PLANT RESEARCH INTERNATIONAL
WAGENINGEN UR

The SWEEP concept: a cost-benefit analysis

C. Kempenaar & C.J. van Dijk

Plant Research International B.V., Wageningen
March 2006

Plant Research International B.V.

Address	:	Droevendaalsesteeg 1, Wageningen, The Netherlands
	:	P.O. Box 16, 6700 AA Wageningen, The Netherlands
Tel.	:	+31 317 47 70 00
Fax	:	+31 317 41 80 94
E-mail	:	info.plant@wur.nl
Internet	:	www.pri.wur.nl

Table of contents

		page
1.	Introduction	1
2.	Weed management and efficacy	3
3.	Herbicide run off	4
4.	Costs	6
5.	Environmental impact	7
6.	Cost benefit assessment	8
References		9

1. Introduction

In a recent study the non-agricultural use of pesticides in The Netherlands for 2004 was estimated at 298.000 kg active ingredient (Straaten-Zwiers *et al.*, 2005). Circa 70% (207.000 kg a.i.) of the total non-agricultural use was used for weed control on hard surfaces. Therefore the use of herbicides on hard surfaces is the largest non-agricultural use of pesticides in The Netherlands (mainly products with glyphosate as active ingredient). Municipalities and other governmental organizations used circa 25.000 kg active ingredient for weed control. For industrial sites, the estimated use is even higher, circa 144.000 kg (Table 1). In other EU-countries in the temperate climate zone the total use can be estimated at least a ten fold of the total use of circa 300.000 kg in The Netherlands. According to water authorities and drinking water producers in The Netherlands the current herbicide use on pavements (e.g. roads, side walks) adversely affects the quality of surface waters and is a potential risk for drinking water production. Herbicide run off from the 100-200 km^2 paved area contributes more than proportional to the costs of drinking water production.

Table 1. Non-agricultural use of pesticides in The Netherlands for 2004, estimated ranges between brackets (Straaten-Zwiers et al., 2005).

Organization	Non-agricultural pesticide use (tons active ingredient)	
	Total use	Use on hard surfaces
Governmental organizations (including railroads)	45* (+/- 6%)	25(+/- 0%)
Non-governmental organizations		
-industrial sites (incl airports, harbors etc.)	145* (+/- 22%)	144 (+/- 22%)
-farmyards	10 (+/- 0%)	7 (+/- 29%)
-private property	76 (+/- 5%)	22 (+/- 18%)
-recreation areas	12* (+/- 8%)	1.5 (+/- 33%)
-housing associations	11* (+/- 37%)	11 (+/- 36%)
Total	298 (+/- 14%)	207 (+/- 20%)**

* values from 2001
** mainly glyphosate

SWEEP demonstrates a new concept for weed control on hard surfaces. The concept aims at a substantial reduction of herbicide emission to surface and soil waters. The concept is a decision support system with protocols that guarantee a substantial reduction in herbicide use and emission. Only a limited amount of herbicides is allowed under specific conditions and no herbicides are allowed when a pavement is close to surface water used for drinking water production. Information on weed prevention, weed control methods and side effects of these methods are put into simple guidelines (shortlists) for sustainable weed management (Figure 1). Sustainable means, cost-effective, environmentally benign and socially acceptable. If methods are considered good practice, and they are legally allowed, they are integrated in the decision support system. The decision support system puts restrictions on certain uses of methods, to reduce unwanted side effects as much as possible. Most attention is given to reduction of herbicide runoff to surface water, because this is a major side effect of weed control practices on hard surfaces in north west Europe.

The SWEEP concept aims at boards (shortlist 0), managers and planners of hard surfaces (shortlist 1) and weed control specialists (shortlist 2). The managers and planners generally work within large organizations (municipalities, management of large industrial sites, harbors, airports etc.), the weed control specialists within small and medium size enterprises. In circa 80 % of the municipalities and presumably 100% of the industrial sites herbicides are used because they are effective and the alternatives are more expensive.

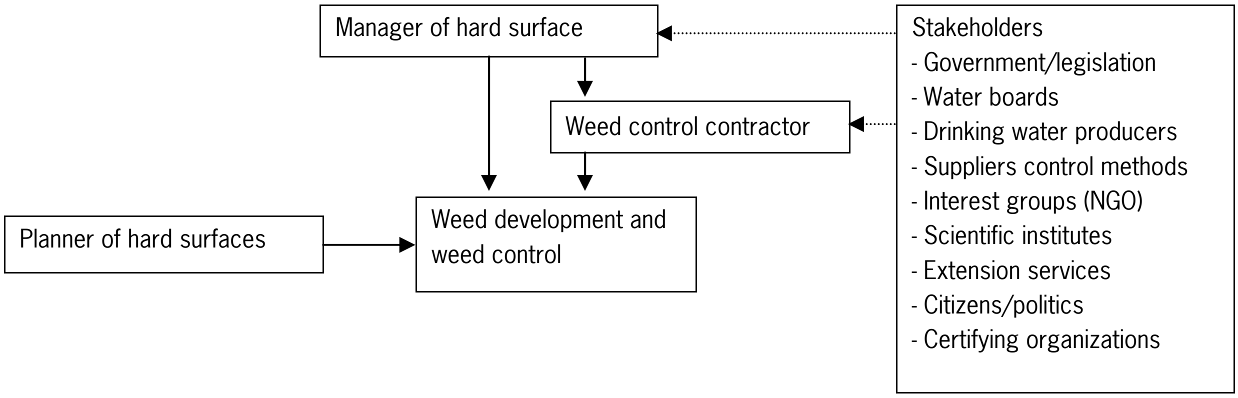

Figure 1. Overview of the parties involved with weed control on hard surfaces.

During the implementation process of the SWEEP concept a number of key parameters were monitored for each of the managements units, i.e. level of weed control, herbicide runoff and costs of weed control. These parameters are used as input for the cost-benefit analysis.

2. Weed management and efficacy

Field studies in different municipalities have shown that weed control under SWEEP guidelines is effective; also in case of high weed pressure such as in the wet season of 2004. A first step in SWEEP is that the board or manager(s) decide which level of weed infestation level is maximally acceptable. Various classification scales for weed infestation are available. SWEEP recommends Table 2 for this use, but other scales can be used as well. In the SWEEP test areas managers decided that weed infestation should not exceed the level of class 3. On average, two control rounds were conducted per season (minimum 1, maximum 3). Brushing, sweeping, burning or mowing was carried out on those places that did not allow herbicide use according to the SWEEP guidelines. The average weed infestation level was kept below the level of class 3 in all test areas.

Table 2. Weed infestation classes for pavements.

Class	Weed infestation level on the pavement
1	No weeds
2	Very few small weeds, less than 5 % cover of bare soil by weeds
3	Few small weeds, hardly any weeds higher than 10 cm, 5-25 % cover of bare soil by weeds,
4	Some weeds higher than 10 cm or some clumbs of weeds, 25-50 % cover of bare soil by weeds
5	Many weeds higher than 10 cm or clumbs of weeds, soil cover more than 50 % by weeds
6	Pavement nearly invisible because of weed cover

In the season of 2002 on average 830 g glyphosate per ha open pavement was applied in the test quarters. In 2003, 324 g glyphosate per ha was applied. Additionally in 6 out of 13 rounds, MCPA was applied too. In the relatively wet season of 2004 the average use of glyphosate increased to 543 g glyphosate per ha and in 3 out of 10 rounds, MCPA was applied too. Reductions in glyphosate use were assessed by relating current use to historical data of the municipalities or to data from comparable quarters in the municipality. Reductions varied from 11 to 66% compared to standard practice. In some situations no herbicides were used at all (100% reduction) because of much surface water nearby or because of municipality-board decisions not to use pesticides. On average a reduction of 35% was realized over the period 2002 till 2004 (Withagen *et al.*, 2004; 2005).

In the season of 2005 circa 15 municipalities applied the SWEEP concept (Van Dijk *et al*, 2006) for weed control in one or more quarters, ten municipalities recorded the use of herbicides (circa 1200 ha). On average 204 g glyphosate per ha was applied and MCPA was applied once (1 out of 37 rounds). An overview of the use of herbicides from 2002 till 2005 is given in Table 3.

Table 3. Overview of the average use of glyphosate per ha open pavement and the appliance of MCPA in different municipalities from 2002 till 2005

Year	Glyphosate	MCPA	
	($g\ ha^{-1}$)	applied	rounds
2002	830	-	-
2003	324	Yes	6 (13)
2004	543	Yes	3 (10)
2005	240	Yes	1 (37)

3. Herbicide run off

Flow rate proportional measurements in different municipalities from 2002 till 2005 (Table 4) showed that glyphosate and AMPA could be detected in the sewage water up to weeks after herbicide application. The concentrations were dependent on relative date and intensity of rain fall. Highest concentrations were detected during or shortly after the first rain event (> 1 mm precipitation). Based on the flow rate proportional monitoring data the amount of glyphosate that emitted from the test quarters via the sewage water system was calculated, and emission factors were derived (which is the amount of glyphosate emitted from the quarter divided by the total amount of glyphosate used in the quarter). On average, the emission factor for glyphosate was 1.8% with a maximum of 5.7%.

Table 4. Emission factors (%) for glyphosate based on Flow rate proportional measurement in different municipalities from 2002 till 2005.

Municipality	Area (ha)	Year	Season	Rainfall (mm)	Periods with rain (>1 mm) after herbicide application	Emission (%)
Papendrecht	6.5	2002	Spring	23	3 (1, 6, 7)*	5.7
		2002	Autumn	20	3 (10, 13, 14)	0,2
		2003	Spring	27	4 (13, 14, 15, 16)	0.5
Dordrecht	2.3	2003	Spring	16	4 (4, 5, 7, 8)	1.1
		2003	Autumn	21	2 (1, 5)	4.0
		2004	Spring	18	2 (18, 21)	0.4
		2004	Autumn	31	4 (8, 11, 12, 13)	3.5
Giessenlanden	0.53	2003	Spring	39	4 (5, 6, 7, 8)	1.6
Vianen	9.7	2003	Spring	23	4 (0, 2, 6, 8)	2.1
		2003	Autumn	34	5 (0, 3, 4, 5, 6)	0.2
		2004	Spring	27	4 (7, 13, 14, 16)	1.5
		2005	Spring	29	3 (2, 5, 15)	1.0

* between brackets: number of days (rounded off) between herbicide application and a rain event with >1 mm rainfall

Concentrations of glyphosate were measured in surface water at positions were run off was most likely and the sewage water systems drains water into the surface water. The highest glyphosate concentration in the surface water samples was 22 µg per liter. The mean glyphosate concentration was 0.8 µg l^{-1} with a 90-percentile value of 1.3 µg l^{-1}. The Maximum Permissible Concentration (MPC), the ecological threshold concentration for surface water of 77 µg l^{-1} was never exceeded. The number of MCPA measurements was limited but the current ecological threshold concentration was not exceeded (data not presented).

Additional measurements were performed in the municipality of Lelystad, where the SWEEP concept was applied to several quarters and compared with standard practice reference quarters (Figure 2). Standard practice showed an maximum glyphosate concentration in surface water samples of 83 µg l^{-1}. The mean concentration was 7.8 µg l^{-1} with a 90-percentile of 28 µg l^{-1}. In the quarters where the SWEEP concept was applied an average glyphosate concentration of 1.6 µg l^{-1} was measured (90-percentile 2.6 µg l^{-1}). On average the 90-percentile value for herbicide run off was reduced by ca. 90%.

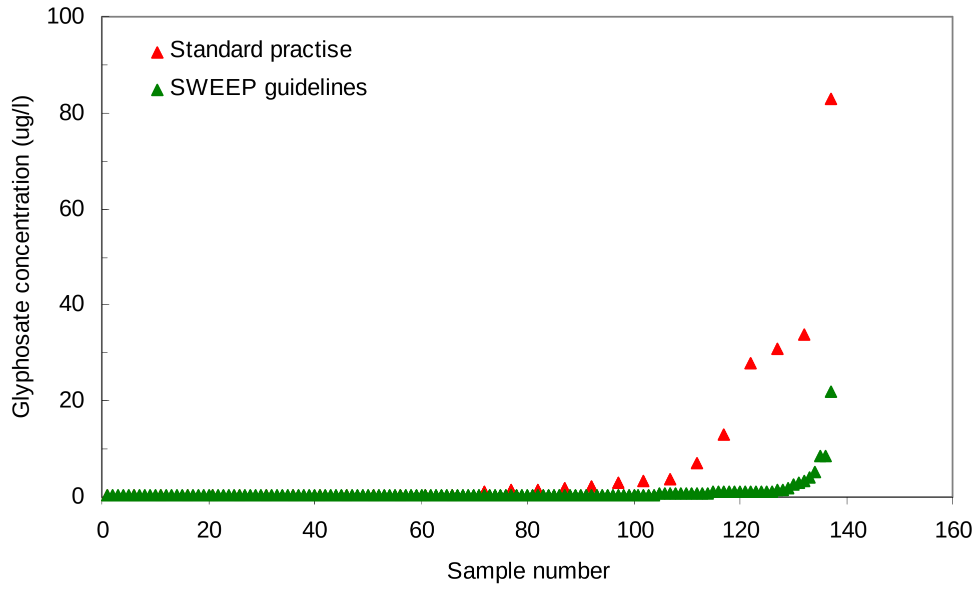

Figure 2. *Glyphosate concentrations (µg l[-1]) in surface water samples from quarters where the SWEEP concept was applied compared with standard practice reference quarters*

Conclusions

Weed control according to the SWEEP guidelines reduces herbicide run off by ca. 90% compared to standard practice. On average, the emission factor for glyphosate was 2% (maximum of 5.7%) and the Maximum Permissible Concentration, the ecological threshold concentration for surface water was not exceeded.

4. Costs

In 2005 a study was performed to estimate the costs for different methods of weed control on pavements. The costs were estimated by expert judgment for the most common methods, brushing, burning, hot water and chemical weed control with the SWEEP restrictions and standard practice (Spijker et al., 2005).
The annual costs of weed control depend on the level of weed infestation that is acceptable and the method chosen (Table 5). The costs for standard chemical weed control ranged from € 0.05 to 0.10 m^{-2} $year^{-1}$. Chemical weed control under the SWEEP restrictions ranged in 2004-2005 from € 0.06 to 0.15 m^{-2} $year^{-1}$. The managers of the municipalities estimated the extra costs of weed control from virtually no increase to a maximum increase of 25% compared to standard chemical weed control (internal costs of the municipalities were not included). This is in particular caused by the use of different techniques at emission-sensitive places such as brushing, burning or hot water and a smaller number of days on which work could be done. Costs for completely non-chemical weed control ranged from € 0.15 to 0.40 m^{-2} $year^{-1}$. However, these costs are presumably underestimated because experiences in the season of 2005 have shown that for brushing and burning, frequencies of six to eight times are more likely than the frequencies mentioned in Table 2. The data on costs are indicative, for instance the commercial tariffs for non-chemical control are under pressure.

Table 5. Annual costs (€) of different methods of weed control on pavements for two levels of weed infestation: 'Few small weeds' (Class 3, Table 1) and 'Very few small weeds' (Class 2, Table 1).

Method	Weed infestation level			
	'Few small weeds' (Class 3)		'Very few small weeds' (Class 2)	
	Frequency	Costs (€ m^{-2})	Frequency	Costs (€ m^{-2})
1. Brushing	3	0,19 - 0,38	3,5 - 5	0,20 - 0,40
2. Burning	-	-	5	0,15 - 0,35
3. Hot water	2,5	0,22 - 0,32	3-4	0,30 - 0,40
4. Chemical	2	0,05 - 0,08	2,5	0,07 - 0,10

Conclusions

The costs for weed control according to the SWEEP guidelines increases with ca. 25% compared to standard practice. The costs for non-chemical weed control at least double compared to the SWEEP-method with restrictions for herbicide use.

5. Environmental impact

The risk assessment study of Saft & Staats (2002) was updated in 2005 (Saft, 2005). The emission factors observed in the test quarters where the SWEEP concept was applied showed a 90 % smaller emission factor than assumed by Saft & Staats in 2002. The results of the monitoring activities were incorporated in the update of the risk assessment study and compared with other (non) chemical methods. For the study the level of weed infestation should not exceed the level of class 2 (Table 2). Relative environmental scores are presented for six weed control methods or combination of methods (Figure 2):

- Standard Chemical: 2.5 times selective application of glyphosate per season assuming a emission factor of 50%; This emission factor was used in the risk assessment study of Saft & Staats (2002).
- Chemical SWEEP-high: 2.5 times selective application of glyphosate per season under the SWEEP restrictions. An emission factor of 25% was assumed.
- Chemical SWEEP-low: 2.5 times selective application of glyphosate per season under the SWEEP restrictions. The emission factor was set at 3% based on the actual flow rate proportional measurements in different municipalities from 2002 till 2004 (see paragraph 3).
- Brushing: 3.5 times per season and using chemicals for weed control around obstacles.
- Hot water: 3 times per season
- Burning: 5 times per season

The height of the columns in Figure 3 indicate the negative impact on the environmental compartments for the different weed control methods. Standard chemical weed control scores relatively high, especially on aquatic environment, due to the high use of herbicides and a high emission rate to surface water. The methods Chemical SWEEP-low, hot water and burning have a comparable, relatively low impact on the environment. Where the chemical method scores mainly on the aquatic compartment due to emission of herbicides, hot water and burning both have an impact on the atmosphere as a result of emissions of flue gasses from burning fossil fuels. In general the effect of chemical weed control on the aquatic environment drops significantly if the SWEEP concept is used.

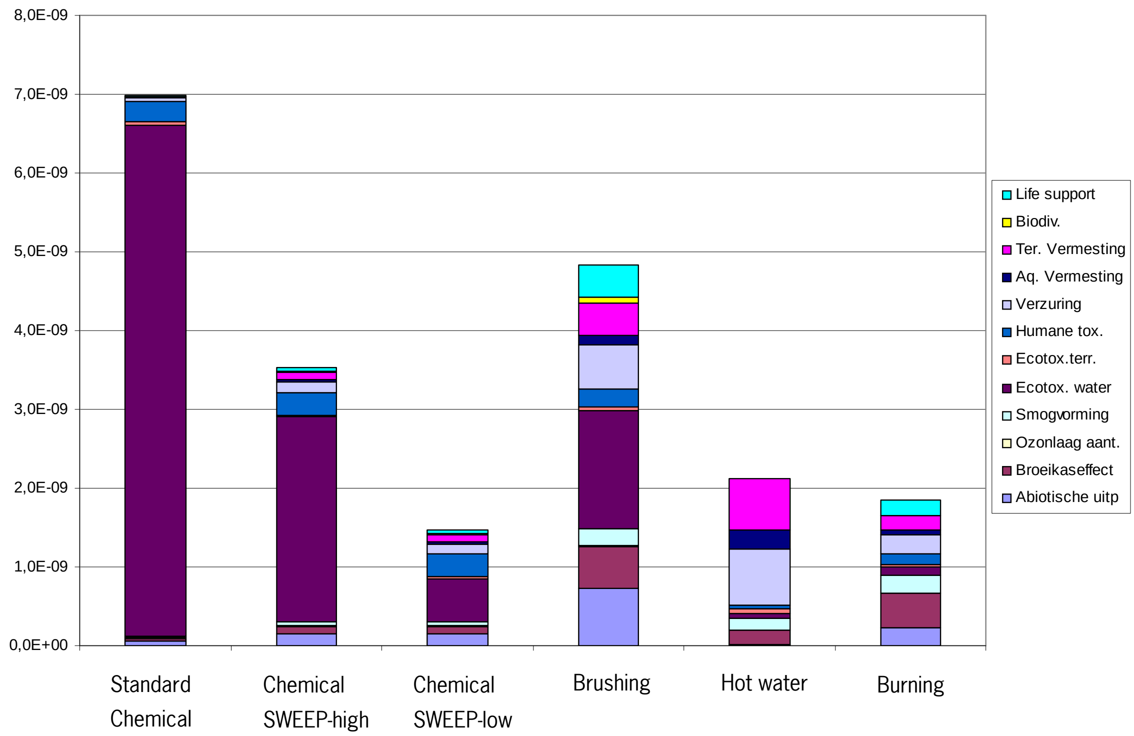

Figure 3. *Relative environmental scores for six weed control methods and maximal weed infestation level class 2 (From: Saft, 2005)*

6. Cost benefit assessment

The development and testing of the SWEEP concept for weed control on pavements started in 2002 (Kempenaar *et al*, 2006). Implementation of the concept on real management units in a number of municipalities started in the season of 2004 and was continued in 2005. During the test period the level of weed control was effective and the overall picture was good to reasonable (even in the wet season of 2004). On average a reduction of 35% of herbicide use was realized, resulting in a average use of glyphosate of ca. 480 g ha^{-1} per season. The mean glyphosate concentration in surface water was 0.8 µg l^{-1}. In quarters with standard chemical practice the mean concentration was 7.8 µg l^{-1}.

Application of SWEEP guidelines significantly reduced herbicide runoff with approximately 90%, mainly as a result of the restricted use of herbicides near surface waters areas. Concentration measurements showed that the ecological threshold level in surface waters was not exceeded. Although the substantial reduction of herbicide run off from pavements by the restricted glyphosate use, emission to surface waters is not completely prohibited. In some samples, concentrations were slightly higher than the drinking water criterion of 0.1 µg l^{-1} given in the EU Water Framework Directive. Therefore additional guidelines were added for pavements near surface waters that have to be protected according to the EU water phrame work directive. This means: no herbicide use on pavements near these waters.

Extra costs of weed control under SWEEP restrictions ranged from almost no increase to a maximum increase of 25% compared to standard chemical weed control. The data on costs are indicative because the commercial tariffs are highly variable at the moment. There is no linear relationship between glyphosate concentrations in surface water and the costs producers of drinking water have to make to purify this water from glyphosate. These costs are estimated at 20 M€ per year. At the moment it is not possible to make a reliable estimation of the reduction in costs, but in the long term reduction of herbicide runoff will lead to a decrease in purification costs and less occasions that the intake of surface water for drinking water production has to be stopped because of exceedance of the glyphosate threshold value of 0.1 µg l^{-1}.

The emission results of weed control under SWEEP restrictions are used in a risk assessment study and compared with other (non-chemical) weed control methods. The impact on the environment of chemical weed control according to the SWEEP-concept is relatively low and comparable to the scores of the non-chemical methods hot water and burning.

Conclusion

Appling the SWEEP method for weed control on pavements will lead to a small increase of costs but herbicide run off is significantly reduced and ecological thresholds for surface water are not exceeded. In the long term this will lead to a decrease in purification costs in the production process for drinking water.

References

Kempenaar, C., L.A.P. Lotz, K. van der Horst, W.J. Beltman, K.J.M. Leemans & A.D. Bannink, 2006. Finding a good balance between costs and environmental effects of weed control on pavements. Crop Protection (in press).

Saft, R.J., 2005. Update Milieuanalyse Onkruidbestrijding op Verhardingen. IVAM Research and Consultancy on Sustainability, Amsterdam.

Saft, R.J., Staats, N., 2002. Beslisfactoren voor onkruidbestrijding op verhardingen 'LCA, risico-beleving, kostenanalyse en hinderbeleving'. Document 0205 (in Dutch, title in English: Decision factors for weed control on pavements 'Life cycle assessment, costs analysis and perception'.). University of Amsterdam, NL.

Spijker, J., Straaten-Zwiers, M. van der, C. Kempenaar, C.J. van Dijk, & J. Hekman, 2006. Kosten voor onkruidbestrijding op verhardingen. Syncera Water, Delft.

Straaten-Zwiers, M. van der, J. van Herk, C. Kempenaar, C.J. van Dijk, J. Spijker & J. Hekman, 2006. Omvang gebruik bestrijdingsmiddelen op verhardingen. Syncera Water, Delft.

Van Dijk, C.J., C. Kempenaar, M. Vlaswinkel & A.C.L. Withagen, 2006. Evaluatie Duurzaam Onkruidbeheer (DOB) op verhardingen 2005. Plant Research International, Nota 389.

Withagen, A.C.L., C.L.M. van der Horst, W.H.J. Beltman, C.J. van Dijk & C. Kempenaar, 2005. Afspoeling van bestrijdingsmiddelen en onkruidbeelden in twee proefgemeenten (2004). Plant Research International, Nota 349.

Withagen, A.C.L., C.L.M. van der Horst, W.H.J. Beltman & C. Kempenaar, 2004. Resultaten monitoring afspoeling glyfosaat en AMPA en waarnemingen van onkruidbeelden in zeven proefgemeenten (voorjaar en najaar 2003) Plant Research International, Nota 297.