2], K. van der Horst[3] & A. Withagen[3]
[1]*Alterra, Wageningen University and Research Centre, P.O. Box 47, NL 6700 AC Wageningen, The Netherlands*
[2]*Plant Research International, Wageningen University and Research Centre, P.O. Box 16, NL 6700 AA Wageningen, The Netherlands*
[3]*Waterboard Hollandse Delta, P.O. Box 469, NL 3300 AL Dordrecht, The Netherlands*

Abstract

Pesticide concentrations in surface water extracted for the production of drinking water sometimes exceed the standard of 0.1 µg/L. To assess the risk of contribution of pesticide run-off from hard surfaces to surface water used for drinking water, run-off is studied at two scales, the field scale and the neighbourhood scale. Run-off percentages of pesticides at field scale followed directly by rainfall are 7 to 44%. The average for glyphosate is 16%. Run-off of glyphosate at neighbourhood scale (SWEEP conditions) is on average 1.9% of the mass applied. The difference between run-off at field scale and at neighbourhood scale is about a factor 10. This difference can be attributed to time effects, scale effects and applying SWEEP. The main factor affecting run-off is the time between treatment and the first rain shower causing run-off of water. Use of glyphosate on hard surfaces can contribute to glyphosate concentrations measured in surface water extracted for production of drinking water.

Introduction

Pesticide concentrations in surface water extracted for the production of drinking water sometimes exceed the drinking water standard for pesticides of 0.1 µg/L. Pesticide use on hard surfaces can contribute to the occurrence of these exceedences. Therefore pesticide run-off from hard surfaces is measured at two scales, the field scale and the neighbourhood scale.

Field experiments

In field experiments, the run-off of the herbicides atrazin, amitrol and glyphosate from a 100 m^2 large pavement of concrete bricks was studied. After treatment with the compounds, the pavement was sprinkled with a realistically high rainfall intensity for the Netherlands of 10 mm/h. In the experiments done in 2000, between 45 and 61% of the rain water flowed into a drain collecting the run-off. The remainder infiltrated through joints between the bricks into the soil below. Samples were taken volume proportional from the drain. The results of all experiments (Beltman *et al.,* 2001; Luijendijk *et al.,* 2003; 2005) have been summarized in Table 1.

Table 1. Run-off of three herbicides from a 100 m^2 concrete brick field.

Herbicide	Year	Treatment	% of dose
Atrazin	2000	4 replicates	18, 34, 43, 44
Amitrol	2000	4 replicates	7, 7, 9, 22
Glyphosate	2000	4 replicates	11, 12, 12, 23
Glyphosate	2002	2 m around sewer not treated	19
Glyphosate	2002	no buffer zone around sewer	22
Glyphosate	2003	dry surface, 2 replicates	14,18
Glyphosate	2003	wet surface, 2 replicates	9,17

The run-off varies from 7 to 44%. The average for all three herbicides is 19%. The average of run-off of glyphosate is 16%. The run-off of atrazin is higher than the run-off of amitrol and glyphosate because the atrazin concentrations in run-off water become higher than its solubility. So, it is likely that atrazin partly runs off as solid product. In the experiments done in 2000, the first 2 mm of washed-off rain contained 53 to 79% of the total herbicide mass running off. Hence, peak concentrations are to be expected with the first flush of discharging rainwater. At extreme rainfall intensities, or less joints m^{-2}, the run-off of herbicides from hard surfaces is expected to be larger than found in the field experiments (De Rooy & Beltman, 2003).

Monitoring neighbourhoods

In 2002 to 2004 in four neighbourhoods, the run-off of glyphosate was measured 11 times in the collection point of an improved separated sewer system (Withagen *et al.*, 2003; 2004; 2005). In an improved separated sewer system, the first flush entering the rain water sewer system is transferred to the waste water sewer system (transporting water to the wastewater treatment plant). This transfer takes place at a central collection point in the neighbourhood. At this collection point discharge proportional samples were collected every 12 or 24 hours. Using the registered discharge volumes and the measured concentrations, the glyphosate mass discharged was calculated. The glyphosate runoff is calculated by dividing the total mass discharged by the mass applied in the neighbourhood (Withagen *et al.,* 2003; 2004; 2005). The calculated runoff is listed in Table 2.

The results of monitoring of run-off of on the neighbourhood scale were obtained in the SWEEP project (Sustainable Weed control on Pavements). With the SWEEP method the emission to surface water is reduced. The SWEEP-method contains practical guidelines for management of weed abatement (http://www.dob-verhardingen.nl/uk/General/).

Table 2. Run-off of glyphosate in four neighbourhoods (Sp = Spring, Au = Autumn).

Municipality	**Area** (ha)	**Period**	**Total rainfall** (mm)	**Number of rainfall events > 1 mm and number of days after treatment that events occurred**		**Run-off** (%)
Papendrecht	6.5	2002-Sp	23	3	(1, 6, 7)	5.7
		2002-Au	20	3	(10, 13, 14)	0.2
	7.2	2003-Sp	27	4	(13, 14, 15, 16)	0.5
Dordrecht	2.3	2003-Sp	16	4	(4, 5, 7, 8)	1.1
		2003-Au	21	2	(1, 5)	4.0
		2004-Sp	18	2	(18, 21)	0.4
		2004-Au	31	4	(8, 11, 12, 13)	3.5
Giessenlanden	0.53	2003-Sp	39	4	(5, 6, 7, 8)	1.6
Vianen	9.7	2003-Sp	23	4	(0, 2, 6, 8)	2.1
		2003-Au	34	5	(0, 3, 4, 5, 6)	0.2
		2004-Sp	27	4	(7, 13, 14, 16)	1.5

At the end of the monitoring periods, glyphosate run-off had not ended yet. Except for one case, the last sample taken contained still low concentrations of glyphosate. However, the major fraction of the total run-off occurred with the first showers. In three cases also, run-off of MCPA was measured. The run-off of MCPA was 0.1% or less.

The runoff measured is between 0.2 and 5.7%. The average run-off of all monitoring cases is 1.9 %. The major part of the total run-off takes place with the first rain showers. When the first rain shower occurred on the same day as the treatment, or on the day after the treatment, the run-off is highest. However, exceptions are for example little run-off occurring on the day of treatment in Vianen (Autumn 2003), and 3.5% of runoff found when the first shower occurred 8 days after treatment in Dordrecht (Autumn 2004). In Figure 1 the run-off percentage is shown as a function of the number of days between treatment and first rain shower. Figure 1 also shows that often the first rain fell within a few days after the glyphosate treatment.

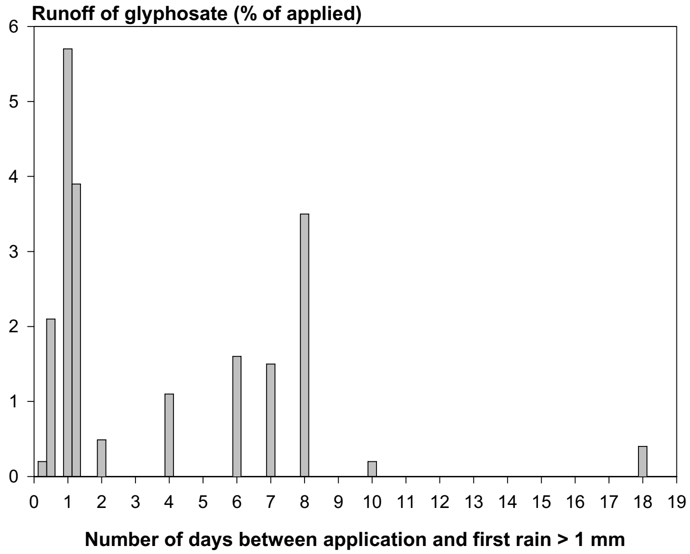

Figure 1. Run-off of glyphosate in neighbourhoods as a function of the number of days between the glyphosate application and the first rain shower larger than 1 mm.

General discussion and conclusions

Run-off percentages of pesticides at field scale followed directly by rainfall are 7 to 44%. The average for glyphosate is 16%. Run-off of glyphosate at neighbourhood scale (SWEEP conditions) is on average 1.9% of the mass applied.

The difference between run-off at field scale and at neighbourhood scale is about a factor 10. This difference can be attributed to time effects, scale effects and application of SWEEP. In the field experiments, the field was sprinkled within a few hours after treatment. In the neighbourhoods, the (natural) rain fell sometimes on the same day, but varied from 0 to 18 days after the treatment. The neighbourhood results show that in general the run-off decreases with increasing period between the treatment and the first rain shower. Another aspect that decreases run-off at the neighbourhood scale is that the total run-off is distributed over several rain showers. Every time a new shower starts, the first rain touching the pavement is sucked up by the hard surface, taking along glyphosate from the top of the hard surface.

The scale aspect is that the field experiments were performed at a pavement of concrete bricks. The maximal distance between the drain and treated bricks was about 10 m. In the urban area, distances between drains and treated area can be larger. Furthermore, the paved area in the neighbourhoods is diverse; bricks, tiles, etc. In the neighbourhoods, glyphosate is applied in a selective way; only those parts are treated where weeds grow. These treated spots may be further away from or closer to the drains. Applying SWEEP focussed on minimizing emissions to surface water will also partly be responsible for the difference between the run-off between the field and the neighbourhood.

The main factor affecting run-off is the time between treatment and the first rain shower causing run-off of water. Run-off fractions at the neighbourhood scale can be in the order of 2% of the applied mass. Reduction of concentrations in surface water during its transport from urban areas to extraction points for drinking water may decrease the concentrations to a limited extent. Hence, use of glyphosate on hard surfaces can contribute to glyphosate concentrations measured in surface water extracted for production of drinking water.

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Environmental risk from using glyphosate on hard surfaces

C. Ramwell
Central Science Laboratory, Environment Department, University of York, Heslington, York YO10 5DD, United Kingdom

Introduction

Weeds can proliferate between the road and kerb edge and along pavements if left unchecked. The vegetation can impede water flow, thus reducing safety for road users, the roots can undermine the structure of roads and pavements, weeds can be a fire hazard and they are considered unsightly. Weeds must therefore be controlled for safety and aesthetic reasons.

Historically, residual herbicides such as atrazine and diuron were used for weed control due to the longevity of control. However, these herbicides were detected in surface and ground waters (Cable *et al*., 1994), and the use of atrazine on hard surfaces has been banned, whilst the use of diuron is currently under review. Due to the perceived minimal environmental impact of glyphosate, this is the herbicide of choice for many Local Authorities in United Kingdom for weed control on hard surface areas such as roads and pavements, the other advantage being that it is cost-effective. A potential concern with the use of glyphosate for weed control in urban areas is that, although it has a good environmental profile, if it is the only compound used in these situations it is highly likely that it will be detected in surface waters due to the total quantity being used.

An understanding of the fate and behaviour of glyphosate from hard surfaces can identify probable routes of exposure and assist in the development of risk assessments of its use. In addition, such studies can assist in identifying the extent to which misuse rather than the correct use may contribute to any potential pollution. This paper first outlines the techniques currently used to examine whether a compound is considered to pose an environmental risk, it describes supporting data for the exposure scenarios and it highlights the need to maintain good practice.

What is risk?

Risk is “a situation involving the exposure to danger”, where danger is “the possibility of suffering harm of injury” (Oxford English Dictionary). Environmental risk is therefore concerned with soil, air, and water and the life within these matrices (the situation) where the danger is a “chemical”. It must be remembered that water is a chemical, thus the danger that a chemical poses depends largely on the quantity involved and the overall risk depends on the organism exposed, the form that the chemical is in and the frequency of exposure.

How is environmental risk measured?

Environmental risk is ordinarily measured by comparing the concentration of the compound under question as it would be, or predicted to be, found in the environment (predicted environmental concentration (PEC)), with the lowest concentration at which it is known that there is no measurable effect on organisms (no effect concentration (NOEC)) representative of the exposure scenario, in this case aquatic organisms. A safety factor can be built into this risk assessment to account for the uncertainty there may be in the extrapolation of the data used to obtain the NOEC (Campbell *et al.*, 1999). If the predicted environmental concentration is lower than the predicted NOEC, then it is unlikely that the compound will be a risk to the environment.

Data are available on the toxicity threshold of many compounds, although these have currently come under review in the EU under "REACH". The predicted environmental concentration is more difficult to define because the presence of the compound in the environment will depend on how the compound is used, its fate after application and the nature of the environmental compartment at risk. Consequently, to assess the environmental risk of herbicides used on hard surfaces, a fundamental issue is the quantity of compound falling off-target (i.e. on the hard surface, rather than the vegetation) that can be removed from, or washed off, the surface.

To support the prediction of environmental concentrations of herbicides applied to hard surfaces, a number of experiments were conducted to physically quantify losses. Herbicides, including glyphosate, were applied at label-application rate to new concrete and asphalt surfaces. Rainfall was simulated 6, 12, 24, or 168 hours after application at a rate of 5 mm, 10 mm or 15 mm. Average losses were 45% of the applied glyphosate from asphalt and 20% from concrete, and losses from asphalt were higher with a short lag time of 6 h compared with the other lag times. (Shepherd & Heather, 1999). The surfaces were new and devoid of any organic matter, or interception by vegetation, thus the quantities removed can be considered 'worst case'.

A field study was also conducted where a length of kerb edge on a road (16 m) was sprayed at label-application rate, and run-off was collected as it discharged from the gulley pot. Total losses of glyphosate were 35% of that applied after 25 mm of accumulated rainfall. Concentrations of glyphosate in the drain water were initially high (650 $\mu g\ L^{-1}$), but declined with successive rain events to concentrations of approximately 3 $\mu g\ L^{-1}$ after 25 mm of accumulated rainfall; this was with no dilution. Although there was some organic debris on the road and kerb edge, no weeds were present and the experiment represented a realistic worst-case scenario. Furthermore, despite checking two weather forecasts that indicated a dry period, rain fell approximately two hours after application (Ramwell et al., 2002).

The results of both studies demonstrated that, under worst-case scenarios, 1) glyphosate losses were in the order of 35% of that reaching the hard surface, 2) the time between application and the start of rainfall influenced quantities removed and 3) the majority of loss occurred within the first few millimetres of rainfall.

A very basic risk assessment using the dimensions of a FOCUS ditch as dilution water (approx. 30,000 L) indicated that, if all the glyphosate removed from the road surface in 24 hours since rainfall initiation entered the ditch, then the predicted environmental concentration would be approximately 50 µg L^{-1} (See Ramwell *et al.*, 2002 for full details). The PEC from a tier-one risk assessment model (HardSPEC) with more detailed exposure scenarios is approx. 10 µg L^{-1}. The predicted no effect concentration for glyphosate is 60 µg L^{-1} (http://www.inra.fr/Internet/Produits/agritox/php/sa.php?source=UE&sa=91). The PEC is less than the PNEC using both risk assessment approaches indicating that the use of glyphosate at label-application rate is unlikely to adversely impact on the environment. However, the data demonstrate that concentrations in the ditches may frequently exceed the drinking water standard of 0.1 µg L^{-1}.

The studies provided real data to demonstrate that off-target herbicide falling onto a hard surface can be rapidly removed to water courses at the onset of rainfall, and that a pulse of glyphosate will occur with the first rainfall following application. The average concentration in the first day was below the toxicity threshold for the most sensitive species, but the concentration was higher than the drinking water quality standard. The studies also demonstrated a continuous release of low concentrations of glyphosate with further rain events.

Although the studies represented worst-case scenarios due to the lack of vegetation cover, there is an assumption that the compound is applied following good practice. The correct application of a chemical is fundamental to the quantity of compound available for removal. The concentration of the spray mix is varied depending on the nozzle output, the height of the lance from the ground and hence the spray swath, and the forward speed of the operator (either on foot or on a vehicle) to deliver a specified application rate. Failure to calibrate the applicator can lead to overdosing. The extent to which overdosing can occur if the spray swath is reduced by dropping the height of the lance and the forward speed is simultaneously reduced is illustrated below (Figure 1) where it can be seen that only small changes are necessary in order for overdosing to occur.

A decrease in speed and width of spray swath compared with the calibration can increase output by over 50%. This could result in glyphosate concentrations in surface waters being above the toxicity threshold. It is essential that any chemical used to control weeds is applied strictly according to the label and following good practices.

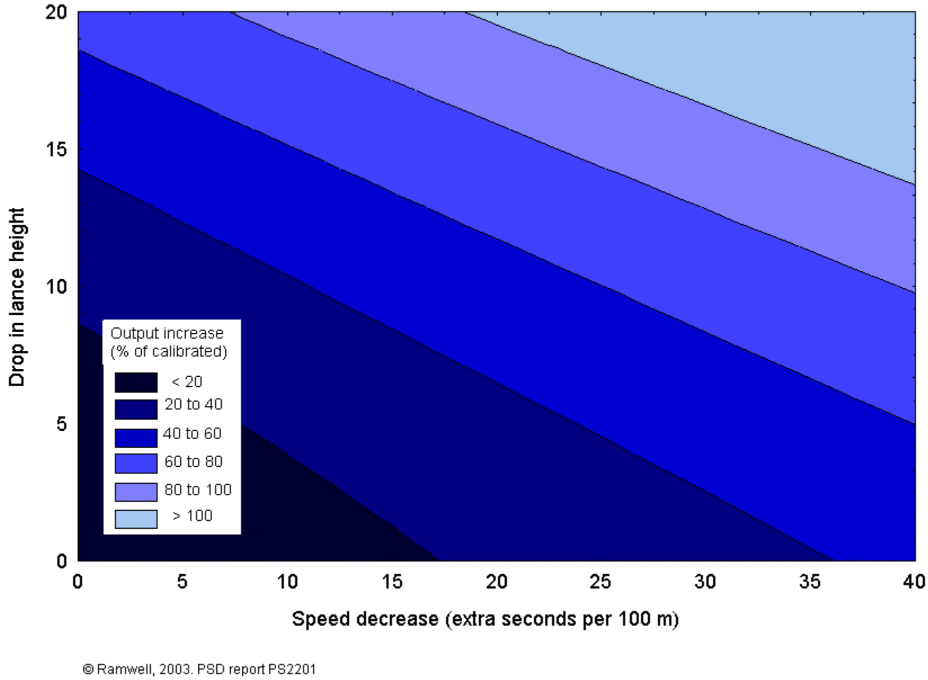

Figure 1. Overdosing potential due to deviation from calibrations.

Conclusions

A proportion of compound falling off-target during herbicide application in urban areas will be transported to receiving water bodies.

Glyphosate concentrations in drain water decline with successive rain events, but glyphosate losses from the hard surface remained after 50 mm of rainfall.

Risk assessments demonstrated that glyphosate concentrations in the receiving ditch are likely to be lower than the toxicity threshold indicating that this compound presents a low environmental risk using current risk assessment methodology.

Glyphosate concentrations in drainage water were frequently higher than the drinking water standard of 0.1 µg L^{-1}.

Correct use of the compound is fundamental to minimising environmental risk.

There is a need to address the problem of weed control, rather than shift the problem between chemicals.

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Summary

Municipalities and cities in many European countries spend extensive time and money on weed control on hard surfaces, such as pavements, parking places and squares. The herbicide, glyphosate, is widely used for that purpose, because of its effectiveness, easiness to use and low cost. However, pesticide use has been severely restricted in some EU-countries. And taking the pesticide policy of the EU into account, it is expected that other EU countries will follow this path in the years to come.

As a consequence of this development, a new INTERREG IIIC operation "Regional Collaboration for Minimising Pesticide Emissions in the Environment", in short "CleanRegion" was launched in early spring 2005. Since policies on pesticide use on hard surfaces vary considerably among the partners in CleanRegion, a one-day conference that was held on 25th April 2006 at Wageningen University with the aim of highlighting these differences. This proceeding contains summaries of the main content given in each talk.