PLANT RESEARCH INTERNATIONAL

Rational Weed Management on hard surfaces

Phase I - Further identification of objectives and elements that should be part of a DSS and Certification System

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Note 69A

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Table of contents

Preface

Monsanto and VEWIN assigned Plant Research International to design a Decision Support System that guarantees the rationalisation of the application of herbicides on hard surfaces, leading to a gradual and significant reduction of the total amount of herbicide being applied on hard surfaces, without affecting the resulting weed control.

This report describes the results of phase I of this project in which an inventory was made of key-elements of such a system. The research was carried out in co-operation with Alterra and CLM. Alterra described the critical situations regarding emission of glyphosate to surface water (Chapter 4) and CLM investigated the possibilities of certification (Chapter 8).

During phase I also a survey was carried out to investigate the attitude and motivation of both principals and contractors towards the use of herbicides on hard surfaces. The results are presented in an appendix to this document. We thank all the respondents for their willing co-operation and the valuable information they provided.

1. Outline of the project

1.1 Weed control on hard surfaces

Recent figures over 1998 showed that as much as 67% (= 32.340 kg a.i.) of the total amount of herbicides used in urban areas in the Netherlands is used for weed control on hard surfaces (e.g. paving, sidewalks, bikeways, railroads) (Kerkhof & Heemsbergen, 2000). Glyphosate and glyphosate related products are by far the most used herbicides for this particular application. The run off of herbicides applied to hard surfaces is considered to be the potentially most important route of emission of herbicides to surface water. In order to ensure that the standards for the acceptable amount of pesticide in water[1] will not be exceeded due to this particular use, it is necessary to further reduce the amount of herbicide being washed off from paved areas, esp. related to non-rational application (e.g. overdosing, use at sites where routes to surface water are very short).

Monsanto and VEWIN have asked Plant Research International to design a system that guarantees the rationalisation of the application of herbicides on hard surfaces, leading to a gradual and significant reduction of the total amount of herbicide being applied on hard surfaces, without affecting the resulting weed control.

1.2 Objectives

The aim of the project is to set up a system that:

1. prevents glyphosate and its metabolite AMPA[2] to wash down to the surface water in such amounts that the existing cleaning steps for getting from surface water to drinking water are not sufficient, see remark 1;
2. ensures the availability of effective weed control systems on hard surfaces.

1.3 Method

The project focuses on:

a) Further identification of objectives and identification of relevant elements of a Decision Support System (DSS) and a Certification System (both application and object oriented) (phase I);
b) Reference measurement at the start of the project: survey to determine the attitude and motivation of both principals and workers towards the use of herbicides on hard surfaces (phase I);
c) Development of a DSS to meet the objectives (phase II);
d) Development of a certification system / framework that guarantees the use of the DSS (phase II);
e) Implementation of the DSS and the certification system (phase III).
f) Reference measurement after phase III: survey to monitor the impact of the introduction of the DSS and the certification system (phase IV)

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1 Definition of acceptable level of pesticide in surface water: there should be no need to shut down water intakes, and the existing cleaning steps for getting from surface water to drinking water should be sufficient to get the glyphosate level below the norm in the drinking water (drinking water norms: 0,1 µg pesticide / l water - individual pesticide; total amount of pesticides: 0,5 µg / l water).

2 The amount of AMPA in surface water should be related to the application of glyphosate since AMPA is also a metabolite from e.g. detergents.

The results of phase I are written down in this startdocument. Phase I focussed on the further identification of the objectives and making them operational. A first inventory was made of the relevant elements that should be part of a DSS and the possibilities of certification.
Furthermore, at the start of the project a reference measurement was carried out to investigate the attitude and motivation of both principals and contractors / workers towards the use of herbicides - esp. glyphosate - on hard surfaces, thus determining the point of departure of the project. The results of the survey are included in an appendix to this startdocument.

The survey will be repeated after the implementation of the DSS in order to determine the impact of the project (scheduled as phase IV).

The results of phase I are determinative for the direction of phase II and will be presented in a workshop.

2. General introduction on weed control on (semi-) hard surfaces

Plants are called weeds if they occur in sites were they are not wanted. The level of weed infestation that is tolerated differs from one location to another, depending on the function and location of the hard surface. In the past weed control was mainly carried out by using herbicides. From the nineties onwards non-chemical control methods were considered like wire brush and flame gun. However these methods also have their restrictions. In general, non-chemical methods are less effective and more expensive compared to the use of herbicides. It became also apparent that these methods are not completely ecologically sound.

2.1 Necessity of weed control

For several reasons weeds are undesirable on (semi-) hard surfaces and need to be controlled:

- weeds do not agree with our image of tidiness
- refuse collects easily around weeds, thus even more degenerating our surroundings
- weeds can cause slipperiness, thus endangering the safety of pedestrians, bikers etc.
- the drainage of rainwater is hindered
- esp. woody weeds can cause actual damage to the pavement and take away sight.

2.2 Critical situations for development of weeds

Situations that are most critical for the development of weeds:

- Weeds generally occur in joints (esp. in places with many and wide joints)
- accumulated sand and organic material
- damaged, dislocated pavement
- pavement that is little walked on
- around 'street furniture' (e.g. road signs, traffic signs, benches)
- all semi-hard surfaces (e.g. gravel, shells).

2.3 Weed species

A wide variety of annual and perennial weed species occur on hard surfaces. The most common ones are listed below.

Annual species: e.g. shepherd's purse (*Capsella bursa-pastoris*), mayweed (*Matricaria discoidea*), common poppy (*Papaver rhoeas*).

Perennial species (both broad leaf weeds and grasses): great plantain (*Plantago major*), annual meadow-grass (*Poa annua*), knotgrass (*Polygonum aviculare*), procumbent pearlwort (*Sagina procumbens*), dandelion (*Taraxacum officinale*).

Mosses: a.o. *Bryum argenteum*.

2.4 Acceptable levels of weed infestation

The level of weed infestation that is acceptable depends - amongst others - on the function, the use and the location of the hard surface concerned and the demands (wishes) of the administrators and users.

Three aspects are to be distinguished:

- functional quality: determines to what extent weed growth influences the function and use of hard surfaces (e.g. passableness, safety, water outlet, roughness);
- technical quality: determines to what extend weed growth influences the lifespan of hard surfaces;
- picture quality: determines to what extent weed growth is acceptable from the aesthetic point of view (wishes of users and administrators).

2.5 Assessment of weed situation

There are several methods to assess the level of weed infestation. A common method is by measuring the joint length with weed growth.

Nowadays a very practical visual assessment method is available based on classification of weed growth in so-called picture quality classes. An example is given in Table 2.5. This classification is documented with photographs.

Table 2.5. Picture quality classes for weed growth (Sluijsmans et al.*, 1997).*

Class*	Weed growth	Description
I	none	no weeds
II	little	in places, no patches
III	moderate	weed growth in many joints, in places patches
IV	heavy	heavy weed growth and patches; no woody weeds
V	very heavy	heavy weed growth and patches, including woody weeds

* *classes IV and V are often combined*

Some cities have drawn up a plan of the city to which they indicate very precisely the picture quality class of weed growth that is acceptable on the different locations. On the basis of such a plan they put out to tender weed control to contractors.

E.g. in the municipality of Eindhoven they differentiate between four type of locations in the city:

1. top location (e.g. city centre, shopping street)
2. residential area
3. industrial area
4. countryside

For each type of location the acceptable level of weed infestation (picture class quality) is indicated. For example picture quality class I applies for top locations. At first around obstacles another picture class quality was accepted (one class higher compared to the location as a whole). Nowadays no differentiation is made between the location as a whole and obstacles.

2.6 Current practice of prevention and control of weeds

2.6.1 Prevention

Prevention of weed infestation starts with regularly brushing of the pavement (removing sand, litter, leaves etc.). This should be an integral part of preventive management. Reducing weed infestation by improvement of the pavement design (e.g. less interspace between paving stones) is an important but rather neglected strategy up untill now. The same accounts for removing non-functional obstacles and hard surfaces that are not used regularly. However, administrators are - understandably - rather reluctant to carry out such drastic measures.

2.6.2 Control

There are a great number of methods for weed control available, varying from mechanical and physical methods (brushing, mowing, burning, hot water) to the application of herbicides.

Mechanical methods

Brushing

Brushing is by far the most commonly used non-chemical method for weed control on hard surfaces. It can be used to control both small and heavy weed growth. Only the above ground parts of the plants are removed, thus favouring perennial weeds. A major advantage of the method is that at the same time it also removes other dirt. The application of brushing is limited to hard surfaces. The method can not be used on semi-hard surfaces or surfaces with back maintenance.

Other major drawbacks of the method are:

- wear of the hard surfaces, thus shortening the lifespan of the surface
- dust, road metal
- noise pollution (> 90 dB)
- emission of combustion gasses
- emission of iron grit
- in situations with substantial weed growth after the brushing the weeds have to be swept together and removed by the cleansing department.

Mowing

Mowing is esp. used as an additional measure to other control methods. It has the advantage that it can be used at places that can not be reached by other non-chemical methods, e.g. around obstacles and on traffic dividers. It can be used in situations with moderate to heavy weed infestation.

Physical methods

Burning

Next in line to brushing is the use of burning apparatus. There are two types of burning apparatus: so-called infrared and flame weeders. Burning can only be applied on small weeds and maximum 30% of the joints with weed growth. After treatment it takes approximately 14 days before the weeds disappear. It can be used at all types of hard surfaces (regardless their condition) except asphalt (risk of melting).

The method has some drawbacks, comparable to brushing:
- noise pollution (80-90 dB)
- emission of combustion gasses (much higher compared to brushing)
- flammable

Hot water apparatus

There are two types of hot water apparatus available, the so-called Waipuna machine and the Weed-cleaner. Both machines are mistakenly called steam apparatus. However, the methods use hot water (approximately 94 ˚C) instead of steam (100 ˚C) to control weeds.

When in contact with hot water, the weeds wilt immediately and eventually dehydrate. As with the other non-chemical methods only the above ground parts of the weed are controlled. Re-growth occurs within weeks, depending on the environmental circumstances during and after application. Dry, sunny weather improves the result.

The Weedcleaner has only be applied experimentally. Major drawback of this machine is its weight (not always compatible with the hard surface). Besides it has a fixed width of 1 m, using a so-called steam beam.

The Waipuna-machine has several advantages: little noise, can be used on all surfaces, can be used around obstacles. The hot water is applied with two mouth pieces comparable to a hoover (vacuum cleaner) thus being very manoeuvrable.

Disadvantages from an environmental point of view are the enormous amount of diesel and water to be used.

Herbicides

Till June 1999 the preventive application of diuron was by far the most frequently used herbicide for weed control on hard surfaces. Since diuron could not meet the environmental criteria for registration this product was forbidden. Only very few other products - all for curative application - are beginning 2001 registered for use on hard surfaces, namely: glyphosate (a.o. Roundup evolution, Roundup Dry), glyphosate-trimesium (Touchdown), glufosinate-ammonium (Finale SL 14), fatty acids (TopGun), dichlobenil (a.o. Casoron G), amitrol (a.o. Weedazol) and 2,4-D (several products).

In practice esp. glyphosate is used. More information about glyphosate and its application is written down in chapter 6 and 7.

In general it can be said that the application of herbicides is relatively easy. There are no restrictions with respect to the type of hard surface, situation or presence of obstacles etc. Both small and heavy weed growth can be controlled. Another major advantage of the use of glyphosate is that it acts both upon the above ground and under ground parts of the plant, thus providing a long lasting effect. Herbicides can also be applied in situations where methods with risk of flammability can not be used (e.g. around industrial plants).

A major drawback of the use of herbicides is their risk for contamination of esp. surface water due to run-off. This is illustrated by a recent survey carried out by the Drinking Water Company WHZ in the 'Bommelerwaard' that showed that 75% of the surface water pollution with pesticides originated from 1% of the total use of herbicides in the area, namely the use of herbicides on hard surfaces (Merkelbach et al., 1999).

People that professionally apply herbicides must have a Spraying-certificate.

Others

The above described methods are the major methods available and used in practise. In addition several other methods are experimentally tested. For example the use of a sandblaster: high pressure application of a mixture of water, air and lime + sand. Also some municipalities experiment with the application of salt (either dry or in water solution). Research is carried out to investigate the possibilities of very high-pressure water application and microwave radiation.

In annex 1 the relevant aspects of the most important control methods are summarised.

In general it is agreed upon that the use of herbicides (esp. glyphosate) is the most effective method. It provides long lasting control, esp. when compared to non-chemical control methods. The application of herbicides is relatively easy. Besides, the application of herbicides can be used for all types of hard surface and all thinkable situations (regardless the number and type of obstacles).

Next in line is brushing. This method is generally more effective compared to burning. However a major drawback of the method is that it cannot be used on semi hard surfaces, traffic dividers etc. Usually with chemical control two applications (one early in the season, one in August /September) are sufficient. When brushing, at least two to three rounds are necessary. With burning at least 4 rounds have to be made. In practise often a combination of several methods is applied.

Restraint with regard to the use of non-chemical methods is especially due to the lesser efficacy -non-chemical control generally results in a greener surrounding - the need to put in much more labour (at least 2-3 times higher compared to chemical control) and the much higher costs. Also municipalities reluctant to switch from chemical to non-chemical control argue that non-chemical control methods also have major environmental drawbacks (esp. emission of combustion gasses).

2.7 Costs and productivity

The costs of the above-mentioned methods differ greatly from one method to another. For the greater part this is due to enormous differences in productivity (expressed as number of m² treated per hour, see Table 2.7).

In general non-chemical methods demand 3-5 times as much labour compared to the application of glyphosate which is also illustrated when comparing costs (see Table 2.7).

Table 2.7. Productivity and costs of different weed control methods (IMAG normenboek, 2001).

Method	m² / hour*	costs / m² *
Brushing	430 - 1500 m²	ƒ0,07 - ƒ0,25 + ƒ0,10 (sweeping + transport)
Mowing (brushcutter)	270 - 1000 m²	ƒ0,06 - ƒ0,22
Burning (flame weeder)	300 - 860 m²	ƒ0,06 - ƒ0,16
Hot water	110 - 450 m²	ƒ0,38 - ƒ1,51
Herbicides (SelectSpray, 1.20 m)	2300 - 4600 m²	ƒ0,03 - ƒ0,06

* *depending on weed situation, type of hard surface and presence of obstacles.*

2.8 Institutions and actors involved

- Users: inhabitants, companies, institutes, social groupings.
- Administrators: city councils, county and state authorities
- Managers: administrators of hard surfaces (a.o. municipalities, Rijkswaterstaat, Provinciale Waterstaten, recreatieschappen, Staatsbosbeheer, cemetery keepers), people and authorities that are in charge of research, design and information.
- Executors: municipal departments ('Public Green' Department, Cleansing Department), contractors.

2.9 Description of current sources of information

There are several sources of information that contribute to the spread of knowledge of weed management on hard surfaces. These sources can be divided in written and oral information sources. Written information sources are journals and manuals, oral sources are meetings, workshops, and contacts with colleagues (network).

Journals

- Tuin & Landschap: two weekly edition. Most important journal with regard to weed management on hard surfaces. Target group: esp. horticulturists.
- Tuin en Park Techniek
- Afvalmanagement
- H2O

Manuals

- *Groenwerk. Deel 3. Onkruid op verhardingen. Praktijkboek voor bos, natuur en stedelijk groen. 1998. IBN-DLO, IPC Groene Ruimte, IKC Natuurbeheer en Misset. 158 pp.*
  Complete manual on weed management practices and available weed control methods.
  Gif van de Straat. Reductieprogramma chemische onkruidbestrijding op verhardingen. 1997. IBN-DLO, VEWIN en gemeente Eindhoven. 64 pp.
- *Gif van de Straat. 1997.*
  Publication of the results of the research project 'Reduction program for chemical weed control on hard surfaces'. This project was carried out in the period 1994-1996 in the city of Eindhoven. The publication provides municipalities a guideline how to switch to non-chemical weed management on hard surfaces with emphasis on the organisational aspects.
- *Ontwerpvoorbeelden onkruidwerende verhardingen, ideeënboek voor constructies van elementverhardingen die weinig kruidengroei toelaten. CROW. Publication 119. 1997.*
  This publication is esp. meant for administrators and designers of (semi-) hard surfaces. It contains ideas concerning the design and construction of (semi-) hard surfaces (including obstacles) in such a way that weed infestation can be prevented and limited.

Meetings / conferences

- Every year the VHG (Dutch organization for horticulturists) organises a meeting for their members. During the last couple of years weed control on hard surfaces (and related subjects) was repeatedly part of the program.

- Occasional meetings. During the last three years several meetings were organised by provincial governmental bodies for municipalities to stimulate the exchange of information and discussion on the subject. The provincial governments provide regional programs to stimulate the reduction of pesticide use.

Network

Probably the most important source of information is the exchange between colleagues for example between neighbour municipalities.

Information service

There are several commercial consultant agencies in this particular field. However, esp. municipalities indicate that they experience a lack of an independent information service to be questioned for advice about weed management practises.

3. Decision Support Systems

In this chapter the use of Decision Support Systems (DSS) related to the objectives of the project is specified.

A decision support system (DSS) can support to achieve several objectives:
1. to support the application of non-chemical methods where possible. Key aspects are availability of non-chemical methods in relation to hard surfaces and objects, and cost-effectiveness.
2. to exclude application in critical situations regarding emission of glyphosate and its metabolite AMPA to surface water. Important aspects of such a DSS are application technique, environmental conditions, type of hard surfaces and objects to be treated.
3. to optimise the amount of glyphosate that is used in order to get maximal effect with minimum amount of herbicide. Such a DSS is directly related to weed species, weed growth (stage), acceptability of weed growth, environmental conditions and application technique to ensure the availability of effective weed control systems on hard surfaces.

Two types of DSS are distinguished in this startdocument, in the first place an object-oriented DSS and in the second place an application oriented DSS.

3.1 Object oriented DSS

Based on the location, functionality and acceptance of weed, a control method is chosen. Often this will result in an integrated approach, using several control methods. Starting-point of an object oriented DSS is that there will be no application of pesticides at locations that are critical in relation to achievement of standards of acceptable level of herbicides in surface water.

Relevant aspects in such a DSS are: critical situations with regard to run off of herbicides, type of location, type of hard surface, objects, function of the location, weed infestation that is present, weed infestation that is acceptable. An object-based DSS can be formulated into a rather simple arrow-diagram.

When the application of chemicals is the best alternative in addition to the object-based DSS one uses the application oriented DSS.

3.2 Application oriented DSS

When it is decided upon that application of herbicides is the best control method, a DSS in order to optimise (= minimise) dose rates of herbicide can be used.

Relevant aspects are: weed infestation that is present (weed species, weed growth stage), environment (T, r.h., rain), application technique, additives, acceptable level of weed infestation. The dose is determined on the basis of several balance factors.

In this startdocument the application oriented DSS is solely worked out for the herbicide glyphosate. In future - depending on the registration of new herbicide products - the DSS can also be adapted to other type of products, e.g. soil herbicides.

In the next chapters a description is given of the critical situations regarding emission of glyphosate to surface water (chapter 4) and the key subjects that have to be part of an object-oriented DSS (chapter 5) and an application oriented DSS (chapter 6).

4. Critical situations regarding emission of glyphosate to surface water

4.1 Introduction

Herbicide run off takes place with the first rainfall event after the herbicide has been applied. In the first millimetre of water flowing into the gully pot of the rainwater sewer up to 30% of the applied mass may enter the sewage system (Shepherd and Heather, 1999). After the first millimetre the mass running off with rainwater decreases in time. When the rainwater sewer drains directly to surface water, the aquatic ecosystem may be harmed because of the peak input of the herbicide. The total mass of glyphosate running off may lead to increased concentrations in rivers from which water is used for drinking water production. Purification of water may be needed. The critical situations discussed in this chapter are in the perspective of the risk that use of glyphosate poses for drinking water production.

The entry of glyphosate via spray drift is not considered. Glyphosate is not volatile. Hence volatilisation of glyphosate will not decrease the amount present on the hard surface after the application.

Critical situations affecting runoff of glyphosate to surface waters can be divided in three categories:

a) type of hard surface, hence the object scale,
b) type of urban drainage system, hence the scale at which an urban area is managed,
c) time of application.

4.2 Type of hard surface

The type of hard surface determines run off at the object scale. After the treatment with glyphosate, at the start of the first rain shower, the hard surface takes up water, dissolving and taking along the glyphosate lying on the top of the hard surface into the hard surface material. When the hard surface material is saturated with water, glyphosate starts diffusing upwards to water flowing over the hard surface. Infiltration takes place simultaneously with runoff. Water with herbicide infiltrates between the joints to the soil below. Water flowing over the surface to the gully pot of the sewage system infiltrates partly during its travel.

Glyphosate run off decreases when the uptake of water and glyphosate by the hard surface material increases. The extent of water uptake is determined by:

- porosity of the hard surface material
- age of the pavement; the porosity decreases by ageing
- slope of the pavement; the uptake of water is maximal for a flat pavement

Glyphosate run off decreases when the infiltration between the stones increases. The infiltration between stones is determined by:

- total area of the joints per surface area
- age of the pavement; new pavements provide a maximal infiltration capacity because joints have not been filled up yet with soil material
- distance to the gully pot; the larger the distance the larger the possibility of infiltration
- infiltration capacity of the type of hard surface; semi-hard surfaces and modern pavements that allow maximal infiltration can infiltrate 100% of the precipitation

Objects with large stones and therefore few joints between the stones have ample possibilities for water to infiltrate to the soil below. These objects will show higher glyphosate run off rates. Semi- hard surfaces like gravel paths don't show run off (except extreme situations), because the rain infiltrates into the soil.

4.3 Type of urban drainage system

The type of urban drainage system determines pesticide emissions at the scale at which an urban area is managed, hence mostly the city. The urban drainage system is the sewage system, which can be a separated sewage system in which the precipitation is discharged directly to the receiving water by storm drains, while the wastewater is discharged to the sewage treatment plant. In a combined sewer system precipitation and wastewater are collected in one system with limited capacity and transported to the treatment plant; the surplus is discharged as combined sewer overflow. In the Netherlands 25% of the urban areas has a separated sewer system and 72% has a combined sewer system.

Emissions from an urban area are determined by the runoff that enters the sewage system from the objects in the area, and by the processes in the sewage system (dissipation and adsorption) that affect the glyphosate before it leaves the urban drainage system. The emission from the urban drainage system related to the use of glyphosate on hard surfaces is determined by:

- area of the hard surfaces on which glyphosate is applied
- separated sewer system or combined sewer system; glyphosate (that adsorbs strongly to soil) may adsorb to suspended material in the wastewater treatment plant. The suspended material settles and is removed from the plant. Then, glyphosate and its metabolites are not transferred to surface waters. Hence a combined sewer system will probably give less glyphosate emissions from urban areas.

4.4 Time of application

Type of hard surface

- the moisture content of the hard surface at the time of application affects runoff: wet surfaces accelerate run off when it starts raining soon after the treatment
- the period between application and the first rain shower can affect glyphosate runoff. For concrete glyphosate run off decreases with increasing period (Shepherd and Heather, 1999). In the Netherlands, concrete bricks are mostly used for pavements and parking lots. For asphalt the period between application and the rain shower does not affect run off (Shepherd and Heather, 1999).
- application on hard surfaces shortly before small rain showers (drizzle), that do not lead to runoff of rain water, will also not lead to glyphosate runoff

Type of urban drainage system

- for areas with combined sewer systems in periods that surpluses are the least likely to occur the emission from the urban drainage system via overflow is minimal. Glyphosate then skips less frequently the wastewater treatment plant.
- in summer the emission of glyphosate will be less than in spring and autumn, because transformation of glyphosate (and AMPA) during transport in the urban drainage system decreases the amount. The transformation rate of pesticides increases with increasing temperatures. In summer the temperatures are higher than in spring and autumn.
- in spring and summer the emission of glyphosate will be less than in autumn, because in spring and summer the number of precipitation events is less than in autumn. The residence time of water in the urban drainage system increases with decreasing precipitation amounts. With increasing residence time of glyphosate in the sewer system the amount of glyphosate decreases by transformation.

Some examples of worst cases for emission of glyphosate are:

- on strong sloping pavement made of material with a low porosity
- on pavements made out of large tiles, hence a small surface area of joints
- on a hard surface that is wet.

5. Key subjects that have to be part of an object-oriented DSS

In this chapter the subjects that should be part of an object-based decision support system will be discussed, starting with a classification of the different hard surfaces that can be distinguished.

5.1 Type of hard surfaces

The type of hard surfaces is a key factor in an object-oriented DSS. On the one hand the type of hard surface is of major importance to the level of weed infestation that can be expected. And on the other hand, the type of hard surface imposes restrictions to the number of control methods that can be applied (see § 2.6). And last but not least as described in chapter 4 the type of hard surface determines the amount of pesticide run-off that can be expected.
The hard surfaces that generally occur in the public area can be divided in three categories:

Category I

- Hard surfaces - closed
  - asphalt
  - concrete
  - ZOAB

  Asphalt is esp. used for streets. Occasionally it is used for shoulders (e.g. in the city of Veenendaal) or side walks (combined with chippings, e.g. city of Vorden). Concrete is a type of hard surface with low aesthetic value, esp. used in industrial areas.
  ZOAB (Zeer Open Asfalt Beton) is used on Dutch highways.

Category II

- Hard surfaces - open (with joints)
  - paving stones, ornamental paving
  - tiles

  Category II is the most commonly applied hard surface in municipalities. The same applies to private properties of citizens (driveways etc.). There is a great variety in paving-stones and tiles, differing form very small ornamental paving (10 x 10 cm^2) to the commonly used tiles on sidewalks (30 x 30 cm^2), bricks on the street (20 x 10 cm^2) to very large stones (e.g. 60 x 40 cm^2), hexagonal stones etc.

Category III

- Semi hard surfaces, e.g. shells, gravel
  This type of hard surface is esp. used for shoulders, footpaths and bikeways.

5.1.1 Type of hard surface related to weed infestation

The level of weed infestation differs greatly from one type of hard surface to another. In general the category I type of hard surfaces has very little problems with weeds. The only exception being the hard shoulders of ZOAB highways were due to accumulation of sand and dirt combined with very low traffic intensity in the middle of the hard shoulder a one meter band of weed growth can occur.

The category II type of hard surface is much more liable to weed infestation. Weed infestation on this type of hard surface depends on intensity of use and length and width of interspaces / joints. The less it is walked or driven on, the more likely weed growth will occur.

Large (wide) interspaces favour weed growth. The same accounts for the length of joints per m². This is influenced by the type of paving stone that is used. The use of small paving stones provide much more joints compared to larger stones as is illustrated in Table 5.1.1.

On semi hard surfaces - category III - weed infestation very generally occurs. The surface provides an excellent growing medium for weeds. Again the level of weed growth depends on the intensity of use of the paving. Shoulders are never walked on, thus they are always liable to development of weeds. For bikeways and footpaths it depends on how often they are frequented.

Table 5.1.1. Length of joints of some commonly used paving-stones.

element type - dimensions		surface per stone	# stones per m²	length of joints / m²	reduction % of joint surface compared to bricks
brick -	20 x 10 cm²	200 cm²	50	1700 cm	standard
ornamental stone -	10 x 10 cm²	100 cm²	100	2200 cm	29% increase
tile -	30 x 30 cm²	900 cm²	11	800 cm	53%
tile -	60 x 40 cm²	2400 cm²	4	500 cm	71%

For both category II and III it is important to take into account the adjacent vegetation to the (semi-) hard surface. Generally it is observed that grass vegetation next to (semi-) hard surface spreads very easily to the hard surface. In this respect it is important to stress the importance of regular maintenance (cut-off) of the grass.

5.1.2 Type of hard surface related to weed control methods that can be used

In §2.6 an overview is given of the weed control methods that are currently available for weed control on (semi-) hard surfaces. Also restrictions with regard to use on different types of hard surface were mentioned. In general brushing can not be applied on semi hard surfaces. Besides it causes wear off of hard surfaces, thus decreasing the lifespan of the hard surface. Burning cannot be applied on asphalt and ZOAB (danger of melting). The other methods do not have any restrictions with regard to the type of hard surface. Mowing is not a full alternative, it is used in addition to other methods. In Table 5.1.2 an overview is given of the available control methods in relation to their applicability to different hard surfaces.

Tabel 5.1.2. The applicability of available control methods to different types of hard surface.

category hard surface	mechanical brushing	mechanical mowing*	physical burning	physical hot water	chemical herbicides
category I – asphalt, concrete, ZOAB	x	x	x / -	x	x
category II – paving-stones	x	x	x	x	x
category III - gravel, shells etc.	-	x	x	x	x

* *additional method*

5.1.3 Type of hard surface related to run-off of pesticides

In chapter 4 this subject is elucidated. It was concluded that the use of pesticides on semi hard surfaces does not show run-off of pesticides, thus application of pesticides on semi hard surfaces does not impose any danger with regard to pollution of surface water.

Also there is a clear relationship between the presence of organic material on hard surface and run-off: the more joints, the less run-off. On hard surfaces with many (wide) joints more sorption occurs, thus leading to reduced run-off. Therefore hard surfaces that consist of small elements (e.g. ornamental paving) impose less problems to surface water compared to hard surfaces with large paving stones (or concrete).

The application of pesticides near gully pots should always be avoided. It should be common practice that at least gutters are brushed instead of treated with a pesticide.

5.2 Different objects and locations

Not only the type of hard surface limits the applicability of the available methods, also different objects or locations pose restrictions. E.g. not all machinery can reach weeds that grow near obstacles (e.g. around benches, traffic signs). The same accounts for shoulders. Also weed management in industrial areas makes demands on the methods to be used.

Table 5.2. Some examples of specification of applicability of control methods towards objects and locations.

Object / location	Mechanical brushing	Mechanical mowing*	Physical burning	Physical hot water	Chemical herbicides
Shoulders	-	x	x / -	x	x
Danger from fire (e.g. industrial areas)	-	-	-	x	x
Semi hard surfaces	-	x/-	x	x	x
Around obstacles	x / -	x	-	x	x

* *brushcutter*

5.3 Efficacy with regard to weed control

In § 2.6 some remarks were made as to the efficacy of the different methods for weed control. In this paragraph an attempt is made to relate the efficacy of the different methods to the picture quality classes as distinguished in § 2.5.

Table 5.3. Efficacy of available control methods related to weed picture quality classes.

Picture picture quality class (base level of weed infestation)	Mechanical brushing	Mechanical mowing*	Physical burning	Physical hot water	Chemical herbicides
class I – no weeds	x	-	-	-	-
class II – in places, no patches	xx	-	xx	xx	xx
class III – weed growth in many joints, in places patches	xx	x	x	x	xx
class IV – heavy weed growth and patches	x	xx	-	x	xx
class V – heavy weed growth and patches, including woody weeds	x / -	xx	-	-	xx

5.4 Organisation and use of an object oriented DSS

All subjects that are part of an object-based decision support system, as described in this chapter, can be arranged in a decision tree, either for use in a computer programme or an arrow-diagram. A first draft of such a diagram is shown in Figure 5.4. There are several ways in which a DSS can be used.

Voluntary use of an object oriented DSS

On a voluntary base a DSS can be used as an instrument to provide administrators and contractors with information about different aspects of weed prevention and weed control methods. Its use can support them in their choice as to what is the best control method or mix of control methods for their specific situation. The use of a DSS will contribute to awareness of different aspects that should be taken into account with regard to weed management (not only effectiveness in relation to type of hard surface, but also in relation to desirable weed picture class quality, and environmental aspects).

Documented Justification System

A documented justification system combines a voluntary use of a DSS with an obliged documentation system for the use of herbicides. A documented justification system includes an exact registration of pesticides used, e.g. what pesticide, what amount, time of application, justification of use (e.g. in relation to weather, weed situation). Only organisations that document their pesticide use according to this system will be allowed to purchase (a restricited amount of) pesticides.

Compulsory use of an object oriented DSS

At the beginning of the project one particular use of an object oriented DSS has been proposed, based on a combination of:

a) a management plan for hard surfaces to be provided by administrators and
b) purchase restrictions - only a limited maximum amount of pesticide to be purchased each year, depending on the number of ha of certain hard surfaces present in the municipality concerned.

In this specific situation the draft of a management plan would be a requisite in order to be allowed to buy and apply herbicides. The DSS can be used as an instrument to draw up such a plan.
Demands of a management plan could be:

- exact number (m^2) of hard surfaces, classified according to the three categories as distinguished in § 5.1
- description of level of weed infestation that is aimed at for different locations
- specification of objects and locations where only herbicides can be applied (see § 5.2)
- plan with regard to integrated approach (combination of (several) control methods), drafted with the use of the DSS.
- long-term plan for reconstruction of hard surfaces considering weed management (removing non functional hard surfaces, use of specific paving material etc.).

People involved

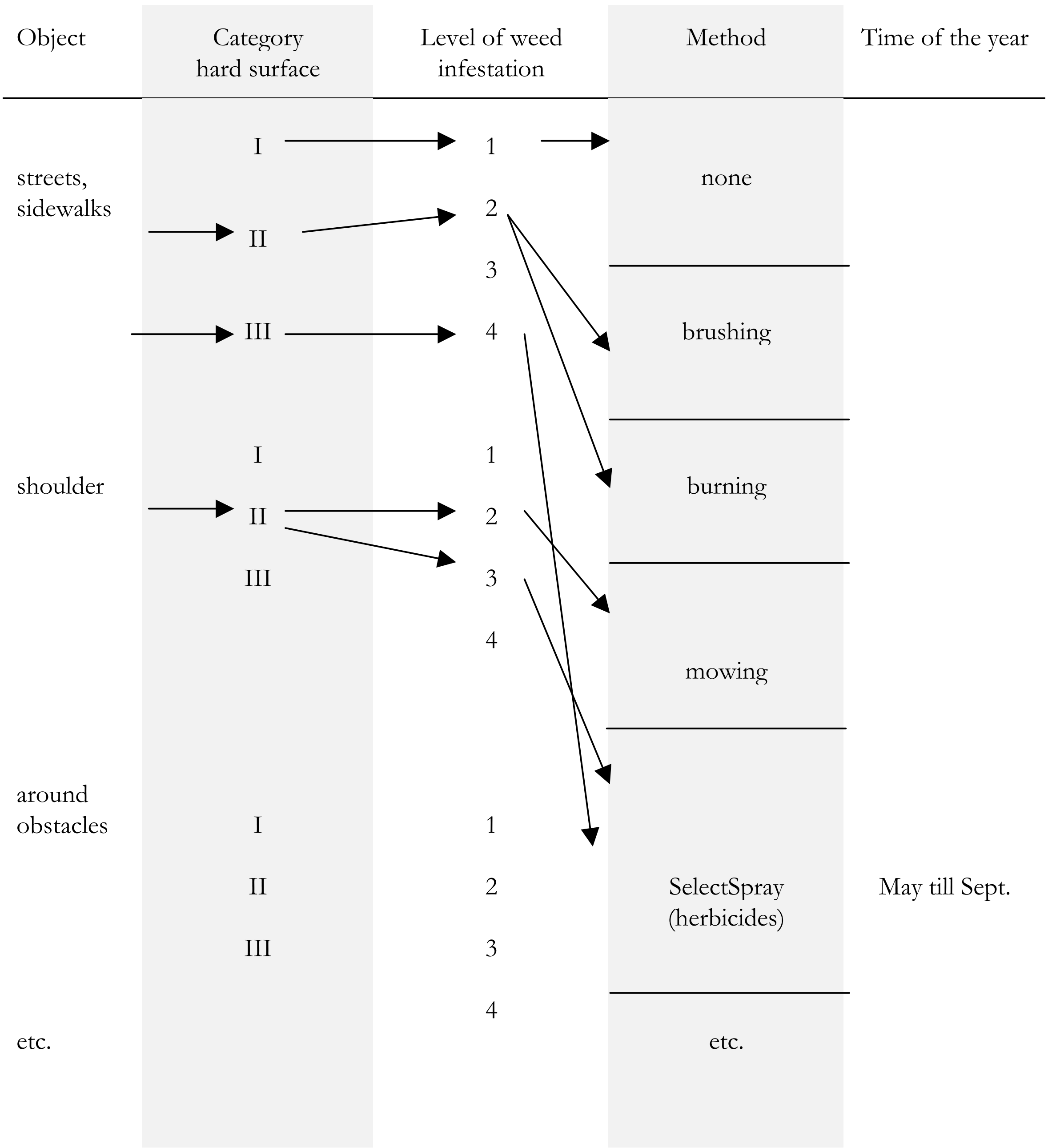
In this section a first start is made to describe in what way a compulsory use of a DSS could be organised and what people would be involved (at municipality level).

Strategic level: the City Council decides upon the draft of a management plan and the use of the DSS. The City Council allocates budget for weed management on hard surfaces.

Tactic level: the City Council assigns policy officials to make a draft of a management plan (in close co-operation with the officials that are in charge of implementation). Subsequently the plan has to be authorised by the administrators before it can be put into action.

Operational level: officials that are in charge of carrying out the weed management contact the contractor(s). With an authorized management plan they (or the contractor?) can buy (a restricted amount of) herbicide. At the end of the season the weed management practise is evaluated.

Figure 5.4. Example of an arrow-diagram DSS (draft)



I	= hard surfaces - closed	1	= no weeds
II	= hard surfaces - open	2	= weeds in places, no patches
III	= semi hard surfaces	3	= weed growth in many joints, in places patches
		4	= heavy weed growth and patches

6. Glyphosate - application aspects

Introduction

Glyphosate is a post-emergence non-selective herbicide which normally enters plants through the aerial, usually chlorophyll-containing parts (= the foliage). Since the shoot is, in practice, the only portal entry of glyphosate, its development, as judged by the number of leaves, their area, angle, surface characteristics and physiological condition, is of key importance in relation to interception, retention, penetration, activity, and eventually, efficacy (see Figure 1). Relevant application aspects determining efficacy of glyphosate are discussed hereafter.

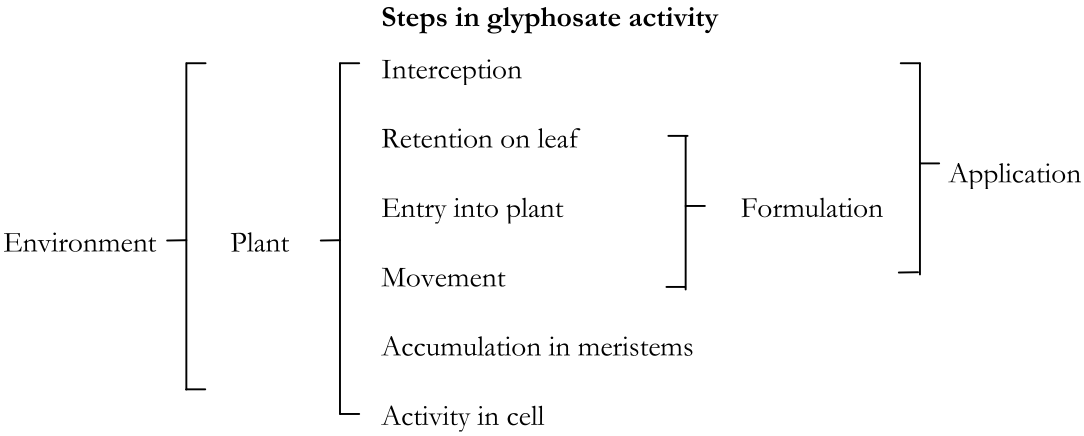


Figure 1. Factors affecting the steps involved in glyphosate activity (after Grossbard & Atkinson, 1985)

Weed species

Though being a non-selective herbicide, weed species differ in sensitivity for glyphosate. It is indicated at the label that the dose of glyphosate depends on the weed species present. Dose recommendations for Roundup and Roundup Evolution are given for three categories of weeds and swath treatment, in order of decreasing sensitivity:

- *annual weeds*, 2-4 l Roundup/ha,
- *perennial grasses*, 3-4 l Roundup/ha,
- *perennial broad leaf weeds*, 4-6 l Roundup/ha.

Relative sensitivity of individual weed species is indicated in annex III.

Weed developmental stage

In addition to a species effect, sensitivity for glyphosate is also affected by plant development stage. It is well established for perennial grasses that a minimum amount of foliage is required for satisfactory control. For broad leaf species, the plant development stage effect is less obvious.

Grasses at an early stage of development tend to have erect laminae which present a small rectangularly projected area for spray interception. From tillering, a more prostrate habit develops and the inner surfaces of leaf sheaths are often exposed where entry and subsequent movement of glyphosate proceed more effectively. Thus, retention and entry may be enhanced at these later growing stages.

Application technique

Label recommendations for the dose of glyphosate are given for swath and spot application (see fact sheet). For swath application by means of multiple nozzles mounted on sprayer vehicle, the recommended dose is weed species dependent (2 to 6 l Roundup/ha). For spot application by means of knapsack sprayer or wipers, a species-independent dose of resp. 2% and 33% Roundup in water is recommended.

Today, weed sensing spray techniques are available that allow spot treatment within swath application. Examples are Weed IT® and SelectSpray®. These modern techniques allow a substantial reduction (> 50%) in spray volume and consequently, use of glyphosate (Kempenaar et al., 2000).

In addition to the application technique the water volume and droplet size (nozzle) influence to a large extent the efficacy. Best results are obtained with 200 l water/ha combined with coarse droplets.

Formulation and additives

The efficacy of a herbicide can be increased by additives. A large number of additives - esp. surfactants - are marketed today, differing e.g. mode of action. Some additives affect retention, others affect uptake or rain persistence. Optimal use of additives in relation to glyphosate is weed and weather situation dependent. A practical, up to date overview on additives in relation to glyphosate was not found. However, a literature search on this topic yielded a large number of publications on additives (see e.g. DLV-publications).

Weather conditions

Weather conditions will affect the efficacy of a herbicide. Important underlying aspects of weather that determine herbicide efficacy are temperature, wind, radiation, relative humidity and rain. They can either directly or indirectly affect the processes indicated in Figure 1 in both positive or negative ways. The best way to deal with this complex issue is to focus on key weather aspects and how they affect glyphosate efficacy. The table below summarises how these key factors affect efficacy of glyphosate against Couch grass.

Table 6. Individual environmental factors leading to maximum control of couch grass Elymus (Agropyron, Elytrigia) repens *with glyphosate (Grossbard, E. & D. Atkinson, 1985).*

Period and duration of factor	Pre-application period Long-term	Pre-application period Short-term	Time of application	Post-application period Short-term	Post-application period Long-term
Light	low**	low*	--	high**	--
Temperature	low**	high**	--	medium**	low**
Humidity	--	high*	--	high***	--
Rain	--	0.5 mm*	< 0.5 mm***	0.5 mm***	--
Soil moisture	medium*	medium***	medium***	medium***	--
Wind	--	--	< 12 km h^{-1}***	--	--

*relative importance of factor: * (least) to *** (most).*

- Temperature

In general, absorption and translocation of foliage-applied herbicides increase with a rise in temperature. This is due to effects on the rate of diffusion through the plant cuticle, increased rates of transpiration and subsequent apoplastic movement, and an increase in the general metabolic activity of the plant providing suitable energy sources for the active loading assimilates in the translocation stream. Efficient translocation of assimilates is probably essential for the optimum translocation of phloem-mobile herbicides such as glyphosate. At constant relative humidity (r.h.), temperature directly influences the rate of spray droplet drying on the plant surface. In this way, glyphosate absorption may be restricted under warm dry conditions since it is thought that water-soluble herbicides need to be in solution to be efficiently absorbed. T will also influence the rate of herbicide metabolism within the plant. Again, in general, a rise in T usually results in increased metabolism. Thus, the final effect of T on herbicide performance will be a result of this complex interplay of all the factors outlined above.

- Relative humidity

There is a close interaction between T and relative humidity with regard to their effect on glyphosate entry, movement and performance.

- Rain

Rain and dew are conductive to a fully hydrated cuticle and to water-soluble compounds such as glyphosate being in solution. Both these situations favour penetration of water-soluble herbicides. Rainfall can wash glyphosate from plant surfaces for as much as 4-6 h after treatment, reducing the effect.

- Optimal growth conditions

Treating weeds under poor growing conditions such as drought stress, disease or insect damage may reduce the effectiveness of the herbicide. Reduced results may also occur when treating weeds heavily covered with dust such as along roadsides.

Decision support

Knowledge on effects of weather conditions is summarised in Decision Support Systems such as Gewis ® (marketed in NL). This computer programme takes into consideration important weather conditions and how they may affect efficacy of pesticides. A recommendation on optimal use of the pesticides is generated on the basis of actual weather conditions.

7. Key factors that have to be part of an application oriented DSS

Introduction

In chapter 6, aspects of application of glyphosate were discussed. In this chapter, these aspects are reconsidered for incorporation in a Decision Support System (DSS) for minimisation of use of glyphosate on hard surfaces. The focus is on swath application, preferably in combination with a weed sensing technique for spot application within swaths. Ideas are presented rather than a detailed description for the DSS. Starting point is that the DSS should help the person that prepares the tank mix with herbicides. Time window of the DSS is half a day to maximum one day.

Weed species

Weed species present on the surface to be treated probably affect the required dose the most. Therefore, an observation of weed species present should be the start in determining the minimum required dose. A table that relates dose to weed species present should be prepared with more a bit more detail than the one that is given on the label:

- annual weeds : 2-4 l/ha
- perennial grasses: 3-4 l/ha
- perennial broad leaf weeds: 4-6 l/ha

Weed development stage

After a principle dose is selected, this dose can be decreased or increased on the basis of weed development stage. The range of possible decrease or increase is circa 1 l/ha when viewing experimental data. The effective dose for broad leaf weed is development stage dependent. E.g. when only small broad leaf weeds are present, 1 l Roundup Pro per ha can be effective. The effective dose for grasses is less dependent on development stage.

Application technique

It is a matter of discussion whether application technique should be accounted for in the DSS. Standard practice should be the use of modern application techniques for swath treatment of hard surfaces. Such techniques produce optimal spray deposition patterns.

Formulation and additives

Effects of formulation and additives can be handled in a similar way as weed development stage. Information on the relative effective dose of different formulations and additives should be developed. They are the basis for a decrease or increase of the principle dose. The range of possible increase or decrease is circa 1 l/ha.

Weather conditions

Weather before, during and after application will affect the required dose. Weather is a very complex aspect. The easiest way to deal with weather effects on glyphosate is to use the Gewis programme (see chapter 6). This programme produces information on adverse application moments and on the level by which a dose can be increased or decreased (-25% till +25%)

End result

The level of control to be achieved can be considered in relation to dose. When less than 100% control is acceptable, the dose can be reduced. This could be the case when already has been decided to treat two times in a season. However, little information on long term effects of such systems are available.

DSS for minimisation of use of glyphosate on hard surfaces

The aforementioned data can be accounted for in a table as indicated below. By viewing the different application aspects, the user can calculate the minimum required dose. It is questionable of costs and environmental effects should also be considered in the DSS. At present it is focussed on how to determine the minimum effective dose, similar to the MLHD approach used in agriculture.

Table. *DSS for dose calculation of Roundup and Round Evolution swath application.*

Application aspect/dose determining factor	Points (l/ha)
Weed	
Klasse gevoeligheid soorten	(2, 4 of 6 l/ha)
Onkruidgrootte	(-1, 0 of 1 l/ha)
Application technique	(? -1, -0.5, 0, 0.5, 1 l/ha)
Formulation and additives	(-1, -0.5, 0, 0.5, 1 l/ha)
Weather conditions	(-1, -0.5, 0, 0.5, 1 l/ha)
Temperature	
Relative humidity	
Rain	
Picture class quality / end result	(? -1, -0.5, 0, 0.5, 1 l/ha)
Total (dose glyphosate 360 g/l)	

8. Certification systems

8.1 Introduction

In this chapter the following subjects are discussed:

- Description of the possible use of the instrument certification
- Specification of conditions when certification can be a powerful instrument
- Options for certification related to DSS for weed control on hard surfaces
- Analysis of the effects of certification
- Recommendations for framework / certification strategy

8.2 Description of the possible use of the instrument certification

A certificate is comparable to an assessment of skills according to well-defined standards. The concepts 'certificate' and 'certification' are not protected. Everybody is allowed to deliver certificates: schools, swimming courses etc.

However a well-developed legally recognised certification system (recognised by the National Council for Accreditation) is based on the following principles:
- all relevant actors are convinced of the benefit of certification and have agreed on the quality level of the requirements;
- the certification is done by an independent and qualified certification body who is responsible for the inspection of the specified requirements/ claims (third party certification);
- there is a possibility of appeal against decisions made by the certification body.

The basic quality level in every certification scheme is the legal standard. Certification plays an important role in the arrangements between producers/suppliers and customers/buyers. It gives reliable information on the quality of for instance products and makes it possible to distinguish quality levels.

All things that can be defined in terms of (mutually agreed upon) quality levels can be certified: products, processes, services, systems and designs.

Quality is defined as the level of correspondence of a product, process or system to the defined requirements. Quality is never 'good or bad' but adequate or inadequate in accordance with specified standards. Quality is a relative concept! Therefore the fact that something is certified does not say anything on the quality level to which it corresponds: this quality level depends completely on the definition of the requirements in the certification scheme.

Certification bodies can be considered as mediators in quality agreements.

Accreditation

Accreditation of certification bodies in the Netherlands is on a voluntary basis. However in certain situations the government can make accreditation a prerequisite for organisations if they want to be appointed for specific inspection tasks.

(Inter)national accreditation of certification bodies is based on the standards of the EN-45000 series. The EN 45000 series is one of the internationally recognised (accredited) certification systems. Other examples of international systems are for example ISO-14000 for environmental quality, ISO-9000 for quality care and HACCP for food safety.

Accreditation of a certification system has its own quality requirements, for instance:

- standards are set by an independent board of 'experts' including all relevant interest groups and independent experts;
- certification is done by an accredited certification body
- there is a possibility of appeal;
- the system is recognised by the Accreditation Council.

Types of certification

The most relevant types of certification for the project are:

- Product certification: the product fulfils the requirement of the standards in the certification-scheme (example: eco-labelling for shoes, garden furniture, food etc.);
- Process: certification of a process or service and specification of end product (example: making of liquid proof floors in gas filling stations);
- Quality system: defines procedures and responsibilities, its focus is on the management system but it does not give insight in the quality level of the product (example: ISO 9000 and 14001).

8.3 Delimitation of conditions when certification can be a powerful instrument

Certification is used in an atmosphere where there is a need, both at the producer level and at the 'customer' level, for guaranteed well-defined requirements for quality and quality control.

Most relevant general conditions for certification are:

1. Certification is a voluntary instrument, there is a demand for and a stimulus related to certification
2. Quality requirements are measurable and rules/ procedures are unequivocal defined
3. The requirements are feasible, cost effective and reliable
4. Auditing and inspection are possible and cost-effective.

8.4 Options for certification related to Decision Support Systems for weed control on hard surfaces

The objectives of certification of DSS are to guarantee the adequate use of the DSS in order to:

- ensure the availability of effective weed control on hard surfaces;
- stimulate rational use of herbicides, that is minimised use and minimal environmental and other negative side-effects;
- prevent the wash down of glyphosate and its metabolite AMPA.

List of possible quality indicators

One of the most important conditions for designing a certification scheme is that the type of quality requirements are well identified. Different types of certification can be used to guarantee the quality of weed management and the appropriate application of DSS. The selection of the most appropriate systems has to be made on the basis of the requirement of quality, reliability, feasibility and the cost effectiveness of the certification system.

The most relevant types of certification in this case are:

- **Quality system**

Weed management by municipalities can be seen both as a system and as a process.
Weed management on the level of a municipality requires communication between different departments: prevention related to the design of paved surfaces, control and communication (acceptance). This requires a type of quality system certification.

1. Integration of a module with specific requirement on weed management in general and more specific on hard surfaces in existing environmental quality schemes, like ISO-14001, used by companies and municipalities. This would cover the certification of the so-called object based approach in the DSS.

- **Process certification**

The correct application of chemical weed management demands for a process oriented type of certification.

2. Certification of the adequate use of the application oriented approach in DSS with well defined decision criteria and procedures.

in combination with

- **Operator certification**

3. Certification of operators who are responsible for the execution of weed control. Operators have a spraying license that has to be renewed every 5 years. Recently the VHG developed an initiative for the calibration of spraying equipment. Specific requirements needed for the weed control procedures according to DSS demands for operator quality guarantees. Requirements will have to be specified concerning skills, knowledge and attitude.

The product approach in certification seems less appropriate for DSS. Two possible approaches are:

4. Water quality: amount of herbicides in μg/l at a predefined point in the water discharge system

5. Effort weed management: amount of herbicide (kg a.i.) per m2 paved surface and/ or financial effort in costs/ m2 related to the type of hard surfaces.

8.5 System limits for weed management

The relevant system aspects of weed control in DSS on hard surfaces are:

1. Which strategy is applied for weed management on paved surfaces?
2. What quality criteria are used to define the type of weed control for different surfaces and objects?
3. What is contribution of prevention of weed growth in the total reduction of herbicides
4. Which alternative non-chemical control methods are applied?
5. When and how is chemical control applied?

6. How is the wash-down of spraying liquid avoided?

Aspects 1-4 are covered by the requirements in the quality system approach and aspects 5-6 by both the process and operator certification.

8.6 Effects of certification (systems)

First design of possible systems, see §8.4. In this paragraph we will evaluate the potential contribution of the different systems to the solution of the identified problems.

Actual situation

548 municipalities follow different strategies to cope with weed management on hard surfaces. On the extremes of this spectre we find:

- Municipalities, e.g. Eindhoven, with a very well documented 100% non-chemical weed management
- Municipalities with 100% chemical weed management.

Actors

There are different problems related to weed management on hard surfaces and different problem owners:

- The central problem lies with the drinking water companies and the Water counties who are responsible for water quality control and enforcement of the legislation on Surface Water Pollution (WVO).
- Monsanto sees itself confronted with a growing demand for and an intensified use of glyphosate with all the risks of careless / non rational application and exceeding the criteria for surface water quality.
- Municipalities are obliged to reduce herbicide use following the covenant 'Public Green' in the Multi Year Crop Protection Programme. At the same time they want to satisfy the quality demand of their citizens for proper and well-maintained streets, pavements and other objects in the public environment. They are confronted with limited budgets and higher costs for non-chemical control. The third main bottleneck is that decision makers are neither convinced of the problem, nor of the positive impact of non-chemical control. The lack of a recognised and balanced support system for the choice between chemical control and other systems makes it hard to change policies. This problem is enhanced by the fact that municipalities have problems to get the more complex preventive and non-chemical approach in weed management organised.

Impact of the certified use of a Decision Support System

- Correct application of the DSS gives support to :
  - the insight in costs and benefits of different weed control methods
  - the insight in the unwanted side-effects of different control methods
  - the operationalisation of different weed control methods
  - the planning of weed management.

DSS does not resolve the problems related to the organisation of prevention of weed control (type of pavements, less paved surfaces etc.) and communication.

- On the basis of a correctly applied DSS a ‘prescription’ system is thinkable which links the availability of glyphosate to certified users. This demands for a well maintained system of sales, purchasing and registered use of glyphosate.
  The amount of ‘prescribed’ produce can be related to the surface of paved surface and the differentiated quality classification (weed free-weed tolerant).
  This has two positive effects:
  1. the municipality is stimulated to develop a planned approach of weed management on paved surfaces;
  2. because there is only a limited amount of glyphosate available, irrational use has to be avoided. This will result in better surface water quality.

  A possible negative effect might be the growth of illegal use of herbicides by municipalities.

- Prerequisite:
  DSS is recognised by all relevant stakeholders as the best approach for rational weed management (see also § 8.4 on quality indicators and § 8.2 accreditation).

Stimulus

To stimulate voluntary certification the certificate must have an added value for the certificate-holder. Different types of stimuli can be made available. Examples:

- Improvement of the cost-effectiveness of weed management
- Support in development of management and application skills.
- Financial reward by drinking water company,
- License to use Roundup in a kind of ‘prescription’ model

Feasibility

No data available yet on use of ISO like systems by municipalities.

Accordance between Agrodis proposal on Registration and Control System and the certification of Weed Management.
The proposal of Agrodis for a registration and certification system focuses on a closed system for the sales and purchasing of pesticides. On the purchaser/ user level important relevant criteria for weed management are:

Beginning of the year:
- the surface of the area to be sprayed with herbicides;
- the dosage per m2;
- the available stock of herbicide.

During application period:
- the registration of the use: date, location, conditions;
- End of the year;
- used quantity related to surface and stock at the end of the year.

8.7 Recommendations for framework / certification strategy DSS

1. Study the possibilities and implications of the recommended certification approaches in 8.4, quality system, process and operator certification;
2. Make an inventory of possible 'reward' systems for certified users and their effect on the weed management strategy of the target group;
3. Design minimal procedures in order to operationalise the systems mentioned under 1;
4. Evaluate cost-effectiveness of the certification of DSS.

9. Survey

At the start of the project a reference measurement / survey is carried out to investigate the attitude and motivation of both principals and contractors towards the use of herbicides - esp. glyphosate - on hard surfaces. Thus the point of departure of the project is assessed. It offers the opportunity to determine - later on - the impact of implementation of a DSS.

Survey design

The survey is carried out by means of discussion-based interviews with a standard questionnaire as guideline (annex IV), following the methodology that is used by the SSLRC in a similar survey in the UK (Shepherd, 2000).

The survey was limited to organisations that actually still choose and carry out chemical control for weed management. Organisations that are already committed to non-chemical weed management were excluded. This unilateral approach is chosen in order to be able to fully focus on the attitude and behaviour of those who are still in favour of pesticides - a worst case approach.

Altogether 11 interviews are carried out, including municipal officials, contractors and a manager of an industrial plant.

The pilot was aimed to cover a wide variety of different situations, i.e. large versus small municipalities, agrarian versus urban communities, different parts of the country.

Results

The results of the survey are written down in a separate appendix attached to this document.

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Appendix I.
Factsheet glyphosate

General

- Systemic, broad spectrum, non-selective herbicide. It can be used to control both annual and perennial grasses, broad leaf weeds and woody plants. Glyphosate is absorbed mainly through the leaves and is transported around the whole plant, killing all parts of it (both aboveground and subterranean parts).
- Application conditions: preferably moderate warm, clouded weather, high relative humidity
- Do not apply during rain and when rain is expected within 4-6 hours after application
- Application on dry weeds

Application techniques

- swath spray with knapsack sprayer
- spot spray with knapsack sprayer
- motorised unit with lance application
- Weed IT (electronic weed spotting) (distributor NL: Kamps-Dewildt)
- SelectSpray (electronic weed spotting) (distributor Nl: Douven)
- weed wiper
- Mankar

Registered products (situation as from 1-1-2001) for application on hard surfaces

For professional use:

Trade name	Formulation	a.i.	Application instructions*	
Roundup Evolution	SL (soluble liquid)	360 g/l	annual weeds perennial grasses perennial broad leaf weeds spot treatment: 2% wiper application: 33%	2-4 l/ha 3-4 l/ha 4-6 l/ha
Roundup Dry	WG (water soluble granule)	42%	annual weeds perennial grasses perennial broad leaf weeds spot treatment: 2% wiper application: 33%	1,75 - 3,5 kg/ha 2,23 - 3,5 kg/ha 3,5 - 5 kg/ha

**watervolume: 200 - 400 l water (code 2M-4G)*

For use by private persons:

Roundup Ready-to-use	7,2 g/l		undiluted, 750 ml / 33 m²
Roundup Huis en Tuin	360 g/l	annual grasses perennial grasses and broad leaf weeds	5 ml / 5 l water / 10 m² 8 ml / 5 l water / 10 m²

Related product for professional use:

	a.i.	Application instructions*
Touchdown (a.i.: glyphosate - trimesium)	480 g/l	same as Roundup Evolution

**watervolume: 200 - 400 l water (code 2M-4G)*

Appendix II.

Overview of non-chemical weed control methods

	Wire brush	**Burning**	**Hot water**	**Herbicides**
efficacy to weeds	only aboveground parts	only aboveground parts	only aboveground parts	both aboveground and subterranean parts
weed growth	little to heavy	little	little to heavy	little to heavy: enough leaf surface necessary for herbicide uptake
influence on vegetation	increase of perennial weeds	increase of annual weeds	?	effective control of both perennial and annual weeds. Also effective against problematic weeds
time of application	both curative and preventive from the end of July till early winter (most effective in autumn)	curative, most effective during the summer and autumn	curative, most effective during the summer and autumn	curative, during the growing season
number of applications / year	2	3	2-3	2
type of hard surface	only on hard surfaces that are flat. Not applicable on semi hard surfaces or surfaces with back maintenance (upkeep).	all surfaces except asphalt	all (no demands)	all (no demands)
disadvantages related to hard surfaces	wear of hard surface	melting of asphalt	none	none
noise pollution	> 90 dB	80 - 90 dB		
environmental effects	combustion gasses, dust, iron grit	combustion gasses (considerably more than brush)	combustion gasses	pollution of surface water (run-off)
other disadvantages	risk of road metal	flammable	none	none
apparatus	zelfrijdende machine, aanbouwapparatuur	infra red / flame weeder		knapsack-sprayer, wiper, SelectSpray
other	can be combined with cleaning-unit			
costs / m^2	*f*0,25 - *f*2,75 (depending on weed growth) + *f*0,10 for brushing and carrying away (transport)	*f*0,06 - *f*0,25		*f*0,05 - *f*0,30

Appendix III.
Relative sensitivity of weeds towards glyphosate

Relative sensitivity of weeds towards glyphosate (+++ = much sensitive, ++ = sensitive, + = little sensitive, - = insensitive) *(to be extended)*.

+++	++	+	-
Root weeds			
Calystegia sepium Hedge bindweed Haagwinde		*Cirsium arvensis* Creeping thistle Akkerdistel	
Elymus repens Couch grass Kweek			
Tussilago farfara Coltsfoot Klein hoefblad		*Sonchus arvensis* Perrenial sow-thistle Akkermelkdistel	
Polygonum amphibium Amphibious bistort Veenwortel			
Grasses			
Lolium spp. Ryegrass raaigras	*Poa annua* Annual meadow-grass Straatgras		
Setaria viridis Green bristle-grass Groene naaldaar			
Digitaria ischaemum Smooth finger-grass Gladvingergras			
Echinochloa crus-galli Cockspur Hanepoot			
Broad leaf weeds			
Polygonum aviculare Knotgrass Varkensgras	*Urtica urens* Annual nettle Kleine Brandnetel		
Viola tricolor spp. arvensis Field pansy Akkerviooltje	*Galium aparine* Cleavers Kleefkruid		
Veronica spp. Speedwell Ereprijs	*Polygonum convolvulus* Black bindweed Zwaluwtong		
Capsella bursa-pastoris Shepherd's purse Herderstasje			
Chamomilla spp. Mayweed Kamille			
Polygonum persicaria Redshank Perzikkruid			
Galinsoga parviflora Gallant soldier Knopkruid			
Solanum nigrum Black nightshade Zwarte nachtschade			