A review of pesticide policies and regulations for urban amenity areas in seven European countries

P KRISTOFFERSEN*, A M RASK*, A C GRUNDY†, I FRANZEN‡, C KEMPENAAR§, J RAISIO¶, H SCHROEDER**, J SPIJKER††, A VERSCHWELE‡‡ & L ZARINA§§

*Danish Centre for Forest, Landscape and Planning, Faculty of Life Sciences, University of Copenhagen, Frederiksberg C, Denmark, †Warwick HRI, University of Warwick, Wellesbourne, UK, ‡Environmental and Health Authority, Municipality of Norrköping, Norrköping, Sweden, §Plant Research International, Wageningen, The Netherlands, ¶Public Works Department, Helsinki, Finland, **Department of Landscape Management, Design and Construction, Swedish University of Agricultural Sciences, SLU, Alnarp, Sweden, ††Alterra, Wageningen, The Netherlands, ‡‡Institute for Weed Research, Federal Biological Research Centre for Agriculture and Forestry, Braunschweig, Germany, and §§State Priekuli Plant Breeding Institute, Priekuli, Latvia

Received 11 May 2007
Revised version accepted 10 December 2007

Summary

An analysis of the regulations of herbicide use for weed control in non-agricultural/urban amenity areas, including actual pesticide use, was carried out as a joint survey of seven European countries: Denmark, Finland, Germany, Latvia, the Netherlands, Sweden and United Kingdom. Herbicides constitute the major part of the pesticides used in urban amenity areas. Herbicide use on hard surfaces is the largest in terms of volume and potential contamination of surface and groundwater. The aim of the study was to investigate the differences in political interest and public debate on the 'use of pesticides in public urban amenity areas', regulations within each country at national, regional and local levels, possible use of alternative weed control methods and the amounts of pesticides used on urban amenity areas. A comparative analysis revealed major differences in political interest, regulations and availability of statistics on pesticide use. Denmark, Sweden, the Netherlands and Germany have, or have had, a strong public and political interest for reducing the use of herbicides to control weeds in urban amenity areas and also have very strict regulations. The UK is currently undergoing a period of increasing awareness and strengthening regulation, while Latvia and Finland do not have specific regulations for weed control in urban amenity areas or on hard surfaces. Statistics on pesticide/herbicide use on urban amenity areas were only available in Denmark and the Netherlands. Developing this kind of information base reveals the differences in herbicide use, regulations and policies in European countries and may enhance the transfer of knowledge on sustainable weed control across countries.

Keywords: policies, non-agricultural herbicide use, regulations, hard surfaces, pavements, municipalities, public authorities, non-chemical weed control, Clean-Region.

KRISTOFFERSEN P, RASK AM, GRUNDY AC, FRANZEN I, KEMPENAAR C, RAISIO J, SCHROEDER H, SPIJKER J, VERSCHWELE A & ZARINA L (2008). A review of pesticide policies and regulations for urban amenity areas in seven European countries. *Weed Research* **48**, 201–214.

Introduction

The use of herbicides for weed control in non-agricultural or urban amenity areas may lead to different environmental issues than when they are used in agriculture, and these need separate consideration (Spliid *et al*., 2004). Water quality monitoring studies have demonstrated that there is a disproportionate contamination of waters by non-agricultural herbicide use (Augustin, 2003; Skark *et al*., 2004; Kempenaar & Saft, 2006; Kempenaar *et al*., 2007). One of the main uses of herbicides in urban areas is to control weeds on

Correspondence: Anne Merete Rask, Danish Centre for Forest, Landscape and Planning, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark. Tel: (+45) 35 33 17 74; Fax: (+45) 35 33 15 08; E-mail: anr@life.ku.dk

hard surfaces. These areas are often constructed for rapid penetration of water or to encourage surface run-off to avoid flooding: this can result in contamination of nearby ditches, drains, sewage systems or groundwater (e.g. Allender, 1991; Ramwell *et al.*, 2002; Skark *et al.*, 2004). Consequently, there is minimal opportunity for herbicide sorption and/or degradation (Ramwell *et al.*, 2002), while the potential for herbicide removal to surface water bodies is high. Additionally, a recent study by Schmidt *et al.* (2006) has shown that besides run-off, leaching of glyphosate from hard surfaces into groundwater cannot be ignored, depending on weather and joint conditions.

According to an inventory study carried out by Puijker *et al.* (2004), the cost of treating water to remove pesticides in all water companies constitutes the main part of the up to 92 million euros for the Dutch drinking water industry during the years 2001–2003. In many countries, the pollution risk to the environment and drinking water reservoirs has led to several restrictions on the use of herbicides for weed control in non-agricultural areas (e.g. Hansson, 2002; Augustin, 2003; Kempenaar & Spijker, 2004; Kristoffersen *et al.*, 2004), which increase the need for alternative control methods.

Weeds in urban amenity areas cause several problems. On hard surfaces, the weeds grow easily in the open spaces such as joints and cracks. There are several reasons for the undesirability of weeds in these areas (Rask & Kristoffersen, 2007):

- Weeds can cause damage to the hard surfaces by breaking up asphalt and the edge of the road seal or they can enlarge cracks.
- Weeds can make asphalt footpaths slippery.
- Accumulation of plant residues can impede storm water run-off and make a substrate for new weed establishment.
- At road verges weeds can impair the visibility of traffic indicators, and thereby cause accidents.

Weeds make streets and pavements unsightly and the presence of weeds tends to indicate a city in decline. In parks and other green areas it is especially perennial weeds that cause problems. In sports areas and golf courses, the problem is mainly dicotyledonous weeds, insects and fungal pests (Kristoffersen & Rask, 2007).

The relevant legislation in force within the European Union (EU) is the Council Directive 91/414/EEC (EEC, 1991), concerning the placing of plant protection products on the market and the EU Water Framework Directive [WFD (EEC, 2000)]. This legislation is the only one used for EU-wide regulation of the use of herbicides for weed control. The directives recognise that plant protection products may involve risks and hazards to humans, animals and the environment, if not properly tested and authorised. Herbicides used in non-agricultural areas where primarily developed for use on cropland because the non-agricultural market is small. Still they are covered by the same pesticide regulation and have to meet similar criteria. Other regulations, both statutory and voluntary, may also exist in each member state.

However, to what extent do other regulations set limits on the use of pesticides in urban amenity areas in European countries? Is there, or has there been, any public or political interest to reduce the use of pesticides on hard surfaces or urban green areas administrated by the public authorities? Are there any statistics on the use of pesticides/herbicides by the public sector? At present, there is no comparative information available on the pesticide/herbicide use by the public authorities and weed control practices in European urban amenity areas. Developing this information base would reveal the differences in herbicide use, regulations and policies in European countries and may enhance the transfer of knowledge on sustainable weed control across the countries.

To address these challenges, this paper presents the results of a survey on political interest and regulations of pesticide/herbicide use in public urban amenity areas in the seven 'CleanRegion' project countries: Denmark, Finland, Germany, Latvia, the Netherlands, Sweden and United Kingdom. 'CleanRegion' or 'Regional Collaboration for Minimising Pesticide Emissions in the Environment' is an on-going 3 year INTERREG IIIC project, partly financed by EU to minimise the use of herbicides for weed control in urban areas. The project links research institutes and local and regional authorities in those seven European countries. In the following, the definition 'urban amenity areas' will describe areas like roads (including interurban roads and roadsides), pavements, squares, parks, gardens, sports grounds, cemeteries, etc., normally administrated by public authorities. Private gardens and other private use of pesticides by civilians are therefore not covered by the definition. Industrial areas are included if administered by the public authorities. It was decided not to include railway tracks as they are administered very differently in each country.

The major aim of the survey was to provide a first overview of current weed control practices and policies in amenity areas (mainly hard surfaces) in the seven project countries. Specifically, the objectives were:

- To provide an overview of the historical/political development in the use of herbicides in urban amenity areas in the respective countries.
- To examine if and how herbicide use in urban amenity areas is regulated.

- To provide an overview of the use of alternative weed control methods in amenity areas, research status and technological innovation in the respective countries.
- To estimate the present use of pesticides/herbicides in amenity areas and on hard surfaces in comparison with total quantity of pesticides used in each country.

Materials and methods

To standardise the national reports, each CleanRegion member was asked to collect information on:

- *Policies:* Description of the political interest (if any) on the topic 'use of pesticides in amenity areas' and a description of how this interest has influenced the historical/political development in pesticide use and the possible use of alternative weed control methods in amenity areas during the recent decades.
- *Regulations:* National, regional and/or local regulations on the use of pesticides in amenity areas (if any). Possible plans for future regulations in amenity areas.
- *Use of herbicides in amenity areas:* Statistics (or, if not available, an estimate) of the quantities of herbicides used in amenity areas administered by public authorities.
- *Total use of pesticides/*herbicides in the country: Statistics of the quantities of pesticides/herbicides used or sold yearly in each country (for comparison with the use in amenity areas).

Each point was elaborated on a questionnaire to equalise the answers. The CleanRegion partners handled the contact to relevant authorities (e.g. environment agencies) to gather the information as a national survey. Each partner elaborated a summary of the national survey, and is presented in the paper. The sources of information vary from country to country, but each partner was expected to gather the information from competent authorities to secure the quality of the review. Some partners were not able to collect all the information that was asked for, so some sections are less detailed.

Results

Denmark

In recent decades, increasing political and public concern about unwanted side effects from pesticide use has been observed in Denmark (Table 1). This concern is especially related to the leaching of pesticides to groundwater, because it represents the major part of the drinking water resource in Denmark (Rasmussen & Højbjerg, 2002). Pesticides and their metabolites have been detected in approximately one-third of the examined groundwater abstraction wells in 2000 and 2001 (Brüsch & Juhler, 2002). In 9% of these, the politically determined limit of 0.1 $\mu g\ L^{-1}$ was exceeded.

In 1992, the use of pesticides in churchyards was banned. After a massive debate on pesticide use in urban amenity areas in the following years, the topic was part of a political hearing on pesticide use in general in 1996. It was decided to initiate an investigation into pesticide use in amenity areas for the preceding year. Initiatives to

Table 1 Political interest concerning pesticide use in urban amenity areas and regulations specifically of amenity areas or hard surfaces in seven European countries

Country	Political interest	Regulations on amenity areas	Specific regulations Sprayer's certificate	Restrictions on hard surfaces
Denmark	High	Very strict	X	Glyphosate and acetic acid banned. Decision on total phase-out of pesticide use by public authorities
Sweden	High	Strict/very strict	X	Glyphosate and acetic acid banned by 50% of the municipalities. Announcement before and after spraying
The Netherlands	High	Strict	X	Swath spraying forbidden. Mandatory use of sweep-guidelines including weed sensors for spot application of weeds.
United Kingdom	Moderate	Strict/moderate	X	Herbicides are allowed but must comply with Code of Practice for the Use of Plant Protection Products, which is a statutory code.
Germany	Moderate	Very strict	X	Specific approvals necessary for each herbicide use, spraying of glyphosate forbidden (only special sweeping technique can be approved)
Finland	Almost none	No specific regulations	X	None
Latvia	None	No specific regulations	X	None

reduce pesticide use were supported as part of the finance act in autumn 1997 and in 1998 the Ministry of Environment and the local authorities entered into a voluntary agreement on phasing out all use of pesticides (including agricultural land administered by the authorities) before 1 January 2003 (Anon, 1998). The basis for this agreement was a report from the Drinking Water Committee, as well as a number of previous initiatives and declarations of intent, all aimed at giving the public sector a leading position in efforts to minimise pesticide use. As part of the voluntary agreement on phase-out, the parties committed themselves to register pesticide consumption midway through the process and at the end of 2002. Furthermore, in autumn 2000, the Danish Environmental Protection Agency decided that pesticides containing glyphosate, which was the only active ingredient used on hard surfaces (Kristoffersen & Rask, 2007), could no longer be used on hard surfaces of any kind. In practice, this meant that weed control in these areas could no longer be carried out using herbicides (except under a few special conditions) and alternative ways to control weeds started increasing (Table 2) (Hansen *et al.*, 2004).

As a result of the strong regulation of pesticide use, technological innovation to advance equipment for alternative weed control has been very high. Equipment for thermal treatments (e.g. gas burners and steamers), mechanical weed control (weed brushers), as well as equipment for semi-hard surfaces, are subject to continual research and development (Kristoffersen & Larsen, 2001; Hansen *et al.*, 2004; Kristensen *et al.*, 2004; Rask & Kristoffersen, 2007). The possibility of using ultraviolet radiation to control weeds has also been investigated by Danish researchers (Andreasen *et al.*, 1999). Within the last few years, different strategies for weed control on paved areas and urban green areas have been developed and published as guidelines for the municipalities, greenkeepers, and park and road managers (Tvedt & Kristoffersen, 2000, 2002; Tvedt *et al.*, 2002; Kristoffersen & Tvedt, 2005).

Table 2 Use of alternative weed control methods, research and technological innovation in alternative weed control in urban areas in seven European countries

Country	Use of alternative weed control	Research in alternative weed control	Technological innovation
Denmark	Common	High	High
Sweden	Common	Moderate	Moderate
The Netherlands	Common	High	High
United Kingdom	None*	Low	Low
Germany	Some*	Low	Moderate
Finland	None	None	None
Latvia	None	None	None

*Except brush-weeders as part of street-cleansing operations.

Statistics on pesticide or herbicide use (total amounts as well as the amounts used by public authorities) are available from the Danish Environmental Protection Agency (http://www.mst.dk, Table 3). In the period 1995–2007 the amount of pesticides used by public authorities has been reduced from 28.8 tonnes of active ingredients to 5.1 tonnes of active ingredients (herbicides constituting about 80% of the total amount of pesticides) (Kristoffersen & Rask, 2007).

Finland

There have been many debates regarding pesticide use in field crop production in recent decades in Finland. However, political concerns over pesticide use in urban amenity areas have been limited to some local debates. There has been no specific national political debate on the topic and there are no national regulations specifically concerning pesticide use in urban amenity areas. The regulations are mainly the same as for agricultural use; however, there may be different local restrictions regarding the use of pesticides in many municipalities (Table 1).

In the beginning of the last century, hard surfaces such as stoned pavements and curbs were only seen in the old and big cities in Finland. Handpicking of weeds was the only method available at that time. In recent years, herbicides have been commonly used to cope with the fast growth of hard surface areas and the rising costs of labour. Herbicides have been cost-effective for weed control and non-chemical weed control is hardly used (Table 2).

In pesticide screenings of Finnish surface waters near agricultural areas, a total of 17 different herbicides, two fungicides, one insecticide and four metabolites were detected from the 100 pesticides that were analysed for. Herbicides were found in 90% of water samples; 2-methyl-4-chlorophenoxy-acetic acid (MCPA) was the most commonly detected. Levels of these pesticides were fairly low; only some peak values were close to the average levels, which are mentioned in the Water Framework Directive (2000/60/EC) (Siimes *et al.*, 2005). Herbicides were also found in groundwater in a survey made in the Salpausselkä Esker area, an important groundwater catchment area in Finland. For example, very small amounts of simazine and atrazine could be detected locally, although the use of these compounds was stopped in the early 1990s (Mannio *et al.*, 2007). Reports of these surveys are under preparation.

Pesticide legislation is based on Pesticide Act (327/69), Pesticide Decree (792/95) and Decisions of Ministry of Agriculture, each with amendments in

Table 3 Statistics of pesticide/herbicide use in agricultural land, amenity areas and on hard surfaces

Country	Land area (km^2)	Population	Population density (pop km^{-2})	Pesticides sold in total in 2002* (tonnes a.i. year^{-1})	Herbicides sold in total in 2002* (tonnes a.i. year^{-1})	Pesticides used on amenity areas (tonnes a.i. year^{-1})†	Hereof: Herbicide use on hard surfaces (tonnes a.i. year^{-1})†	Fraction: amenity areas/total pesticide use %
Denmark	43 094	5 432 335	126.1	2722	2105	5.1 (3.6 tonnes of glyphosate)	3	0.19
Sweden	449 964	9 001 774	20.0	1711	1447	No info available	No info available	.
The Netherlands	41 528	16 954 584	392.0	8072	2215	220	185	2.73
United Kingdom	244 820	59 553 800	243.3	31 064	21 133	829‡	No info available	2.7‡
Germany	357 021	82 431 391	230.9	29 531	14 328	<1000 (<2 glyphosate)	<100 (<2 glyphosate)	<3.4‡
Finland	338 145	5 223 442	15.4	1614	1273	5–6‡	No info available	0.6‡
Latvia	64 600	2 306 988	36.0	1681	1205	No info available	No info available	.

Only Denmark and the Netherlands have official statistics on pesticide use in amenity areas. The figures are from 2006 and 2001 respectively. The fraction of pesticides used in amenity areas in relation to total amounts of pesticides that are sold in each country are therefore calculated on basis of data from different years, and for Germany, United Kingdom and Finland the figures are based on estimates.

*Data are from http://epp.eurostat.ec.europa.eu. Data from Latvia are sold quantities in 2005.

†Data are from different sources and years, specified in the description of each country.

‡Estimate, no statistics available.

different years. Furthermore, there is the Chemical Act (744/89), the Chemical Decree (675/93) and some other Acts, Decrees, Government Decisions, along with their amendments, which all regulate pesticide use. In recent years, EU regulations have also become more important.

According to the pesticide legislation, a permit from the environmental authority at the municipal council is required, if pesticides are to be used in groundwater protection areas. Additionally, there are requirements to use pesticides, including:

- Only approved substances can be used [approved by the Finnish Food Safety Authority (Evira)].
- The person using very toxic pesticides has to be qualified, which means that the person has to pass a course every 10 years.

Since 1954, data on the quantities of pesticides (active substances) sold in Finland have been published annually in *Kemia-Kemi* (Chemistry), a journal. The annual data are available on Evira's website (http://www.evira.fi) (Table 3). The data on quantities sold are based on information from registration holders and representatives of pesticide companies. In spite of an increase in the total use of pesticides in the recent years, the rate of application of pesticides in Finland is still among the lowest in Europe (Savela & Hynninen, 2004). This is mainly due to the low population density and short vegetation period, which causes fewer weed problems in comparison with urbanised areas in other parts of Europe.

There are no statistics on the quantities of pesticides used in urban amenity areas, but it is estimated that the use is approximately 5–6 metric tonnes of active substance per year (total use of 1614 tonnes in 2002). This estimation is based on interviews with different main users (cities, road administration). However, a survey on pesticide use in 80 Finnish municipalities was carried out in 2007. Of these, 46 municipalities answered the questionnaire, representing communities with totally about 2 million inhabitants (40% of the total population in Finland). Only one-fifth of these municipalities used herbicides regularly. Nearly two-thirds of the municipalities reported occasional use and only 15% never used herbicides. About 35% of the municipalities had some local restrictions on pesticide use. The reported use of pesticides of these municipalities was about 1000 kg (commercial products). The majority of the municipalities had used glyphosate in recent years and in most cases on hard surfaces. Other products mentioned were small doses of MCPA, glufosinate-ammonium, isoxaben and aclonifen. Nine municipalities used acetic acid and citric acid, and several others said that they were interested in using these products (T. Lavonen, L. Linden, P. Leskinen & J. Raisio, unpubl. obs.).

Germany

The first legislative provisions on plant protection were decreed in 1919 and a compulsory registration of pesticides was implemented in 1968. Further revisions and amendments followed, in order to minimise potential risks of pesticides on environment and health. The authorisation of pesticides and their uses are currently defined in the German Plant Protection Act of 1998 and additional national amendments and regulations [Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), 2006]. These federal legal standards can be tightened with further provisions and guidelines of the federal states (Länder). Some municipalities do not allow spraying of herbicides on hard surfaces or have even voluntarily banned pesticide use in urban areas. According to the Act, authorised pesticides cannot be applied if the user expects that their use in individual cases will have a harmful effect on human and animal health, on groundwater, or have any other serious adverse effects. Furthermore, pesticides are only allowed in agricultural, forestry and horticultural land. Therefore, in principle, weeds on hard surfaces in urban areas cannot be controlled by herbicides (Table 1).

However, the responsible authority in the Länder can grant exceptions, if the purpose is urgent and cannot be achieved in any other way and if it does not conflict with overriding public interests. The authority can also carry out other necessary measures in order to meet the above-mentioned requirements. As this approval procedure is a task handled by the Länder, some of them have passed a number of clarifying provisions and some Länder strictly prohibit herbicide applications on hard surfaces. An approval can be given, depending on the case, for certain applications, including a specific authorised herbicide and use. The applicant has to provide considerable documentation for the herbicide use, which is mostly based on other legal obligations like the liability of premises, fire prevention, etc. Without an approval, the applicant cannot purchase herbicide for the intended use.

According to the German Plant Protection Act, the Länder are also responsible for the control of marketing and use of pesticides. Control methods have been specified and harmonised by the Plant Protection Control Program implemented in 2004 [BVL (Bundesamt für Verbraucherschutz) (2006a)].

Currently, the following active substances are authorised for uses on hard surfaces: diuron, flumioxazin, glufosinate, glyphosate, quinoclamin, acetic acid and pelargonic acid. Because of additional restrictions, only acetic acid and pelargonic acid are allowed to be sprayed on hard surfaces if there is any risk of run-off. Use of glyphosate can be approved, if the authority can specify an application technique avoiding run-off. This is in principle possible when using a manual wick applicator. A more efficient technique can be provided by a roller wiper, the so-called Rotofix system in combination with glyphosate. The Rotofix machine is hand-operated and consists of a rotor sprayer on the top, positioned at least 20 mm above surface. It has been officially proven in line with legal requirements. Instead of spraying a single plant, treatment by the Rotofix system reduces glyphosate volume to 75–95%. Contamination of surface water and groundwater is unlikely if the Rotofix system is used appropriately (Hermanns *et al.*, 2006). Rotofix applications are often approved together with restrictions, such as additional use of non-chemical control methods.

Of the above-mentioned active substances, only diuron has been found in surface water. During the period 1996–2003, the level of 0.1 μg L^{-1} was exceeded by 0.7–0.9% of approximately 12 000 estimations [Pesticide Action Network Germany (PAN), 2006]. As in a large number of European countries, use of diuron is strictly prohibited on hard surfaces or areas where there is a risk of run-off. The very low number of herbicides authorised for weed control in hard surfaces and the strong application restrictions reduce the risk of ground and surface water contamination.

Besides the strict provisions for herbicides and their uses, there are several additional requirements concerning personal qualification, recording, when to carry out the weed control, and location of the applications. In order to avoid any environmental risk, operators should follow the principles of Good Professional Practice [Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV), 2005]. According to these rules, for example, even approved applications are prohibited if rainfall is expected soon after application.

Because of these restrictions and the high administrative input, municipalities are also interested in non-chemical measures for weed control (Table 2). Sweeping and brushing of hard surfaces are likely the most common methods to remove weeds and avoid new weed infestation. Manual weed control is carried out as well, mainly on small or hardly accessible areas. Recently there has been a technical improvement and more frequent use of thermal weed control methods, especially steam and hot water with foam. The extent of use and experiences of non-chemical weed control methods are very different from municipality to municipality.

Statistics on production and consumption of pesticides in Germany are published yearly according to the Plant Protection Act. Detailed data on herbicides applied on hard surfaces or quantities used on amenity areas or hard surfaces are not available (Table 3). However, except glyphosate, herbicides registered for

non-cropping areas are marketed in a total amount less than 230 tonnes yearly (BV, 2006b). Even though there is no precise information as to the share for urban areas, it is estimated to be very small compared with agricultural uses. As a consequence of the limitation to localised application of glyphosate, based on a recent national questionnaire, consumption of glyphosate is likely to be less than 2 tonnes year^{-1}.

Latvia

The politicians of Latvia are not actively working on programmes to minimise pesticide use, as the public debate has been minimal. In addition to this, the use of herbicides is considered to be low in comparison with other EU countries. This is also the official opinion of the Ministry of Agriculture. Specific regulations of pesticide use in urban areas do not exist and there is practically no control of pesticide use by public authorities (Table 1). Some non-chemical weed control is carried out with brush weeders in larger cities or hand-hoeing in small areas (Table 2).

The first regulation regarding pesticide use for plant protection on agricultural land was introduced in 1913. It included management of the plant protection activities within the Republic, the elaboration of a set of measures for combating weeds, plant pests and diseases, and control of plant protection measures of all land under the control of land users. On 1 August 1995, the State Plant Protection Station was assigned a new function: issuance of specific licences for trade in plant protection products. In the same year, the Trade and Usage Control Group of Plant Protection Products was established. After 1 year, when the number of special licences issued had grown considerably, an inspection to monitor the plant protection regulatory enactments was initiated. On 3 January 2000, Plant Protection Products' Trade and Usage Control Division was established, which since 1 February 2002, was named Plant Protection Products' Circulation Control Organization Division. This organisation controls pesticide use in the country. The type and amount of pesticide that can be purchased by the user depends on his qualification and whether he has a certificate for plant protection or not. The person using the pesticide has to be qualified, and therefore attend to pass a course organised by State Plant Protection Service.

There are more than 75 herbicides on the list of approved pesticides in Latvia. Especially glyphosate, MCPA, dichlorprop and mechlorprop are widely used for weed control. Although there is no official information of herbicide use on hard surfaces, it is known that the most commonly used herbicide by the municipalities is glyphosate (Table 3).

The Netherlands

The use of synthetic pesticides for weed, insect and plant disease control increased rapidly in Dutch municipalities after World War II. However, since the 1970s, several municipalities voluntarily reduced or banned pesticide use in amenity areas because of the concern about the unwanted side effects of these pesticides. These forerunner municipalities were in most cases large municipalities in urban areas of the Netherlands (Kempenaar & Spijker, 2004). In 1993 and 1994, a particular side-effect became evident when the drinking water company 'Waterwinningbedrijf Brabantse Biesbosch' had to stop the intake of water from the river Meuse for drinking water for 7 weeks because of high concentrations of diuron (Sluijsmans *et al*., 1997). A study of Aarnink *et al*. (1996) showed that diuron used on hard surfaces was an important source of this problem. At this point, the government, the water authorities and the drinking water companies realised that not only the agricultural use of pesticides, but also the use of pesticides (in particular herbicides) in the urban environment had serious impact on water quality.

About 40% of the drinking water in the Netherlands is derived from surface water. This share is expected to rise to 50% in 2030 [VROM (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer) (2001)]. The pollution of surface water by pesticides decreases very slowly in the Netherlands. In some locations, the concentration of pesticides does not always comply with the guidelines for drinking water of 0.1 μg L^{-1} for individual pesticides, and 0.5 μg L^{-1} for total pesticides [Milieu en Natuur Planbureau (MNP), 2006].

After recognition of the drinking water production problems in 1993 and 1994, several municipalities reduced the use of pesticides, stimulated by a national voluntary agreement (covenant) between governmental bodies in 1997 [Bestuurlijke afspraken uitvoering Meerjarenplan Gewasbescherming Openbaar Groen (MJPG-OG), 1997]. The covenant was among others signed by the national government and the three umbrella organisations of municipalities, provinces and water boards. The two main objectives of the agreement were to reduce use by 43% in 2000 and to reduce emission to the environment by 90% in comparison with the situation in the period 1984–1988. The covenant was evaluated in 2001, where it was concluded that the use objective was met (in fact a reduction of 69% was achieved), but not the emission objective. Furthermore, it was concluded that weed control on hard surfaces was still highly dependent on herbicide use. During the last 5 to 10 years, additional regional covenants were signed in several provinces of the Netherlands (e.g. Zeeland, Limburg, Friesland) to further reduce and/or stop

pesticide use in urban areas (Convenant Duurzaam Beheer 2001; Intentieverklaring Duurzaam Beheer Fryslân, 2003). Only a few of the participating municipalities managed to stop using herbicides completely on hard surfaces, mainly because alternative non-chemical weed control is less cost-effective than herbicide weed control. Nevertheless, the regional covenants contributed to further reductions in pesticide use and awareness of the problem.

In 1999, the use of diuron on hard surfaces was legally banned, because concentrations of the compound in surface waters used for drinking water production repeatedly exceeded the environmental threshold concentration (in Dutch: MTR). After the ban of diuron, glyphosate became the most used herbicide on hard surfaces. In 1997, a technique for automatic weed detection was implemented on a small boom sprayer for hard surfaces (Sluijsmans & Drijver, 1997). With this system, contact herbicides can be sprayed selectively on weeds. Since 2000, swath spraying of hard surfaces is legally forbidden in the Netherlands and use of weed sensors and selective application are mandatory (Table 1) (Kempenaar *et al*., 2000). In 2006, the technology involved was further improved (Kempenaar *et al*., 2006), allowing reductions of more than 60% compared with swath spraying (Table 2).

In 2004, the National Administrative Organization Water [Landelijk Bestuurlijk Overleg Water (LBOW)] established a commission 'Weed Control Hard Surfaces'. The goal of the commission was to develop best practice for weed control on hard surfaces safeguarding the quality of surface waters. The commission reported their conclusions to LBOW in autumn 2006. The commission recommended more weed-preventive methods, reduction of herbicide use compared with current standard practice, mandatory run-off reducing measures such as the ones described in the Sustainable Weed Control on Pavements (SWEEP) system (Table 1) (SWEEP consists of, e.g. no-spray buffer zones, weather and technology criteria and dose caps; for details, see shortlists on http://www.weedcontrol.eu), certification, and local banning of herbicides near specific waters (e.g. surface waters that are used for drinking water production).

Non-chemical weed control in urban green and on hard surfaces increased in the period 1992–2001. For urban green, the area under non-chemical control increased from 14.5×10^3 ha in 1992 to 19.5×10^3 ha in 2001, and for hard surfaces from 2.2×10^3 to 8.5×10^3 ha (http://statline.cbs.nl). In 2001 32% of the municipalities did not use herbicides in the urban green, and 19% of the municipalities did not use pesticides on hard surfaces (CBS). Alternative methods to control weeds that are regularly used include brushing, flaming, mowing, hand hoeing, hot water and soil coverage with wood chips. Brushing was the first alternative technique on hard surfaces in the 1970s and 1980s followed by flaming. The first hot water weed control machine was introduced in the Netherlands in the municipality of Heemstede in 1999. Thereafter, some improvements have been developed, such as higher working speed, adaptations for the use of surface water instead of drinking water, combination with foam, and selective treatment by automatic weed detection system (WAVE) (Table 2).

Different methodologies have been developed for efficient non-chemical weed control and for sustainable weed control. Sluijsmans (1994) developed a reduction programme for the use of pesticides by municipalities. The key to the programme is the co-ordination between the design of hard surfaces and urban green, weed control and communication with all individuals and organisations involved. An improved version of this methodology is published by Spijker *et al*. (2002a,b). Kortenhoff *et al*. (2001) described a theoretical system for sustainable weed control on hard surfaces. The system was developed in practice from 2002–2005 (Kempenaar, 2004) and named SWEEP (http://www.weedcontrol.eu). This has a number of practical guidelines that enable those responsible for weed control to work under boundary conditions with cost-effective weed control while emission of herbicides to surface water is reduced to levels so that drinking water criteria are met (Kempenaar *et al*., 2006, 2007). The system includes transparent organisation, prevention, restrictions on herbicide use, definition of a maximum level of weed infestation, registration and certification.

Data regarding the use of pesticides by were published by public authorities (CBS, 1986, 1992, 1995, 2001) (Table 3). Publication of the figures for 2006 is expected in 2007. The figures are based on a questionnaire, which was sent to all governmental bodies. However, Van Straaten *et al*. (2005) estimated that the total use by governmental bodies may well be 15% more than the CBS figures.

Sweden

Today, Sweden has strict regulations of the use of pesticides in urban amenity areas (Table 1). The regulation is a result of a public and political debate of the use of pesticides, and of the work of the environmental and ecological movements in recent years. The issue gained momentum in the 1970s, specifically with an intensive public discussion of the use of Agent Orange (a mixture of the phenoxy acid herbicides 2,4,5-T and 2,4-D) in forestry. Agent Orange, which was usually applied by aerial spraying, was used in large scale from the beginning of the 1950s against unwanted shrubs and

bushes after the clearing of lumber. Agent Orange was also used along the railways to keep the weeds down. In 1972, aerial spraying was prohibited, after debates about the unwanted side-effects, but was re-allowed in 1975, provided that the municipal council authorities and the public were informed about the spraying. In 1977, aerial spraying was completely banned, but the debate of the use of pesticides in public areas continued.

Until the end of 1980s, long-acting soil herbicides were commonly used on hard surfaces. However, the discovery of chemical residues in watercourses in Sweden (when water quality surveys started in 1985) served as a wake up call (Ulén *et al*., 2002), and the use of herbicides on hard surfaces was prohibited.

In 1984, the regulations were changed giving the municipal council the authorisation to decide if chemical pesticides should be allowed in areas with children, e.g. on playgrounds. Within 7 years, approximately 70% of the municipal councils in Sweden had policies for weed control on hard surfaces. According to these policies, either no herbicides were to be used on council properties or only a few types of herbicides were allowed. Many of these policies are even valid today (Schroeder & Hansson, 2006).

In 1987, a federal government decision stated that herbicide use should be halved by 1990. In order to achieve this goal, the price of pesticides was raised with taxes. Within 3 years the amount sold was halved.

A radical change in the regulation of pesticide use occurred in 1997, when the environmental authority was given more influence at the municipal council [regulation: Föreskrifter (1997, p. 2) om spridning av bekämpningsmedel]. It was stated that a permit from the environmental authority at the municipal council was required in order to use pesticides on grounds of apartment blocks, playgrounds and schoolyards, in water catchment protection areas and on ground construction works. The regulation is still valid today. Additionally, the environmental authority at the municipal council has to be informed if pesticides are to be used on railway embankments, sports grounds and areas larger than 1000 m^2, to which the public has access (not agricultural land). Even if permission from the authority is not required, the authority can prohibit the usage. In situations where the public has access, information is given with a notice on site.

It is required that the person applying a pesticide is qualified. Qualification is acquired through completion of a course organised by The Swedish Board of Agriculture and must be updated every 5 years. Fines amounting to 500–100 Euros are levied for application of pesticides by persons without the right qualification.

Acetic acid and glyphosate are the herbicides most commonly used on hard surfaces by Swedish municipal councils. Still, in approximately 70% of the municipal councils the use of herbicides with glyphosate is prohibited. Additionally, in approximately 50% of these councils, use of acetic acid is also prohibited. In 30% of the municipal councils, however, there are no restrictions on the type of pesticide used, as long as the chemical is approved by the Swedish Chemicals Inspectorate (Schroeder & Hansson, 2006). Non-chemical weed control, such as flaming, brushing, steaming, etc. are regularly used to control weeds on hard surfaces (Schroeder & Hansson, 2006) (Table 2).

Statistics of the quantities of pesticides (active substances) sold in Sweden have been published annually by The Swedish Chemicals Inspectorate (2006) (http://www.kemi.se) since 1979; the data are based on information from holders of pesticide approvals (Table 3). No statistics are available regarding the quantities of pesticides used in urban amenity areas.

United Kingdom

In the UK, there is increasing awareness regarding the potential contribution made by herbicides applied to hard surfaces to the contamination of surface freshwaters. Herbicides are still permitted for use on hard surfaces in the UK and remain the primary method of control (Table 1). As a rule, herbicides (predominantly glyphosate) are used two or three times during the season to keep streets clear and this is often combined with regular street sweeping. There has been considerable fragmentation in the way weed management has been dealt with by Government Local Authorities (LAs), but in recent years there have been efforts to increase the level of co-ordination between all tiers of the LAs to improve efficiency, including the Cleaner Greener and Safer agenda (Grundy, 2007). Non-chemical strategies are not generally used and equipment would need to comply with strict Health and Safety Executive (HSE) regulations for them to be used in public places (Table 2). Industry concerns regarding the efficacy and the cost and risk of physical damage to the urban amenity surfaces have also restricted their current uptake in the UK (National Association of Agricultural Contractors, NAAC, 2004). More recently, the carbon impact of non-chemical alternatives has entered the discussion. Prior to the UK Pesticide Safety Directorate (PSD) revoking amenity approval for triazine herbicides, water service companies were regularly reporting concentrations of these active ingredients above the acceptable EU limit. As a result, in 1991, all triazine-containing product approvals for uses in the amenity sector were finally revoked and spray contractors had to use their remaining stocks by August 1992. With the loss

of these products, diuron became widely used as the natural successor and stewardship programmes developed by the agrochemical industry were used to reduce any potential risks posed by products to drinking water quality. These stewardship programmes also had the added incentive of maintaining the availability of products for use on non-porous surfaces through responsible use.

Most of the top nine pesticides that are frequently found in UK surface freshwaters and groundwaters are herbicides that are mobile and persistent (Environment Agency, 2006a,b), with most of these pesticides coming from agricultural sources (NAAC, 2004).

There are long-standing legal requirements in the UK for the LAs to keep street areas clean [Environmental Protection Act; (Defra, 1990)] and remove certain weed species to prevent their spread and contamination of land [The Noxious Weed Act (Defra, 1959)] and also the Wildlife and Countryside Act (JNCC, 1981). There is no single UK body that controls the use of pesticides in urban and amenity areas and hard surfaces in the same way as for farming in the countryside. However, this does not mean that pesticide application is unregulated. For example, there are a number of British Agrochemical Standards Inspection Scheme (BASIS) and National Proficiency Test Council (NTPC) qualifications required by law from contractors regarding pesticide sales, advice, storage and application in urban and amenity areas. LAs are guided on policy by the *Manual of Contract Documents for Highway Works*; Volume 1 Specification for Highway Work Series 3000 refers to Landscape and Ecology, Clause 3001 refers to Pesticide Application and Clause 3002 refers to Weed Control [generally injurious weeds such as *Fallopia japonica* (Houtt.) Ronse Decr. and *Senecio jacobaea* L.]. In Clause 3001, it states that pesticides should be fit for purpose and that application of pesticides must not pollute watercourses or water supply. Guidelines and regulations for these pesticide applications are given by Department of the Environment, Food and Rural Affairs (Defra) and Environment Agency (EA) consent is required. The PSD is ultimately responsible for the registration of all pesticides for use in agriculture, horticulture, forestry and garden in the UK. Therefore, operators (including commercial contractors) that handle or apply herbicides, 'must comply with a raft of legislation and be suitably trained'(National Association of Agricultural contractors; NAAC 2004). Historically, there has been a voluntary industry code of practice and self-regulation in the amenity sector produced by the NAAC and the former British Agrochemical Association (Code of Practice for the Use of Pesticides in Amenity and Industrial Areas – referred to as the 'Orange Code'). However, there have been instances where there has been failure to follow up and check those codes of conduct are being adhered to. From December 2005, this Orange Code was integrated into the existing agricultural 'Green Code'. This 'New Code' has been issued by the PSD and HSE to form a mandatory revised [Code of Practice for the Safe Use of Plant Protection Products (Government Departments, 2006)]. The Code's statutory basis means that it can be used in evidence if people are taken to Court for offences involving pesticides.

The UK Strategy for the Sustainable Use of Plant Protection Products, aims to promote uses of them in ways that achieve high standards in environmental protection whilst maintaining adequate crop protection. Action Plans will deliver the Strategy's outcomes; one of these is an Amenity Use Action Plan, which will seek to minimise the impact of amenity use on water pollution and biodiversity. The Plan will cover increased awareness of controls, training, hard surface and aquatic weed control, through such bodies as the Amenity Forum of the industry-led Voluntary Initiative (VI) to bring together key stakeholders and encourage best practice.

Some data on the quantities of pesticides used in UK are available at the Central Science Laboratory and the Scottish Agricultural Science Agency, but precise data on the quantities used by the amenity sector in urban areas are not available. The Crop Protection Association (CPA, formerly the British Agrochemical Association) statistics for 2005 has estimated that the amenity sector uses approximately 829 tonnes of the total amount of pesticides applied annually in the UK (Table 3). Despite the good efforts of stewardship programmes to reduce diuron concentrations in recent years, it consistently remains one of the most frequently occurring products exceeding the non-statutory Environmental Quality Standard (EQS) of 0.1 $\mu g\ L^{-1}$ and importantly the majority of its use is by the amenity sector (Environment Agency, 2006a,b). Of about 2700 samples assessed each year between 1995 and 2004 in England and Wales, between 9.8% and 14.5% exceeded the EQS (Defra 2006). This indicates a disproportionately large contribution relative to the size of the amenity sector's total usage of herbicides. However, the impending phasing out of diuron around the end of 2008, as part of the ongoing European Community Pesticides Review programme (Plant Protection Products Directive 91/414/EEC), will no doubt have a significant impact on reducing the levels found. It may also have knock-on effects on amenity weed control in the UK and reopen the debate on the need to explore non-chemical alternatives.

Discussion

The sources of information and differences in data patterns between countries make direct comparisons difficult. However, it is possible to see some general trends in the seven project countries regarding herbicide/pesticide use, use of alternative weed control, political interest in reducing pesticide use and regulations specifically on urban amenity areas.

An evaluation of the available pesticide/herbicide statistics in seven EU countries allows the conclusion that non-agricultural pesticide use is a small fraction of the total pesticide use. The total pesticide use in the countries included in the investigation ranges from about 1614 to 31 064 tonnes of active ingredients per year. Pesticide use on amenity areas accounts for approximately 0.2–2.7% of total pesticide use per year (Table 3). However, although the non-agricultural fraction may be low, there is relatively more concern about the non-agricultural use (especially use on hard surfaces), because the run-off fraction to surface waters is estimated to be at least a factor of 10 higher for non-agricultural uses than for agricultural uses of pesticides (Kempenaar *et al*., 2006). The amounts of pesticides used in total are to some extent reflected by the land area and population density in each country (Table 3). Only Denmark and the Netherlands collect data on the quantities of pesticides used by public authorities on urban amenity areas.

The survey reveals great differences in political interest, regulations of herbicide use on urban amenity areas and use of non-chemical weed control methods. In the Netherlands, about 40% of the drinking water is derived from surface water and detection of pesticides in rivers has caused public and political concern. In Denmark, detection of pesticides in groundwater has caused a similar concern, as it represents the major part of the drinking water resource. In Germany, water quality monitoring studies have revealed a disproportionate contamination of surface waters by non-agricultural pesticide use (Augustin, 2003). The use of herbicides for weed control on hard surfaces has been a particular focus in these countries, because of the higher risk of run-off (Ramwell *et al*., 2002; Phillips & Bode, 2004), consequently resulting in a strict regulation of the use of herbicides. In Denmark, it has been decided to completely phase out the use of all pesticides by the public authorities, and the regulations in the Netherlands, Germany and Sweden substantially reduce the possibilities for using pesticides by public authorities, e.g. by requiring an announcement before and after spraying (Sweden) or restrictions on application techniques (Germany, the Netherlands). The UK is currently undergoing a period of increasing awareness and strengthening regulation, and herbicides are allowed but must comply with the Code of Practice for the Use of Plant Production Products (Table 1).

Latvia and Finland do not have specific regulations for weed control on urban areas or hard surfaces, neither has there been any public and/or political concern about the use of pesticides in these areas. In Finland, unlike other Nordic countries, there has never been a strong environmental movement against the use of pesticides on urban areas, although public opinion is against use of pesticides in forestry and for restrictions in agriculture. The low population density and short vegetation period cause fewer weed-related problems in comparison with urbanised areas of southern Scandinavia, where the vegetation period is also notable longer.

On hard surfaces, the weed control level is often determined by aesthetic considerations and different hard surfaces need different levels of control. In Denmark and the Netherlands, weed control strategies dividing the paved areas into different classes are being developed in order to categorise the level of weed control according to the quality, use and placement of the hard surfaces (Hansen *et al*., 2004; Vermeulen *et al*., 2006). The levels range from no weed control at all, to a very high level of weed control (e.g. in city centres). The aim of the strategies is to help the road administrators and local authorities to give priority to their weed control effort and to go from the present relative short-term operational planning to longer-term strategic planning (Hansen *et al*., 2004).

Non-chemical weed control is regularly carried out in Denmark, Sweden, the Netherlands and to some extent, in Germany, as a result of the strict regulations. Therefore, research and technological innovation are more advanced in these countries, especially in Denmark and the Netherlands (Table 2). As the non-chemical weed control methods do not have to be officially approved, there is generally no detailed information on the frequency and extent of using these methods. There is a substantial need to develop effective and more economic non-chemical weed control methods, especially to obtain effective control of root-propagated weeds on hard surfaces (Rask & Kristoffersen, 2007). A transfer of knowledge and experiences across the countries, as enabled by the CleanRegion project, may enhance sustainable weed control in European countries.

Acknowledgements

Publication of this paper was made possible within the 'policy component' of the INTERREG IIIC project 'Regional Collaboration for Minimising Pesticide

Emissions in the Environment' (in short CleanRegion). This support is gratefully acknowledged.

References

Aarnink WHB, van der Bolt FJE, Merkelbach RCM & Westein E (1996) Belasting van grond- en oppervlaktewater met bestridjingsmiddelen in de stroomgebieden van de Beerze, Reusel en Rosep (Load of pesticides in ground and surface waters in the river basins of Beerze, Reusel and Rosep). Rapport 456, Staring Centrum, Wageningen, the Netherlands (in Dutch).

Allender WJ (1991) Movement of bromacil and hexazinone in a municipal site. *Bulletin of Environmental Contamination and Toxicology* **46,** 284–291.

Andreasen C, Hansen L & Streibig J (1999) The effect of ultraviolet radiation on the fresh weight of some weeds and crops. *Weed Technology*, **13,** 554–560.

Anon (1998) *Pesticidaftalen* (*The Pesticide Agreement*) (available at: http://www.kl.dk/1490, in Danish).

Augustin B (2003) Urban areas – source of pesticide-contamination of surface water? In: *Second 2003 International Symposium on Plant Health in Urban Horticulture*, Berlin, Germany, 166–169.

BMELV (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) (2005) *Grundsätze für die Durchführung der guten fachlichen Praxis im Pflanzenschutz* (available at: http://www.bmelv.de).

BMELV (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) (2006) *Gesetz zum Schutz der Kulturpflanzen (Pflanzenschutzgesetz (Fassung vom 14.05.1998))*. (available at: http://www.bmelv.de).

Brüsch W & Juhler R (2002) Pesticider og nedbrydningsprodukter (Pesticides and their metabolites). In: *Grundvandsovervågning 2002* (ed. LF Jørgensen), Geological Survey of Denmark and Greenland – GEUS, Copenhagen, Denmark, 57–74 (in Danish).

BVL (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit) (2006a) *Pflanzenschutz-Kontrollprogramm, Jahresbericht 2004* (available at: http://www.bvl.bund.de).

BVL (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit) (2006b) *Absatz der Pflanzenschutzmittel in der Bundesrepublik Deutschland, Ergebnisse der Meldungen gemäß § 19 Pflanzenschutzgesetz für das Jahr 2005*. (available at: http://www.bvl.bund.de).

CBS (1986, 1992, 1995, 2001) *Statistics on Pesticide Use in Amenity Area*. Central Office for Statistics, The Hague, the Netherlands (available at: http://statline.cbs.nl, in Dutch).

Convenant Duurzaam Beheer (2001) *Zeeuwse overheden samen sterk bij het afbouwen van chemische onkruidbestrijding. Gemeenten Borsele, Hulst, Kapelle, Noord-Beveland, Sas van Gent, Schouwen-Duiveland, Terneuzen, Tholen and Veere, Waterschap Zeeuwse Eilanden, Waterschap Zeeuws-Vlaanderen, Rijkswaterstaat directie Zeeland, Provincie Zeeland and Havenschap Zeeland Seaports, NL (Covenant Sustainable Weed Control; Zeeland governments cooperate in reduction of chemical weed control)*. Provincie Zeeland, Middelburg, the Netherlands. (in Dutch).

Defra (1959) *The Noxious Weed Act* (available at: http://www.defra.gov.uk/farm/wildlife/weeds/index.htm).

Defra (1990) *Environmental Protection Act* (available at: http://www.defra.gov.uk/environment/localenv/litter/code/index.htm).

Defra (2006) *Pesticides in Surface Water Samples: 1995–2005. England & Wales* (available at: http://www.defra.gov.uk/environment/statistics/inlwater/iwpesticide.htm).

EEC (1991) Council Directive 91/414/EEC (available at: http://ec.europa.eu/food/plant/protection/index_da.htm).

EEC (2000) *Water Framework Directive* (available at: http://www.ec.europa.eu/environment/water/water-framework/index_en.html) [accessed on 28 January 2008].

Environment Agency (2006a) *Pesticides Report 2005; Pesticides in Rivers, Groundwater and Pollution Incidents* (available at: http://www.environmentagency.gov.uk/yourenv/eff/1190084/business_industry/agri/pests/915588/).

Environment Agency (2006b) *Pesticides in surface waters by substance in England and Wales, 1998 to 2004* (available at: http://www.environmentagency.gov.uk/commondata/103196/132012?referrer=/yourenv/eff/1190084/business_industry/agri/pests/915588/).

Föreskrifter (1997) *om spridning av bekämpningsmedel* (available at: http://ww.naturvardsverket.se).

Government Departments (2006) *Code of Practice for the Safe Use of Plant Protection Products* (available at: http://www.pesticides.gov.uk/farmers_growers_home.asp#Codes_of_Practice). [accessed on 28 January 2008].

Grundy AC (2007) Weed occurrence on pavements in the UK: the results from a survey of Leamington Spa. *Aspects of Applied Biology* **82,** *Vegetation Management*, 175–182.

Hansen PK, Kristoffersen P & Kristiansen K (2004) Strategies for non-chemical weed control on public paved areas in Denmark. *Pest Management Science* **60,** 600–604.

Hansson D (2002) Hot water weed control on hard surface areas. PhD thesis, Department of Agricultural Engineering, Swedish University of Agricultural Sciences, Alnarp, Sweden, Report 323.

Hermanns H, Meyer E, Reichel F & Bartels U (2006) *Erprobung verschiedener Verfahren zur Wildkrautbeseitigung in der Sportschule der Bundeswehr Warendorf* (available at: http://www.wasser-und-pflanzenschutz.de/index.php?id=25).

Intentieverklaring Duurzaam Beheer Fryslân (2003). *Friese overheden werken samen bij het afbouwen van het gebruik van chemische bestrijdingsmiddelen in groen en verhardingen (Declaration of intent Sustainable Weed Control province Fryslân. Frisian governments cooperate in reducing the use of pesticides in green and pavements)*. Friese gemeenten, Provincie Frieslân, Wetterskip, Fryslân, the Netherlands (in Dutch).

JNCC (1981) *Wildlife and Countryside Act 1981* (available at: http://www.jncc.gov.uk/page-3614) [accessed on 28 January 2008].

Kempenaar C (2004). *Handleiding DOB-systeem, Version 1 (Manual SWEEP-system)*. Plant Research International, Wageningen, the Netherlands (in Dutch).

Kempenaar C & Saft RJ (2006) Weed control in the public area: combining environmental and economic targets. In *Clean Region Conference 2006 on Policies of Weed Control on Pavements*, Wageningen, the Netherlands, 17–26.

Kempenaar C & Spijker J H (2004) Weed control on hard surfaces in the Netherlands. *Pest Management Science* **60,** 595–599.

Kempenaar C, Groeneveld RMW & Uffing AJM (2000) Quantitative evaluation of liquid deposition by herbicide application systems for weed control on hard surfaces. Note 52. Plant Research International, Wageningen, the Netherlands.

Kempenaar C, Groeneveld RMW & Uffing AJM (2006). Evaluation of Weed IT model 2006 MKII: spray volume and dose response tests. Note 418. Plant Research International, Wageningen, the Netherlands.

Kempenaar C, Lotz LAP, van der Horst K, Beltman WJ, Leemans KJM & Bannink AD (2007). Trade off between costs and environmental effects of weed control on pavements. *Crop Protection*, **26,** 430–435.

Kortenhoff A, Kempenaar C, Lotz LAP, Beltman WHJ & den Boer L (2001) Rational weed management on hard surfaces. Note 69A. Plant Research International, Wageningen, the Netherlands.

Kristensen K, Hansen P & Kristoffersen P (2004) Simulation of vegetation cover on sidewalks in Denmark. *Pesticide Management Science*, **60,** 588–594.

Kristoffersen P & Larsen SU (2001). *Pesticidfri ukrudtsbekæmpelse på naturstensbelægninger: resultater fra forsøg udført på Slotsholmen (Weed control without pesticides on cobblestone pavement: results from experiments at Slotsholmen)*. Park – og Landskabsserien, Denmark, no. 29 (in Danish).

Kristoffersen P & Rask AM (2007). *Undersøgelse af pesticidanvendelsen på offentlige arealer i 2006 (Investigation of pesticide use on public areas in 2006)* (available at: http://www.mst.dk/Udgivelser/Publikationer/2007/05/978-87-7052-481-0.htm, in Danish).

Kristoffersen P & Tvedt T (2005) *Ukrudtsbekæmpelse på veje (Weed control on roads)*. Centre for Forest, Landscape and Planning, KVL, Hørsholm, Denmark (in Danish).

Kristoffersen P, Larsen SU, Moller J & Hels T (2004) Factors affecting the phase-out of pesticide use in public areas in Denmark. *Pest Management Science* **60,** 605–612.

Mannio J, Siimes K & Gustafsson J (2007) Environmental monitoring of pesticides in Finland. In: *Establishing a Nordic Pesticide Monitoring Network*. TemaNord, 2007:514. ISBN. 978-92-893-1462-6, 41-49.

MJPG-OG (Bestuurlijke afspraken uitvoering Meerjarenplan Gewasbescherming Openbaar Groen) (1997) *Ministerie van Landbouw, Natuurbeheer en Visserij, Ministerie van Ruimtelijke Ordening en Milieu, Ministerie van Verkeer en Waterstaat, Ministerie van Defensie, Ministerie van Volksgezondheid, Welzijn en Sport, Stichting GroenRaad, Vereniging van Nederlandse Gemeenten, NS/*Railinfrabeheer, Unie van Waterschappen, Bosschap en Vereniging van Samenwerkingsverbanden in de Openluchtrecreatie (OSO) (Covenant Implementation Multi Year Crop Protection Plan Urban Green) (in Dutch).

MNP (Milieu en Natuur Planbureau) (2006). *Tussenevaluatie van de nota Duurzame gewasbescherming (Mid-term evaluation of 10-year national policy on sustainable crop protection)*. MNP, Bilthoven, the Netherlands (in Dutch).

NAAC (2004). *Weed Control in Public Spaces Best Value, Best Practice or Best Price?* (available at: http://www.naac.co.uk/bestvaluereport.pdf).

PAN (Pesticide Action Network Germany) (2006): *Häufig nachgewiesene Pestizid-Wirkstoffe und Metabolite 1996–2000, 2003* (available at: http://www.pestizidreduktion.de/pestizide_im_wasser/grundwasser/wirkstoffe_und_metabolite/2002.html).

Phillips PJ & Bode RW (2004) Pesticides in surface water runoff in south-eastern New York State, USA: seasonal and stormflow effects on concentrations. *Pest Management Science* **60,** 531–543.

Puijker L, van Beek K, Beerendonk E & Gijsbertsen A (2004). *Door drinkwaterbedrijven gemaakte kosten als gevolg van bestrijdingsmiddelengebruik. Inventarisatie over de periode 2001–2003 (Costs made by drinking water companies as result from the use of pesticides)*. VEWIN and KIWA, KWR 04.094 (in Dutch).

Ramwell CT, Heather AIJ & Shepherd AJ (2002) Herbicide loss following application to a roadside. *Pest Management Science* **58,** 695–701.

Rask AM & Kristoffersen P (2007) A review of non-chemical weed control on hard surfaces. *Weed Research* **47,** 370–380.

Rasmussen P & Højbjerg AL (2002). Grundvandsressourcen og hydrologisk modellering (Groundwater resources and hydrological modelling), In: *Grundvandsovervågning 2002* (ed. LF Jørgensen), Geological Survey of Denmark and Greenland – GEUS, Copenhagen, Denmark, 75–86 (in Danish).

Savela ML & Hynninen EL (2004) Slower growth in pesticides sales. *Kemia-Kemi* **31,** 57–59.

Schmidt H, Balder B, Glitschka M, Boas P & Pestemer W (2006): *Accompanying experiments on weed control on public footways using the roller wiper ''Rotofix''. Mitteilungen aus der Biologischen Bundesanstalt*, Biologische Bundesanstalt fur Land- und Forstwirtschaft, Berlin und Braunschweig, 400, 435 (in German), Berlin, Germany.

Schroeder H & Hansson D (2006) *Koll på tillväksten: uthållig ogräsbekämpning på hårdgjorda ytor*. Sveriges Kommuner och Landsting, Stockholm, Sweden.

Siimes K, Kirsti K, Heinonen J & Mannio J (2005). Pesticide screening in Finnish surface waters. In: *Seventh International Conference of Environmental Sciences. Science for Sustainability: Proceedings* (eds P Meriläinen, L Sivula & A Oikari). University of Jyväskylä, Jyväskylä, Finland. 295–298.

Skark C, Zullei-Seibert N, Willme U, Gatzemann U & Schlett C (2004) Contribution of non-agricultural pesticides to pesticide load in surface water. *Pest Management Science* **60,** 525–530.

Sluijsmans JJL (1994) *Reductieprogramma chemische onkruidbestrijdingsmiddelen bij gemeenten. Fase 1: Opzet van een reductieprogramma (Reduction program chemical weed control for municipalities; Phase 1: Development of a reduction program)*. IBN-report 098 (in Dutch).

Sluijsmans JJL & Drijver CA (1997) *Terugdringen van het gebruik van chemische onkruidbestrijdingsmiddelen op verhardingen met behulp van detectie-spuittechniek (Reduction chemical weed control on pavements with sensor technology)*. Instituur voor Bos- en natuuronderzoek & Plant-

enziektenkundige Dienst, Wageningen, the Netherlands (in Dutch).

Sluijsmans JJL, Spijker JH & Betist MHH, (1997) *Gif van de straat, Reductieprogramma chemische onkruidbestrijding op verhardingen (Pesticides out of the streets. Reduction program chemical weed control on pavements)*. VEWIN, Gemeente Eindhoven, Alterra, the Netherlands (in Dutch).

Spijker JH, Hekman J, Teunissen MB & Mantingh R. (2002a) *Onkruid vergaat wel! Handboek voor gifvrij beheer van groen en verhardingen in gemeenten (Handbook for management and maintenance of pavements and public green without the use of pesticides)*. Provinmcie Overijssel. Alterra, the Netherlands (in Dutch).

Spijker JH, Hekman J, Teunissen MB & Mantingh R (2002b) *Handboek gifvrije onkruidbestrijding door gemeenten (Handbook for management and maintenance without the use of pesticides by municipalities)*. Zuiveringschap Limburg, Alterra, the Netherlands (in Dutch).

Spliid NH, Carter A & Helweg A (2004) Non-agricultural use of pesticides – environmental issues and alternatives. *Pest Management Science* **60,** 523.

The Swedish Chemicals Inspectorate (2006). *Försålda kvantiter av bekämpningsmedel 2005. Sold quantities of pesticides 2005*. Sveriges officiella statistik, Stockholm, Sweden (in Swedish, summary in English).

Tvedt T & Kristoffersen P (2000). *Ukrudtsbekæmpelse på kirkegårde (Weed control on churchyards)*. Danish Ministry of Ecclesiastical Affairs, Copenhagen, Denmark & Centre for Forest, Landscape and Planning, KVL, Hørsholm, Denmark (in Danish).

Tvedt T & Kristoffersen P (2002). *Ukrudtsbekæmpelse på belægninger (Weed control on hard surfaces)*. Centre for Forest, Landscape and Planning, KVL, Hørsholm, Denmark & the Danish Environmental Protection Agency (Danish EPA), Copenhagen, Denmark (in Danish).

Tvedt T, Fischer J, Larsen SU & Kristoffersen P (2002) *Pesticidfri pleje af fodboldbaner og golfbaner (Non-chemical weed control on football pitches and golf courses)*. Centre for Forest, Landscape and Planning, KVL, Hørsholm, Denmark & the Danish Environmental Protection Agency (Danish EPA), Copenhagen, Denmark (in Danish).

Ulén B, Krueger J & Sundin P (2002). *Bekämpningsmedel I vatten från jordbrug och samhälle (Pesticides in water coming from agriculture and communities)*. Nr. 5, 2002, SLU, Fakta Jordbruk, Uppsala, Sweden (in Swedish).

Van Straaten M, Spijker JH, Hekman J, van Dijk C & Kempenaar C (2005). *Omvang gebruik bestrijdingsmiddelen op verhardingen (eindrapport)*. Syncera Water, Delft, the Netherlands (in Dutch).

Vermeulen GD, Verwijs BR & Kempenaar C (2006) *Effectiveness of Weed Control on Pavements*. Plant Research International, Wageningen, the Netherlands.

VROM (Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer) (2001) *Vierde Nationaal Milieubleidsplan: Nota vastgesteld door het kabinet in haar vergadering van 8 juni 2001*. NMP4\2001 047 767, VROM, Den Haag, the Netherlands (Fourth National Environment Plan; in Dutch).

