Cardiff Council

Testing & Evaluation

Weed Control Trial 2021: Final Project Report

Advanced Invasives
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ADVANCEDINVASIVES

Document

Final report: this document contains the final project report for testing and evaluation of pavement weed control methods by Advanced Invasives on behalf of Cardiff Council.

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Advanced Invasives

Advanced Invasives is the leading invasive plant species consultancy in the UK.

We solve invasive plant species problems, with a specialist focus on Japanese knotweed and the complex technical, legal and public relations challenges faced by large landowners, private companies and herbicide manufacturers.

Based in South Wales, Advanced Invasives was founded in 2016 by Dr Dan Jones (PhD, MSc, BSc, MA, CIEEM) from Swansea University's Department of Biosciences out of a desire to set a new standard of evidence-led invasive species management.

We work across six main areas with our clients: expert witness, research and product testing, best practice strategy, complex ecological projects, continuing professional development (CPD) and public guidance services.

Summary of research findings

In 2021 Cardiff Council and its weed control contractor trialled three pavement weed control methods across the City of Cardiff to find out how effective and sustainable each method was, as measured against four key criteria: cost, environmental, customer satisfaction and quality. Control methods trialled included glyphosate-based herbicide (applied three times per year), acetic acid-based herbicide (applied four times per year) and hot foam herbicide (applied three times per year). Efficacy and sustainability results showed that glyphosate was the most sustainable, being cost effective, with low environmental impacts and high customer satisfaction and quality. In contrast, acetic acid delivered intermediate costs and environmental impacts with low customer satisfaction and quality, while hot foam generated high costs and environmental impacts, but high customer satisfaction and quality.

Based on the cost, environmental, customer and quality criteria (efficacy and sustainability criteria) measured, the most effective and sustainable weed control method currently available for pavement weed control in the UK involves the use of glyphosate-based herbicide.

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1. Introduction

1.1 Sustainability

Sustainability is an often-used term with a wide range of meanings and interpretations. Commonly, sustainability means that current economic activities are carefully considered in order that such decisions do not place an unequal burden on future generations (Foy 1990, Tisdell 1996, Giddings et al. 2002). In practice, this means that we reduce our impacts on the environment now, rather than continuing with 'business as usual' and leaving future generations to deal with the problems that we cause today. More generally, sustainability is now often used in the context of the capacity for Earth's biosphere and human civilisation to co-exist in the present and in the longer term.

Sustainability involves three sectors, including environment (ecology), society (people, including those who manage weeds) and economy (monetary; Figure 1.1). Sustainability in the context of the three sectors is difficult to resolve because of the timescales in which they operate: economic timescales are shorter than social, which are in turn shorter than ecological. Further, although sustainability is presented as bringing the three sectors together in a balanced way and resolving conflicts, this is often not the case. Economic considerations are frequently placed above societal and environmental concerns and land management systems will not be sustainable unless they are economic in the present and remain so in the future. Crucially, a project may be economically viable in the short-term, yet in the longer term could be unsustainable with respect to other sectors (Foy 1990, Tisdell 1996, Giddings et al. 2002).

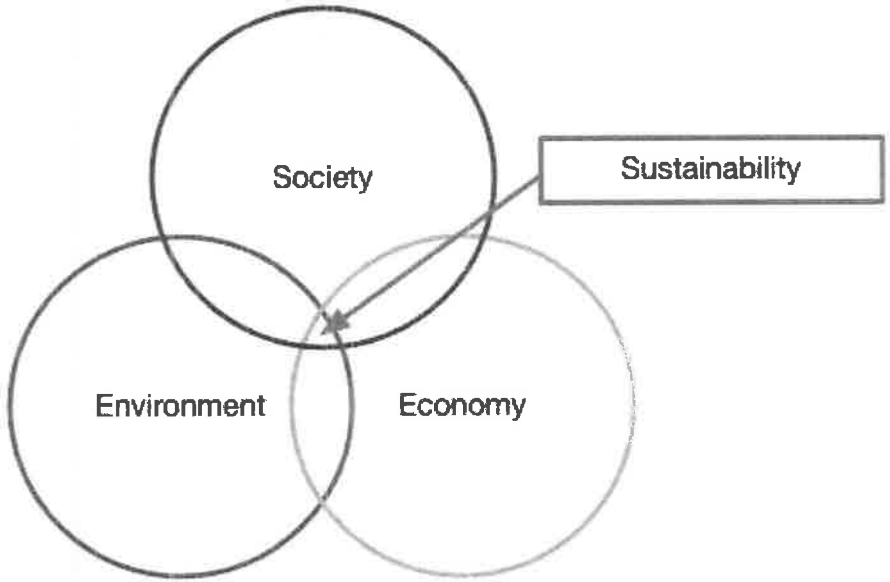

Figure 1.1: Sustainability in the context of the environment (ecology), society (people, including those who manage weeds) and economy (monetary). Note that 'sustainability' occupies a small area of overlap between these three sectors.

There are at least two ways in which sustainability is used in the context of land management systems:

1. Describe properties or features of outputs from the system and/or
2. Refer to whether use/adoption of a system will be continued or maintained in the longer term.

Even when sustainability is used in the context of long-term adoption (second context), sustainability in the sense of system outputs (first context) will be relevant as it should determine whether a system will be adopted or maintained. From an environmental and/or societal perspective, weed management practices cannot be judged without consideration of impacts beyond the area of interest (Tisdell, 1996, Jones, 2015).

Focussing on the amenity sector, calculating how sustainable processes are is made difficult by different ways of measuring things (multiple evaluation criteria), working in different places and over different time periods (i.e., a range of assessment criteria at different spatial and temporal scales). This is often made worse by the lack of evidence-based research investigating the efficacy of control methods and their respective environmental and economic costs (Tisdell 1996, Hanegraaf et al. 1998, Giddings et al. 2002, Jones and Eastwood 2019). However, control methods are most likely to be adopted sustainably when they:

- Are less costly than the alternatives
- Involve (comparatively) low levels of investment or financial requirements
- Create little risk or uncertainty (i.e., they are evidence-based)
- Define control and management timeframes through evidence-based research (Cobb & Reade 2010, Wynn et al. 2014, Jones and Eastwood 2019).

Welsh Government sustainability legislation

In 2015 Welsh Government introduced The Well-being of Future Generations (Wales) Act 2015 which requires public bodies in Wales to think about the long-term impacts of their decisions, to work better with people, communities and each other, and to prevent persistent problems such as poverty, health inequalities and climate change (Welsh Government 2015). This legislation that is unique to Wales aims to ensure that future generations have at least the same quality of life as we do now, i.e., ensuring that sustainability underpins long-term decision-making at the local level through to the national scale. Effective control of pavement weeds requires such long-term thinking and where this is informed by evidence-based research, the impacts of these processes on climate change can be minimised, particularly where the results can be scaled to the Wales-level.

1.2 Pavement weed control

In the UK, there are three key sectors where weed management is practised extensively:

1. **Agricultural -** e.g. arable and pastoral farming.
2. **Horticultural -** non-agricultural (e.g. flower production, landscape design).
3. **Amenity -** non-agricultural (e.g. public sports grounds, hard surfaces).

Amenity hard surfaces are defined as:

'areas with a ground-covering, such as asphalt, paving-stone and concrete, or surfaces with a top layer of sand, gravel or crushed material.'

Weeds grow easily in the open spaces present, such as joints and cracks (Rask & Kristoffersen 2007). Within the urban environment, weed management on hard surfaces is undertaken to:

- Ensure public safety - minimise the risk of slips, trips and falls to the public and ensure adequate surface drainage of roads (weed growth can reduce water flow).
- Reduce infrastructure asset maintenance costs - weed growth impairs the function of hard surfaces and the growth of roots reduces their useful lifetime (i.e., replacement or renewal of pavement materials are required).
- Improve the visual appearance of infrastructure (highly subjective; Hansson et al. 2006, Ramwell 2006, Fagot et al. 2011, Rask et al. 2013, East Malling Research 2015).

Local government has a duty of care to maintain safe pavements for residents (i.e., removing weed trip hazards), minimise the cost of infrastructure asset maintenance and maintain clean pavements for residents. Further, Different pavement types need different levels of weed control (Rask et al. 2013). To successfully achieve these objectives, control methods must be effective in addition to being economically sustainable (practical and cost-effective) to remain viable. Further, methods should aim to minimise herbicide, fuel and water use to ensure the environmental sustainability of weed management (Wynn et al. 2014).

However, herbicide-based weed control on amenity hard surfaces often leads to different environmental issues compared with their agricultural use. Hard surfaces are normally constructed for rapid penetration of water or to encourage run-off to avoid flooding. As a result, contamination of nearby ditches, drains, sewage systems or ground water with herbicide may occur, as these compounds do not stick to the surface (absorption) and degrade over time as they would in agricultural soils. As a result of this, some Northern European countries have restricted the use of herbicides for weed control in urban areas, increasing the need to investigate alternative control methods (Kempenaar & Saft 2006, Rask & Kristoffersen 2007, Fagot et al. 2011).

1.3 Herbicide regulation

In response to public concern and medical evidence demonstrating the harmful effects of pesticides on human and wildlife health, the most common herbicide-based weed control methods are coming under considerable scrutiny. While increasingly restrictive national and supranational legislation has minimised the range of herbicide active ingredients (herbicide types) that can legally be applied and reduced the overall quantities of herbicide used, there is considerable appetite for alternative weed control methods to be found which can reduce overall herbicide use still further. However, few of these alternative weed control methods have been evaluated in terms of control method efficacy (weed killing ability) and overall environmental and economic impact and sustainability.

To address this knowledge gap, Advanced Invasives recommended independent evaluation of pavement weed control methods trialled by Cardiff Council under realistic 'real world' conditions. Further, to determine treatment sustainability, key economic and environmental criteria associated with treatment deployment were considered to inform overall council decision-making.

1.4 Integrated Pest Management (IPM)

Amenity sector weed management may be achieved using a range of weed control methods, including:

- Cultural (preventative)
- Physical (mechanical)
- Biological (biocontrol or bioherbicides)
- Chemical (herbicides, also known as plant protection products; PPPs)
- Integrated Pest Management (IPM)

True IPM systems combine cultural, physical, biological and/or chemical methods, helping to mitigate selection of resistant weed populations (Van der Weide et al. 2008, Harker & O'Donovan 2013, Cordeau et al. 2016). Figure 1.2 summarises the pros and cons of IPM weed control methods available to the UK amenity sector. Ideally, pavement weed control should be directed toward immature annual and perennial plants for a short period after plant emergence. This is because at this time, weeds have accumulated fewer resources from which to recover from control method application (Rask & Kristoffersen 2007).

Figure 1.2: Pros and cons of Integrated Pest Management (IPM) weed control methods available to the UK amenity sector (De Cauwer et al. 2013, Rask et al. 2013, EMR 2015b, Bristol City Council 2017, Hanson et al. 2006, Kempenaar & Saft 2006, SKL 2006, Kempenaar et al. 2007, Rask & Kristoffersen 2007, Neal & Senesac 2018, APSE 2019a, APSE 2019b, APSE 2020, Martelloni et al. 2020, APSE 2021, Corbett pers comm. 2021, Kay pers comm. 2021, Mason pers comm. 2021, South Lanarkshire Council 2021, City of York Council 2022).

Control category	Desired effect	Control method(s)	Examples	How do they work?	Does it work?	Positives	Negatives
Cultural	Prevent and/or minimise weed population growth	Design and build of infrastructure	Planning and initial design integration	Prevent and/or minimise weed population growth	Yes	- Long-term reduction in costs and carbon emissions associated with weed management	- Costly, resource and carbon intensive in the short-term - Long lead-in time
Physical	Bring weed population under control	Machine-based	**Cutting:** - Mower - Flail	Destroy above ground weed growth	Yes	- Does not use herbicides	- Costly and carbon intensive in the short to longer-term - Increased treatment frequency relative to glyphosate-based herbicides
			Friction: - Steel brushes	Destroy above ground weed growth	Yes	- Does not use herbicides	- Costly, resource and carbon intensive in the short to longer-term (e.g. production of steel for brushes is carbon intensive) - Brush systems involve very heavy work (reduce shift length to minimise occupational vibration) - Increased treatment frequency relative to glyphosate-based herbicides
			Thermal: - Flame - Hot water - Hot foam - Electricity	**Flame, hot water & hot foam:** - Destroy above ground weed growth **Electricity:** - Destroy above and below ground weed growth	**Flame & hot water:** - No **Hot foam & electricity:** - Yes	- Does not use herbicides **- Hot foam:** 1) Fewer excluded areas 2) Can be applied in all weather conditions	- Costly, resource and carbon intensive in the short to longer-term - Currently use is unregulated - Increased treatment frequency relative to glyphosate-based herbicides - H&S risks may arise - **Flame:** excluded areas as flame poses a significant H&S and environmental risk (cannot be used near parked cars/other flammable materials (e.g. leaves)
		Labour-based	**Cutting:** - Mower - Strimmer - Brush cutter	Destroy above ground weed growth	Yes	- Does not use herbicides	- Costly and carbon intensive in the short to longer-term - Increased treatment frequency relative to glyphosate-based herbicides - Can cause overuse injuries to operator

Figure 1.2 continued.

			Friction: - Hoe	Destroy above ground weed growth	Yes	- Does not use herbicides	- Costly in the short to longer-term - Increased treatment frequency relative to glyphosate-based herbicides - Can cause overuse injuries to operator
			Thermal: - Flame	**Flame:** - Destroy above ground weed growth	Yes	- Does not use herbicides	- Currently use is unregulated - See H&S risks above
Biological	Bring weed population under control	Biocontrol or bioherbicides	N/A	Minimise weed population growth	N/A	N/A	N/A
Chemical (PPPs)	Bring weed population under control	Machine and/or labour-based	**Systemic herbicide:** - e.g. glyphosate	Destroy above and below ground weed growth	Yes	- Low costs and carbon emissions in the short to longer-term	- Uses herbicides
			Non-systemic: herbicide (e.g. acetic and pelargonic acids)	Destroy above ground weed growth	Variable	- Less costly and carbon intensive in the short to longer-term than other physical control methods	- More costly and carbon intensive in the short to longer-term - Increased treatment frequency relative to glyphosate-based herbicides - Products are significantly more expensive than glyphosate-based herbicides
Integrated pest management (IPM)	Bring weed population under control	Combine cultural, physical, biological and/or chemical methods	IPM system (e.g. brush cutter + systemic herbicide)	Destroy above and below ground weed growth	Yes	- Can be more effective than the use of individual control methods in isolation	- Do not integrate weed control methods unnecessarily, for example by treating twice with two different methods where one effective method would be sufficient (doubling the treatment mileage)

1.5 Aims

To test the efficacy and sustainability of three pavement weed control methods in the City of Cardiff. All three weed control methods will be compared with sites throughout the city receiving no weed management (i.e., untreated scientific 'controls'). Further, acetic acid and hot foam weed control methods will be benchmarked against the existing glyphosate-based control method under realistic 'real world' conditions.

Weed control methods will be evaluated against four key criteria:

1. **Cost** - labour is the largest cost component of weed management activities and here it is used to provide a relative economic evaluation of all weed control methods. Costs are a key consideration for the long-term economic sustainability of weed control programmes.
2. **Environmental** - frequently, the environmental impacts of weed management activities are not quantified due to cost considerations. To address this information gap, in the present study the following key variables were measured to address control method environmental sustainability:
    - ***Product use (total)*** - to include all herbicides and/or other compounds added to the water used for each weed control method.
    - ***Water use (total)*** - to include all water used in each weed control method.
    - ***Fuel use (total)*** - to include all hydrocarbons (diesel and petrol) used in each weed control method.
    - ***Life Cycle Analysis (LCA)*** - this will quantify carbon dioxide emissions (CO_2) and other environmental burdens (e.g. primary energy) associated with each control method.
3. **Customer satisfaction** - public complaint data held by Cardiff Council will be used to assess satisfaction with each of the three weed control methods; these results will be compared with previous years (i.e., change in public complaints between 2020 and 2021).
4. **Quality** - direct evaluation of weed control method efficacy (weed level). This will be undertaken 4 times, once before (pretreatment) and three times after (post treatment) weed control methods are applied.

2. Methods

2.1 Experimental design: Cost and environmental data

Prior to undertaking any of the tested weed control methods, Advanced Invasives in consultation with Dr Trisha Toop (Agri-EPI Centre) specified the data required to evaluate control method cost and environmental impacts (e.g. water use), and undertake Life Cycle Analysis (LCA) of control method processes. Data was collected and supplied by Complete Weed Control Ltd (CWC), Cardiff Council and Advanced Invasives (Figure 2.1); details of the equipment, products and materials required to undertake application of the three weed control methods are provided in Appendix 1.

LCA may differ in objectives, scope, simplicity and data intensity. However, all provide a structured, comprehensive and internationally standardised approach to environmental assessment. LCA quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with the entire life cycle of any goods or services ('products'). Increasingly, this approach is being recognised as an important technique for managing the environmental impacts of human activities. LCA can be defined as:

'the interdisciplinary process of identification, analysis and appraisal of all the relevant natural and human processes, which affect the quality of the environment and environmental resources.'

(Kempenaar & Saft 2006)

Life Cycle Analysis (LCA) treatment modelling was undertaken in SimaPro, with report preparation complying to the relevant ISO standards for LCA (Appendix 2).

Data & materials	Supplier
Product specifications (e.g. glyphosate)	CWC Cardiff Council
Product Material Safety Data Sheets (MSDS)	CWC Advanced Invasives
Equipment specifications	Cardiff Council CWC
Product required to undertake the weed control methods	CWC
Water required to undertake the weed control methods	CWC
Fuel required to undertake the weed control methods	CWC
Time taken to undertake the weed control methods	CWC

Figure 2.1: Data & materials specified to evaluate control method cost and environmental variables, and undertake Life Cycle Analysis (LCA) of control method processes. Data & materials suppliers are shown.

Note: only direct labour costs of control method application were included in the cost (economic) and LCA analyses.

2.2 Experimental design: Customer satisfaction

Public complaints regarding weed control standards across the City of Cardiff are collected routinely by Cardiff Council staff via telephone and email correspondence. Prior to analysis, Cardiff Council staff ensured that complaints for the three evaluation wards (Penylan, Riverside Ward, Pontprennau & Old St Mellons) related only to public perception of weed control standards and not 'missed streets' (i.e., streets which have not received weed control).

Note: a ward is a local authority area that is frequently used for electoral purposes.

2.3 Experimental design: Quality

Evaluation wards

Three pavement weed control methods (glyphosate, acetic acid and hot foam) were assigned and trialled in three separate wards of the City of Cardiff and selected areas across the city received no weed management (i.e., untreated scientific 'controls'): weed control methods were applied across the whole of each evaluation ward (Figure 2.2).

Ward	Weed control method	Frequency
Penylan	Glyphosate-based herbicide (Monsanto Amenity Glyphosate XL)	3 times per year
Riverside	Acetic acid-based herbicide (New-Way Weed Spray)	4 times per year
Pontprennau & Old St Mellons	Hot foam herbicide (Foamstream®)	3 times per year

Figure 2.2: Evaluation wards showing weed control method tested and frequency of control method application.

Monitoring sites

Six monitoring sites were identified in each of the three evaluation wards (total number = 18), with a further six untreated control monitoring sites (receiving no weed management) across the City of Cardiff (overall total = 24).

Monitoring sites for each evaluation ward and the untreated control monitoring sites included two:

- Main thoroughfare routes
- Representative residential street routes
- Residential street routes in close proximity to open space/parkland

Details of all monitoring sites are provided in Appendix 3. All monitoring site routes were provided with a route map (see Figure 2.3 below) showing the start and finish of the data collection route.

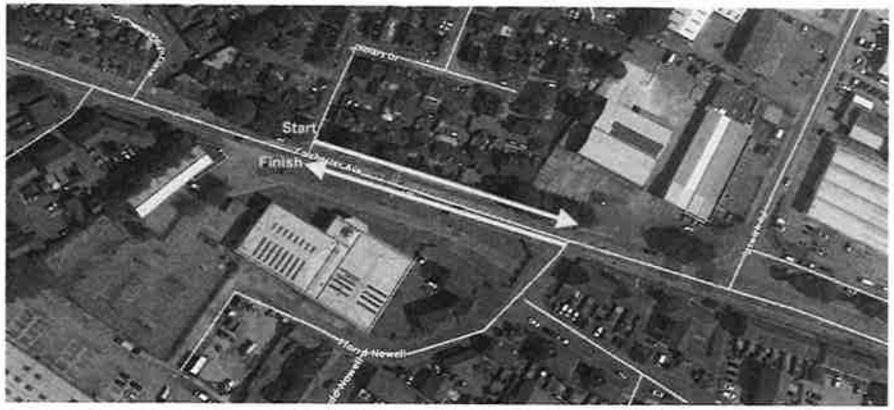

Figure 2.3: Example of monitoring site route map, showing start and finish point of route (image acquisition date 2021; map data © 2022 Google).

Data collection

The overall aim of data collection was to evaluate treatment efficacy throughout 2021 on an on-going basis (i.e., to take comparative 'snapshots' of treatment efficacy throughout the growing season). Data collection was undertaken four times at each monitoring site:

1. Pretreatment - completed by 17/04/21
2. Post treatment 1 - completed by 23/06/21
3. Post treatment 2 - completed by 14/09/21
4. Post treatment 3 - completed by 02/11/21

Data collection involved digital photographic image capture (minimum image resolution settings: 4032 x 3024 pixels). Pretreatment data collection was undertaken by Advanced Invasives, while Cardiff Council staff performed all three post treatment assessments. Cardiff Council staff data collection was preceded by training from Advanced Invasives, supported by a data collection Method Statement (28/04/21).

Digital photographic image capture was undertaken 8 times total per monitoring site (four times on each side of each monitoring site route; Figure 2.3), to include:

- Start of route (looking forwards; image 1)
- Middle of route (looking backwards; image 2)
- Middle of route (looking forwards; image 3)
- End of route (looking backwards; image 4)
- **Repeated for second (opposite) side of route (images 5 to 8)**

Logical landmarks were selected as fixed point photography locations (e.g. street signs, drain covers, lamp posts) during the pretreatment assessments as opposed to marking the pavement as paint may be removed for a variety of reasons during the experiment. Landmark images preceded data image capture to ensure that the same images were captured (including landmarks) at each assessment time.

Weed level

Digital photographic images were retained prior to 'batch' image assessment by one individual (Dr Jones). Each image was assigned a 'weed level' following methods described by East Malling Research (2015a, b) and Bristol City Council (2017) and training received from Cardiff Council staff (Figure 2.4); weed levels were subsequently used to compare weed control method efficacy.

Criteria			Score	Level	Description
Height (mm)	Weed diameter /length (mm)	Joint coverage (mm)			
<10	<50	<10	<3	1	No noticeable weeds
10-50	50-100	0-20	4-6	2	Occasional small weeds
50-100	100-150	20-30	7-9	3	Patchy weed growth with some flowering weeds
100-150	150-200	30-40	10-12	4	Numerous weeds, many flowering, view annoys/irritates public
150-200	200-300	40-50	13-15	5	Numerous large weeds presenting risk, slip and/or trip hazard
>200	>300	>50	16-18	6	Numerous large weeds, many tall and flowering causing an obstruction

Figure 2.4: Weed level scale and evaluation criteria (adapted from East Malling Research (2015a, b) and Bristol City Council (2017).

Assessments were based on the following:

- 8 observations per street (mean weed level score 1-6)
- 6 streets per ward
- 4 wards (mean weed level score 1-6)
- 192 observations per assessment
- 4 assessments
- 768 observations overall

Weed levels were based on the following areas of operation:

- Pavement
- Base of trees and tree pits

The following areas were excluded from the assessment:

- Gutters
- Gully pots (drains)
- Roads
- Landscaping

2.4 Data analysis

Cost data

Number of treatment applications (treatment frequency), treatment application time (hrs), equipment cleaning time (hrs) and the number of operators required to undertake each weed control method were calculated to provide:

- *Labour time/treatment (hrs/person)*
- *Total labour time (hrs/person)*

Note: due to changes in how the hot foam machine was vehicle mounted and the reduced working day length in the second and third treatments, relevant cost data was averaged across the three treatments, to provide working day mean values supplied in Figure 2.5.

Process	Average time (mins)
Equipment pickup - yard	60.0
Fill up tank (780 L)*	45.0
Empty tank**	72.9
Fill up tank (780 L)*	45.0
Empty tank**	72.9
Lunch	60.0
Fill up tank (780 L)*	45.0
Empty tank**	72.9
Equipment drop - yard	60.0
Total time	**533.8 mins (8.9 hrs)**

Figure 2.5: Working day mean values for hot foam application processes based on three treatments undertaken by CWC. Where: *tank fill using street hydrant - this time is longer using lower pressure mains supply from a residential property (c.1 hr); **tank emptying speed is based on mean time per tank, averaged across the three treatments. **Note:** older residential areas also do not have as many street water hydrants, meaning that that tank filling is slower than in newer residential areas. Application time can be increased further through operator and equipment downtime and obstacles such as inaccessible roads etc.

Environmental data - product, water and fuel use

Number of spray tanks, spray volume (L), total product use per treatment (L) and the product/tank (L) required to undertake each weed control method were calculated to provide:

- *Total product use (L)*
- *Total water use (L)*

Treatment (machine) fuel (L), vehicle fuel (L) and fuel use/treatment (L) required to undertake each weed control method were calculated to provide:

- *Total diesel use (L)*
- *Total petrol use (L)*

Treatment distance and units of analysis

Distance per treatment (km; glyphosate, acetic acid, hot foam) was calculated from ward route data suppliec by CWC. These data were then used to calculate:

- *Labour (hrs)/km*
- *Product use (L)/km*
- *Water use (L)/km*
- *Diesel use (L)/km*
- *Petrol use (L)/km*

Life Cycle Analysis (LCA) data

Product, water and fuel use per unit distance (km) were used to assemble the LCA.

Customer satisfaction data

Public complaint data supplied by Cardiff Council before (2020) and after (2021) the application of the pavement weed control methods (glyphosate, acetic acid and hot foam) was used to highlight any change in customer satisfaction across three Cardiff electoral wards (Figure 3.5).

Quality data

Following 'batch' image assessment, a single overall average (mean) weed level was calculated for the glyphosate, acetic acid and hot foam treatments and untreated control at each assessment before (pretreatment) and three times after (post treatment) weed control methods were applied.

2.5 Data collection and reporting

Data collection and archiving was conducted in accordance with ORETO standards (certification held by Swansea University; Advanced Invasives operate under this certificate).

Further to the final report provided in journal format style, the following has been made available:

- Raw data
- Statistical package analysis outputs
- Graph images (high resolution)
- Digital photograph record pre and post treatment (high resolution)

3. Results

3.1 Cost comparison

Glyphosate was the least labour intensive of the three pavement weed control methods tested with a labour requirement of 0.16 hrs/km to undertake (Figure 3.1). Acetic acid was more labour-intensive than glyphosate requiring 0.23 hrs/km to undertake. The labour requirement of hot foam was the largest, being 31 times greater than that of the glyphosate-based weed control method (4.89 hrs/km).

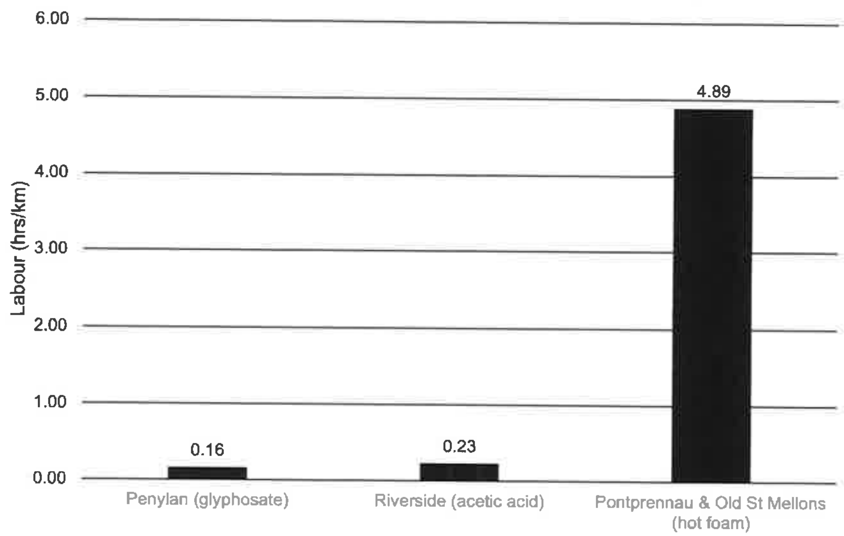

Figure 3.1: Total labour requirement (hours per kilometre) to undertake three pavement weed control methods (glyphosate, acetic acid and hot foam) across three Cardiff electoral wards.

3.2 Environmental comparison

Product use (total)

Glyphosate required the least product of the three pavement weed control methods tested using 0.33 L/km of glyphosate (Figure 3.2). Acetic acid used 4.06 L/km of acetic acid i.e., 12 times more herbicide than glyphosate. The product requirement of hot foam was the largest, being 16 times greater than that of glyphosate (5.38 L/km).

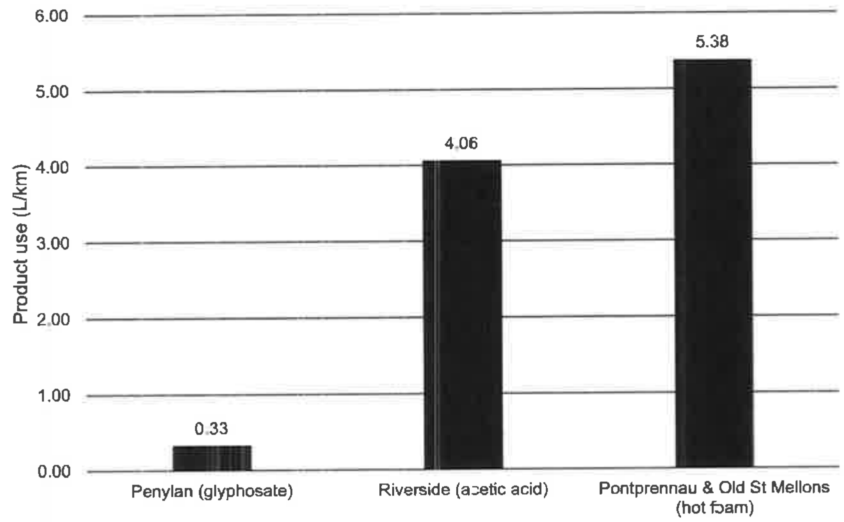

Figure 3.2: Total product use (litres per kilometre) to undertake three pavement weed control methods (glyphosate, acetic acid and hot foam) across three Cardiff electoral wards.

Water use (total)

Glyphosate used 13.00 L/km of water to apply (Figure 3.3), while acetic acid used 8.44 L/km i.e., less water than glyphosate to apply. Water use of hot foam was significantly greater than that of the glyphosate or acetic acid-based weed control methods and was 48 times larger than that of glyphosate (629.64 L/km).

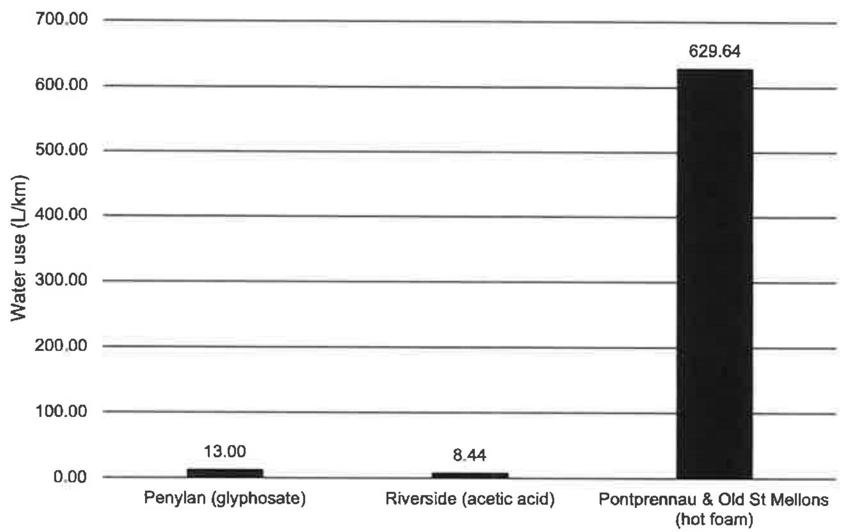

Figure 3.3: Total water use (litres per kilometre) to undertake three pavement weed control methods (glyphosate, acetic acid and hot foam) across three Cardiff electoral wards.

Fuel use (total)

Glyphosate used the least fuel of the three pavement weed control methods tested requiring 0.18 L/km of diesel and no petrol (Figure 3.4). Acetic acid-based weed control used more fuel than glyphosate requiring 0.19 L/km diesel and no petrol. The fuel use of hot foam weed was greater than that of glyphosate or acetic acid-based weed control: hot foam diesel use was 63 times greater (12.33 L/km) and petrol use was 100 % greater (2.13 L/km) than that required for the glyphosate-based weed control method (12.33 and 0.00 L/km, respectively).

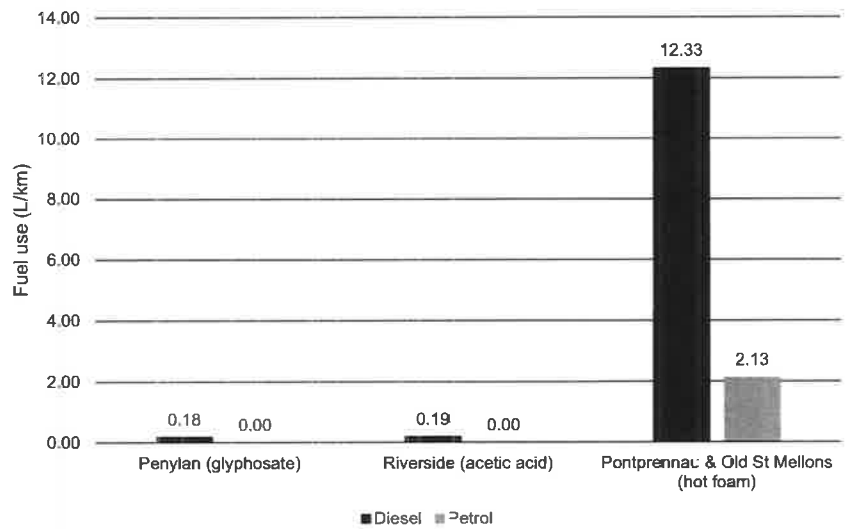

Figure 3.4: Total fuel use (litres per kilometre) to undertake three pavement weed control methods (glyphosate, acetic acid and hot foam) across three electoral wards in the City of Cardiff.

3.3 Life Cycle Analysis (LCA)

Direct comparison was made between all weed control methods per 1 km of pavement treated (Figure 3.5; Appendix 2). Foamstream® has higher environmental impacts in all impact categories calculated except for freshwater eutrophication.

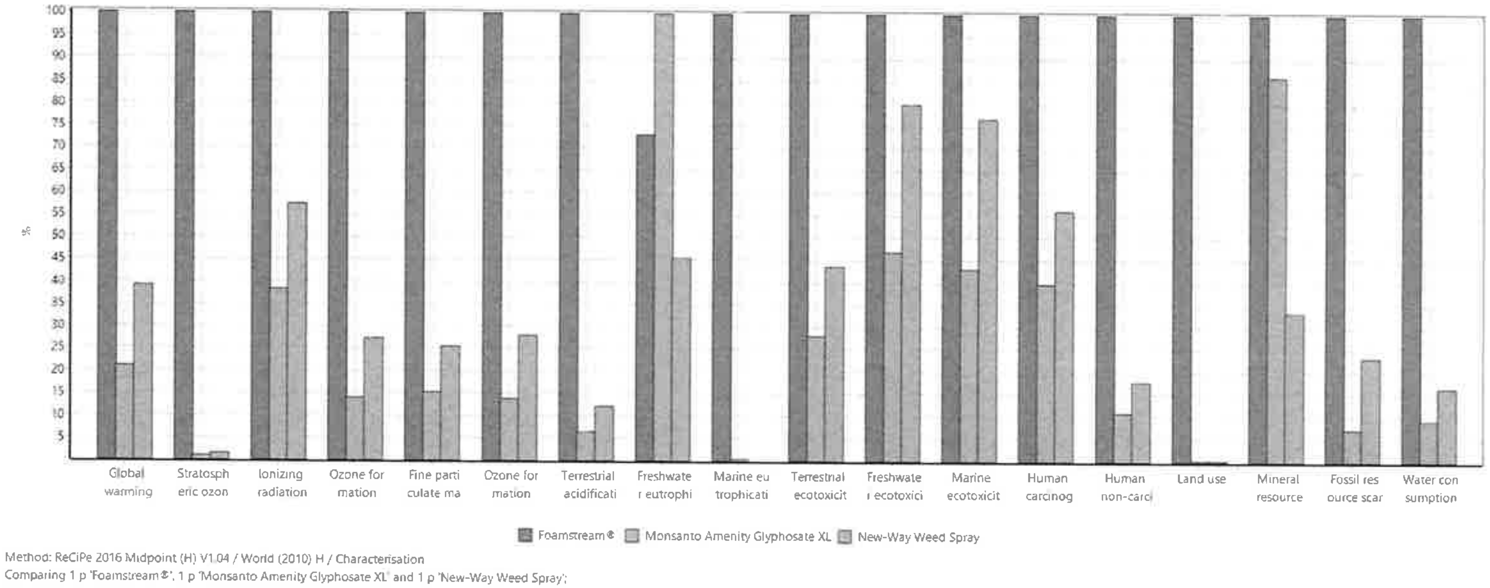

Figure 3.5: LCA comparison of three pavement weed control methods (hot foam, glyphosate and acetic acid) environmental impacts across three electoral wards in the City of Cardiff. Relative percentage (%) contribution of each treatment to assessed impact categories is shown.

Details of the environmental impacts for the weed treatments tested are shown in Figure 3.6 (see Appendix 2). All impacts relate back to the functional unit of 1 km of pavement treated.

Impact category	Unit	Monsanto Amenity Glyphosate XL	New-Way Weed Spray	Foamstream®
Global warming	kg CO2 eq	3.725906632	6.920265219	17 62954775
Stratospheric ozone depletion	kg CFC11 eq	0.00	3.71233E-06	0.000219686
Ionizing radiation	kBq Co-60 eq	0.333211153	0.499734199	0.870118201
Ozone formation, Human health	kg NOx eq	0.008903155	0.01745232	0.064022231
Fine particulate matter formation	kg PM2.5 eq	0.00736806	0.0123352	0.048506821
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.009142212	0.0186019	0.066531821
Terrestrial acidification	kg SO2 eq	0.014106715	0.02609239	0.215053388
Freshwater eutrophication	kg P eq	0.005180359	0.002346239	0.003780149
Marine eutrophication	kg N eq	0.000345545	0.000150603	0.059807027
Terrestrial ecotoxicity	kg 1,4-DCB	16.26066476	25.29477007	58.13958906
Freshwater ecotoxicity	kg 1,4-DCB	0.250487795	0.427871658	0.534874363
Marine ecotoxicity	kg 1,4-DCB	0.31026383	0.554566163	0.72170849
Human carcinogenic toxicity	kg 1,4-DCB	0.167244915	0.236177538	0.421593391
Human non-carcinogenic toxicity	kg 1,4-DCB	4.463951492	7.370060901	41.27578609
Land use	m2a crop eq	0.101314072	0.127103301	33.33581954
Mineral resource scarcity	kg Cu eq	0.064759475	0.025142473	0.075130588
Fossil resource scarcity	kg oil eq	1.337191228	4.259576156	18.29370741
Water consumption	m3	0.104360548	0.186825836	1.133128599

Figure 3.6: Results from the LCA comparison of the environmental impacts of three pavement weed control methods (glyphosate, acetic acid and hot foam) across three electoral wards in the City of Cardiff.

3.4 Customer satisfaction comparison

From a single complaint in 2020, glyphosate weed control complaints rose four-fold to 4 in 2021, though this control method overall received the fewest complaints in 2020 and 2021 (Figure 3.7). Between 2020 and 2021 public complaints more than tripled following the application of acetic acid from 8 complaints in 2020 to 29 complaints in 2021. Only hot foam public complaints declined between 2021 and 2020 from 23 to 22 complaints.

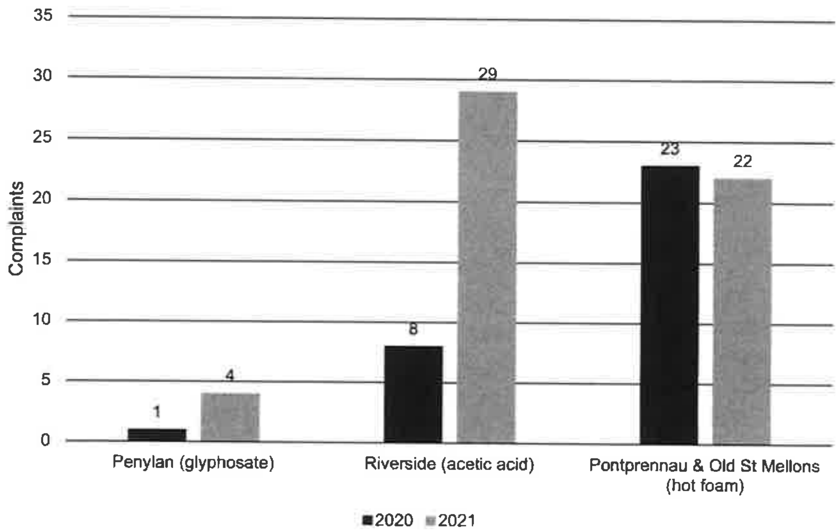

Figure 3.7: Total public complaints before (2020) and after (2021) the application of three pavement weed control methods (glyphosate, acetic acid and hot foam) across three Cardiff electoral wards.

3.5 Quality

Figure 3.8 shows average (mean) weed levels for all weed control methods and the untreated control. In Penylan (green line), Riverside (blue line) and the untreated control (grey line) spring growth of annual and perennial weeds is underway in April (weed level range 1.6 to 1.8), despite extended cold conditions in spring 2021. As summer approaches in June (weed level range 2.1 to 3.1), maximum weed level is reached for Riverside (acetic acid; 3.1) and this is maintained until early November 2021. Independently, Penylan (glyphosate) and CONTROL (no treatment) weediness increases to September (POST 3) though both show a decline thereafter; it is notable that glyphosate-based weed control provides the greatest reduction in between assessment weed level of the three pavement weed control methods (glyphosate, acetic acid and hot foam) from 2.4 in POST 2 to 1.3 in POST 3 (lowest observed value). The Hot foam control method maintains the weed population at a low level throughout the year (1.4 from PRE to POST 2), before the weed level rises slightly to 1.6 in POST 3.

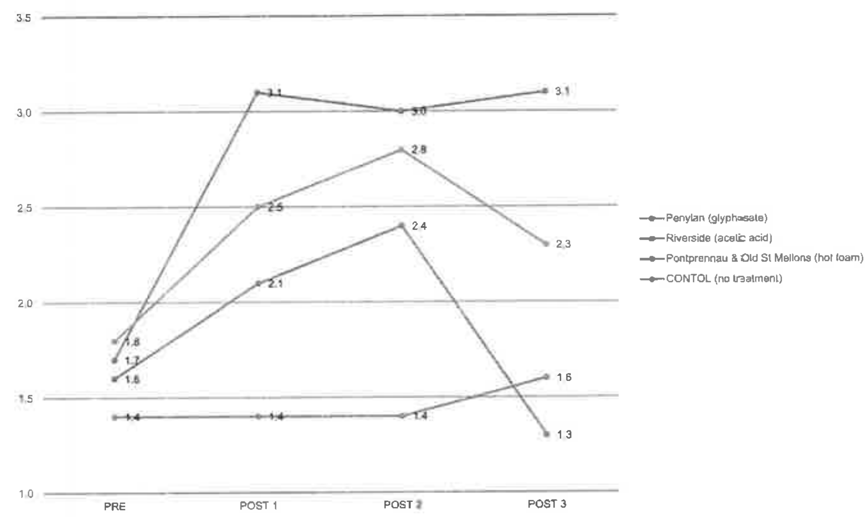

Figure 3.8: Weed level (low = 1; high = 6) before (PRE) and after (POST 1-3) the application of three pavement weed control methods (glyphosate, acetic acid and hot foam). Where: Pretreatment (PRE) completed by 17/04/21; Post treatment 1 (POST 1) completed by 23/06/21; Post treatment 2 (POST 2) completed by 14/09/21, Post treatment 3 (POST 3) completed by 02/11/21.

4. Discussion

4.1 Key criteria - results summary

Section 3 reports on pavement weed control testing results in the context of four key criteria (cost, environmental, customer satisfaction and quality). These results are summarised in Figure 4.1 and discussed further in the context of efficacy, practicality and sustainability at the UK and European levels below.

Control method	Cost	Environmental	Customer	Quality
Glyphosate	Low	Low	High	High
Acetic acid	Medium	Medium	Low	Low
Hot foam	High	High	High	High

Figure 4.1: Summary of pavement weed control results evaluated against four key criteria (cost, environmental, customer satisfaction and quality). Where: red = negative outcome vs. key criteria; orange = intermediate outcome vs. key criteria; green = positive outcome vs. key criteria. Environmental criteria include: product use (total), water use (total), fuel use (total) and Life Cycle Analysis (LCA) outputs.

4.2 Cost

Project evaluation

Labour is the largest cost component of weed management programmes and here it is used to provide a relative economic evaluation of the weed control methods. Glyphosate required the least labour to undertake (0.16 hrs/km Figure 3.1). Acetic acid took longer to undertake (0.23 hrs/km), while hot foam took 4.89 hrs/km to undertake; this is 31 times greater than the glyphosate-based weed control method (0.16 hrs/km). This is because glyphosate-based herbicides provide almost complete kill of most pavement weed species, while other control methods mainly affect the above ground plant parts (Figure 1.2; Rask et al. 2013). Therefore, control methods which do not involve the use of glyphosate require repeated treatments and increased costs and may lead to the unnecessary waste of energy (Rask et al. 2013).

Based only on labour costs, application of hot foam alone is therefore 31 times more expensive than glyphosate; however, it is notable that this estimated cost does not account for the greater equipment purchase costs associated with hot foam treatment compared with the application of both acetic acid and glyphosate. From a practical standpoint, all control methods were tested on individual wards and it should be emphasised that if control methods were to be applied at the city scale (29 wards), these costs would rise substantially (in part due to the impracticalities of hot foam application).

Based on the Cardiff Council weed control contract route (c. 2,000 km), Chris Phillips (Managing Director, CWC) estimated the following labour requirement for glyphosate and hot foam control methods citywide:

- Glyphosate
    - 8 weeks labour (40 hr weeks)
    - 2 machines, 2 people per machine
- Hot foam
    - 248 weeks labour (40 hr weeks)
    - 5 machines, 3 people per machine
    - Machines would be working constantly

This research and practical understanding of control method application demonstrates the economic sustainability of glyphosate and, to a lesser extent, acetic acid (Figure 4.1). In contrast, the economic sustainability of hot foam is limited, particularly over larger spatial areas (i.e., citywide), though this control method may prove useful in smaller (discrete) areas where it is earmarked for specific tasks (e.g. children's play areas).

Note: it is possible to rebuild the Weed-IT machines for acetic acid application by changing the internal seals to minimise clean down times between treatments (Bristol City Council 2017, Phillips pers comm. 2021).

Wider context

In the UK, North Yorkshire County Council tested hot foam in 2021 and due to cost and logistical considerations in more rural areas of the county they will not be deploying this control method in the coming years (City of York Council 2022). During 'The Cotham Trial' undertaken by Bristol City Council (UK), Bristol Waste Company (BWC) estimated that the relative cost of each control method trialled:

- Glyphosate = £60,000 per application
- Acetic acid = £216,000 per application
- Hot foam = £392,000 per application

BWC noted the difficulty of assembling these cost estimates. Further, cost estimates were based on the 20 km distance of The Cotham Trial; in contrast the total treatment distance of the Cardiff Council Trial was 10 times larger (c.235 km), meaning that cost estimates (and the comparability of these) is based on more extensive data. Regardless, the BWC cost estimate for acetic acid treatment was 3.6 times greater than glyphosate, while hot foam treatment was 7 times more than that of glyphosate. In short, as Bristol City Council state:

> *'What is clear is that the use of acetic acid and hot foam are always considerably more expensive than glyphosate.'*
>
> (Bristol City Council 2017)

Note: New-Way Weed Spray is the only legally approved and available professional acetic acid based herbicide in the UK. For comparative purposes other pavement weed control trials in the UK and Europe utilising acetic acid-based herbicides are referred to in this section, though application details (i.e., product formulation and application rates) are frequently not reported. It is notable that New-Way Weed Spray has a very low acid content, relative to diluted acetic acid and other non-optimised product formulations tested 10-15 years ago, being specifically co-formulated with adjuvants, spreaders etc. to increase herbicidal activity.

In the Netherlands, Kempenaar & Saft (2006) reported the cost of hot water being approximately 4 times greater than that of glyphosate-based weed control (Figure 4.2), while Kempenaar & van Dijk (2006) reported costs of physical weed control methods being 2-8 times greater than those of glyphosate-based weed control. 'The Thanet Trial' undertaken by East Malling Research on behalf of Defra provided similar cost estimates, with hot foam being upto 8 times more expensive to apply than the application of glyphosate alone (EML 2015b). It is likely that the increased costs reported in the present Cardiff Council Trial reflect the size (spatial scale) of the experiment and the smaller number of control methods tested, providing detailed comparison of relative treatment costs at the citywide scale (i.e., 'like-for-like comparisons'; Rask & Kristoffersen 2007, Fagot et al. 2011, Martelloni et al. 2020).

It is notable that few weed control experiments outside of the agricultural sector are big enough (scaled appropriately) that strong (robust) conclusions can be made and later applied practically over large areas. Rather, large-scale management recommendations are based on small-scale case studies and experiments which do not provide enough information to inform wider best practice management (Jones et al. 2018).

System	Threshold weed growth specification			
	Little weed growth*		Very little weed growth**	
	Frequency	Costs (€ m^{-2})	Frequency	Costs (€ m^{-2})
1. Brushing	3	0.19-0.38	3.5-5	0.20-0.40
2. Flame	N/A	N/A	5	0.15-0.35
3. Hot water	2.5	0.22-0.32	3-4	0.30-0.40
4. Herbicides	2	0.05-0.08	2.5	0.07-0.10

Figure 4.2: Annual frequency of application and cost per square metre (m^{-2}) of four pavement weed control methods in the Netherlands in 2005. Where: *little weed growth means less than 25 % of bare soil in the pavement is covered by weeds, very few weeds taller than 5 cm and no clumps of weeds; **very little weed growth means less than 5 % of bare soil is covered by weeds, no weeds taller than 5 cm and no clumps of weeds (adapted from Kempenaar & Saft 2006).

4.3 Environmental - product, water and fuel use

Weed control practices in the UK amenity (non-agricultural) sector differ from those in agriculture. For example, while 'blanket' herbicide application in agricultural crops may be permitted, in the amenity sector such treatments in paved areas (i.e., non-porous hard surfaces) are not permitted as there is little surface absorption of pesticide and consequently, there is a high risk of run-off to drains and water bodies (HSE 2012). Therefore, to meet legislative requirements, pavement weed control methods are 'spot treatments' made to visible weed vegetation only when the plants are actively growing. In practice, all control methods evaluated in the present study (acetic acid, glyphosate and hot foam) are spot treatments and were not applied in a blanket fashion along the whole length of the Cardiff Council weed control contract route (c. 2,000 km).

Product use

Understanding that pavement weed control involves the direct targeting of weeds is important for understanding product use volumes (Figure 3.2). Glyphosate application used the least product (0.33 L/km), while acetic acid and hot foam used larger product quantities (4.06 and 5.38 L/km, respectively). The low product application volume associated with glyphosate is the result of a number of key factors:

- Glyphosate poisons whole plants effectively at low application rates (i.e., it is highly specific and 'systemic' through all parts of the plant).
- Precision targeting of herbicides directly at living green plant material (via near infra-red (NIR) light) using devices such as the Weed-IT.
- Effective, low herbicide application rates achieved through the inclusion of appropriate spray additives such as water conditioners that buffer acid-base balance (pH) in the herbicide spray, freeing up glyphosate molecules to do more work.

The larger acetic acid product application volume mainly relates to the fact this molecule is not specifically poisonous (herbicidal) to plants, does not work at low concentrations and does not move around all parts of the plant (i.e., it is not systemic). Consequently, despite the use of Weed-IT machines, the product application rate is far greater than that associated with glyphosate-based weed control. This presents a logistical challenge for operators as large product volumes are required for relatively small areas of pavement, reflecting results reported by Hansson et al. (2006) in Sweden.

Hot foam required the most product per unit distance, in part due to the application of hot foam with a hand lance as opposed to precision equipment. Importantly, the herbicidal component of hot foam is not the product, but rather the (non-specific) hot water applied with the foaming product mix; therefore, a larger volume of water and product are required compared with specific chemical control methods such as glyphosate. Further, the hot foam product contains plant oils and sugars and such molecules require sourcing, processing, manufacture and transport to the point of use. Therefore, the environmental burdens of such processes are high and accompanied by greater overall product use (16 times more hot foam product is used that glyphosate), which may lead to wider human health and ecotoxicological concerns (see: Life Cycle Analysis (LCA); section 6.4 Report statement: impact of weed control methods on pollinators).

Water use (total)

Understanding that pavement weed control involves the direct targeting of weeds is important for understanding water use volumes (Figure 3.3). Acetic acid application used the least water (8.44 L/km), while glyphosate used 13.00 L/km and hot foam application used 629.64 L/km; this represents a water use 48 times greater than that of glyphosate application. The large associated water use of hot foam is principally due to the use of hot water as a non-specific herbicide. While this is addressed in the Life Cycle Analysis (LCA) section, it is important to note that the abstraction, supply and subsequent heating of drinking (potable) water to 98 °C (Appendix 1) requires large amounts of energy and consequently, these carbon intensive processes undermine both the economic and environmental sustainability of hot foam for pavement weed control.

Note: less water is used to apply acetic acid compared with glyphosate as the herbicide product volume per unit distance is much greater than that of glyphosate i.e., more herbicide and less water is required for application.

Fuel use (total)
Per unit distance, glyphosate and acetic acid-based control methods required the least fuel to undertake, with glyphosate requiring 0.18 L/km petrol and 0.00 L/km diesel (Figure 3.4) and acetic acid requiring 0.19 L/km petrol and 0.00 L/km diesel. The slightly higher petrol requirement of the acetic acid control method is due to the additional treatment per year (four), compared with glyphosate (three; Figure 2.2). In contrast, hot foam requires 12.33 L/km petrol and 2.13 L/km diesel i.e., 100 % more petrol than glyphosate or acetic acid application and 63 times more diesel than glyphosate application. There are two main reasons for the greater hydrocarbon requirement of the hot foam control method:

- Hot foam was originally applied using an L12 Foamstream machine mounted on a flatbed truck; in the second and third treatment, the machine was remounted on a Toyota Hilux. In contrast, Weed-IT machines are mounted on much smaller quad vehicles with lower fuel requirements.
- Water in the hot foam control method is heated by the Foamstream machine to 98 °C (Appendix 1) prior to application and this requires very large amounts of energy, particularly when this control method is applied over larger areas.

Hot foam is therefore a carbon intensive control method, the environmental sustainability of which should be carefully considered prior to widespread deployment as a pavement weed control method (see Life Cycle Analysis; Figure 4.1; APSE 2020).

Wider context - product, water and fuel use
Often, hard surface weed control methods which are not based on the use of systemic herbicides (normally glyphosate) lack information about their product, water and fuel use. Further, due to the need for more frequent treatments, their use of product, water and fuel are often greater than control methods based on the use of glyphosate (Figure 1.2). More frequent treatments are required using these methods because they mainly affect the aboveground plant parts, whereas systemic herbicides (i.e., glyphosate) kill the entire plant and therefore only require one or two treatments per year (Rask & Kristoffersen 2007).

Treatment frequency depends on factors including:

- Type of hard surface
- Weed control method
- Weed acceptance level
- Weed cover
- Climate
- Weed species composition

In Denmark, experiments evaluating different thermal methods and brushing on pavements during a three year period suggested that 11-12 treatments per year were necessary to achieve acceptable weed control on areas heavily infested with perennial weeds, regardless of the method applied. In the Netherlands, experiments on pavements used fewer treatments, with 4-6 brushing treatments, and 3-5 flame and hot water treatments per year. In general, treatment at an early developmental stage reduced fuel inputs, increased driving speed and reduced labour costs (Rask & Kristoffersen 2007).

In the UK, Bristol City Council (2017) estimated that hot foam application used between 75-85 times more water (15,000 to 17,000 L/hectare) than glyphosate application (200 L/hectare). While the estimated units provided by Bristol City Council differ from those provided in the present Cardiff Council Trial (L/hectare as opposed to L/km); proportional estimated hot foam water use compared with glyphosate application was greater in Bristol (75-85 times more water) than that recorded in the Cardiff Council Trial (48 times greater). City of York Council (2022) reported that hot foam application used on average between 1,000 to 1,500 litres of water per day, depending on how soiled/weeded the treatment area; this equates to around 0.5 tonnes carbon dioxide (CO_2) emissions per day. Reported water use in the City of York (2022) was less than that recorded in The Thanet Trial (c.4,000 to 6,000 litres of water per day; EMR 2015b) and the Cardiff Council Trial (2,340 litres of water per day; Figure 2.5). In summary, product, water and fuel use was consistently lower for glyphosate application than all other control methods tested in The Thanet Trial, the Cardiff Council Trial and by the City of York (EMR 2015b, Bristol City Council 2017, City of York Council 2022). Bristol City Council note:

> *'The operational speed, problems with transporting large amounts of water combined with high energy use give a high price and environmental impact. Whether the high energy doses needed for thermal treatments can be considered as sustainable needs careful consideration.'*
>
> (Bristol City Council 2017)

4.4 Environmental - Life Cycle Analysis (LCA)

Foamstream® had the highest environmental impacts in all categories except for that of freshwater eutrophication, where Monsanto Amenity Glyphosate XL had the higher impact (Figures 3.5 & 3.6; Appendix 2). Both Monsanto Amenity Glyphosate XL and New-Way Weed Spray control methods have an overall lower environmental impact than Foamstream®; and the treatment that has the lowest overall environmental impact is Monsanto Amenity Glyphosate XL. These impact assessment results were not surprising given the higher number of inputs into the Foamstream® system. Further information from the manufacturers on the overall composition of the control method product (Foamstream® V4) would give more accurate results.

Note: a conservative approach was taken on how to determine the composition of the Foamstream® V4 product from information that was available and this will have resulted in an underestimation of the environmental impact. If further information becomes available at a later date it is recommended that the LCA be recalculated.

Wider context - Life Cycle Analysis (LCA)

In summary, the overall LCA conclusion is that Monsanto Amenity Glyphosate XL has less environmental impact than the other control methods tested in this study. Results found in the Cardiff Council Trial above are comparable to those found in a similar UK study of weed treatments for controlling weeds on hard surfaces (The Thanet Trial; EMR 2015b). East Malling Research (EMR) found that freshwater impacts are the only ones where glyphosate-based control methods are higher than those of non-herbicide approaches. However, EMR only investigated the use of integrated (IPM) treatment approaches, making direct comparison of figures difficult, but broadly comparable in general.

In the Netherlands, an LCA investigating pavement weed control methods (Kempenaar & Saft 2006) also found that freshwater impacts (aquatic ecotoxicity) contributed toward elevated glyphosate-based control method results, but noted that physical control methods (brushing, flaming and hot water) produced less favourable results than herbicide application.

4.5 Customer satisfaction

Customer satisfaction was measured by comparing the change in public complaints between 2020 and 2021 for each pavement weed control method (Figure 3.7). Between 2020 and 2021, glyphosate showed a small increase in complaints (from 1 to 4), while hot foam showed a small decrease in complaints (from 23 to 22). In contrast, the application of acetic acid more than tripled public complaints between 2020 and 2021, from 8 to 29. Consequently, customer satisfaction is rated high for glyphosate and hot foam, but low for acetic acid (Figure 4.1).

In the UK, City of York Council (2022) reported public complaints only following the application of acetic and pelargonic acids. In contrast, complaints were received by Bristol City Council (2017) following application of all control methods in equal numbers. Due to differences in trial approach, it is not possible to make more general comments regarding customer satisfaction following the application of pavement weed control methods.

4.6 Quality

Weed control method efficacy was measured four times using a weed level (low = 1; high = 6) before (PRE) and after (POST 1-3) the application of the three pavement weed control methods (Figure 3.8). The quality of acetic acid was poor throughout the year, while glyphosate took some time to bring the pavement weed population under effective control following plant growth in spring and summer. In contrast, the hot foam control maintained the weed population at a low level until late in the year, when the weed level increased slightly from 1.4 to 1.6 in POST 3. This late increase in weed level is likely to reflect regrowth of weeds with deeper roots treated earlier in the year; hot foam does not kill the root systems of perennial pavement weeds allowing recovery from control method application.

Glyphosate and hot foam were the most effective control methods, though the underlying design and build of pavements in the respective wards are likely to have influenced treatment efficacy. Paving in Pontprennau & Old St Mellons (hot foam) consisted of sealed tarmac paths which leave few gaps for weed growth; in contrast, footpaths in Riverside and Penylan (acetic acid and glyphosate, respectively) consist of slab paving with many more gaps available for weed colonisation and subsequent growth. These differences in design and build should be considered in the context of overall treatment quality (Figure 4.1; Rask & Kristoffersen 2007).

Wider context - quality

In the UK, Bristol City Council (2017) state that acetic acid can be as effective as glyphosate for weed control if it is applied more frequently; however the treatment frequency and likely costs associated with this are not provided, though they are likely to be prohibitively expensive (Bristol City Council 2017). Following the application of acetic and pelargonic acids, City of York Council reported that weeds survived application of the control methods and continued to grow, resulting in more public complaints (Bristol City Council 2017, City of York Council 2022). Mirroring trial results in the UK, Hasson et al. (2006) state that acetic acid does not work against perennial weeds growing in paved areas, resulting in increased treatment frequency and presumably greater negative environmental impacts (Figure 4.1).

In Belgium, Fagot et al. (2011) note that while there are a large number of alternative (non-herbicide) weed control methods available for use on hard surfaces, these are less effective than glyphosate-based herbicides, requiring more frequent treatments. Further, the effectiveness of alternative control methods is strongly related to weed species and growth stage at the time of treatment. For example, weeds which grow flat on the ground (prostrate), with protected growth points (meristems) and narrow, thick leaves such as Procumbent Pearlwort (*Sagina procumbens*), show a greater tolerance to thermal treatments. This is because lethal heat transfer to the growing points and deeper plant tissues is reduced compared with upright plants which are fully exposed to treatment. Similarly, mechanical weed control methods are less effective in removing deep-rooted, broad-leaved perennials with protected growth points near or below ground level (e.g. Dandelion, *Taraxacum officinale*; Broadleaf Plantain, *Plantago major*). Further, these species can regrow quickly, even after full removal of all aboveground plant growth (defoliation; Rask & Kristoffersen 2007, Fagot et al. 2011).

Rask et al. (2013) reported that there was no significant difference between the number of required treatments per year with hot water or glyphosate. However, while hot water, air and steam are safer than flame (Figure 1.2), the energy consumption associated with these control methods are greater. Further, while hot foam systems may be practical in certain settings (e.g. traffic islands), the purchase price of the equipment is high compared with flamers on the market (Rask & Kristoffersen 2007, Rask et al. 2013). Broadly, these findings align with those of the present Cardiff Council Trial; while hot foam is an effective control method, the costs and environmental impacts of the system are in most cases greater than those of glyphosate-based pavement weed control methods (Figure 4.1).

Due to the efficacy, ease of use and low cost of glyphosate, this herbicide is the mainstay for weed control on hard surface areas such as roads and pavements in the UK and Europe (Hasson et al. 2006, Rask & Kristoffersen 2007, Bristol City Council 2017, City of York Council 2022). However, a concern with the frequent use of glyphosate in urban areas is that despite having a safe environmental profile, if it is the only herbicide used in these settings it is highly likely that it will be detected in surface waters due to the total quantity being used (Ramwell 2006). Correct (legal) use of glyphosate is therefore fundamental to minimising the environmental risks posed by this compound. For example, avoiding gully pots (drains) reduced potential contamination of water courses with glyphosate-based herbicides in the Netherlands by 15 % (Ramwell 2006, Kempenaar et al. 2007).

5. Conclusions

5.1 Overview of findings

Previous pavement weed control trial experiments have been limited by:

- **Small-scale studies** - logistical problems and increased environmental and economic costs (e.g. equipment access, water use) may not show up in smaller trials and are only seen when the control methods are scaled up to larger areas.
- **Short-term studies** - studies that are very short (less than one month) often overestimate the effectiveness of weed control methods that damage aboveground weed growth as the experiment does not last long enough to observe any weed regrowth.
- **Not comparing 'like with like'** - control methods are not compared directly with one another or are compared with non-standard approaches; this may result in overestimating control method efficacy and sustainability (Rask & Kristoffersen 2007, Fagot et al. 2011, EMR 2015b, Martelloni et al. 2020).

Further, previous research has found that in all but a few limited settings, the efficacy of a number of physical weed control methods (friction, thermal, covering) has been limited (Kempenaar et al. 2007, De Cauwer et al. 2013, Wynn et al. 2014).

To deliver sustainable weed management over large areas it is essential that control methods are examined scientifically to determine how well they work (efficacy) and how large their environmental and economic impacts are i.e., using an Integrated Pest Management (IPM) approach to testing (Jones & Eastwood 2019). The scientific (reproducible) approach followed in the current experiment enables us to find out what works under 'real world' conditions and then make evidence-based decisions on how we want to manage weeds. This is in sharp contrast to the 'trial and error' approach normally taken, which frequently results in the application of more expensive and environmentally harmful control methods due to increased resource use (labour, water, product) and carbon dioxide (CO_2) emissions. Further, there is a misunderstanding that IPM means that herbicides should not be used. What IPM actually means is that weed control methods should be sustainable; where experiments show that control methods which are not based on herbicides are ineffective and unsustainable, they should not be used to ensure that overall sustainability criteria are met. The IPM approach to testing control method efficacy and practicality followed in the Cardiff Council Trial is crucial to ensuring treatment sustainability in the longer-term.

If pavement weed control is understood to be necessary, it must be accepted that the management approach selected will involve compromises - it is unlikely there is a 'silver bullet' control method. The results of the present trial, based on testing over large areas (large spatial scales e.g. citywide) show that glyphosate was the most effective and sustainable weed control method tested, while hot foam was effective but unsustainable and acetic acid was both ineffective and unsustainable. However, glyphosate is not without proven drawbacks, such as freshwater eutrophication (Figure 3.5; Appendix 2) which has led to its use in water being banned in all but a few European countries (Kudsk & Mathiassen 2020). Understanding the pros and cons of each control method enables us to make reasoned decisions on how we reduce the environmental and economic impacts of weed control, ultimately improving management sustainability at the landscape scale.

5.2 Wider context - overview

Urban areas throughout Europe spend a great deal of time and money on hard surface weed control. Historically, because of the effectiveness, low cost and ease of use of glyphosate, it was widely used as the main tool used for weed management in these settings. However, as pesticide use has been restricted at the EU-level through to the regional scale in some EU countries, alternative control methods have been sought (DIAS Report No. 126 2006).

However, 'alternative' implies a 'substitute' for glyphosate-based herbicides; presently, there are no comparable control methods available for the large-scale management of weeds in urban and rural areas. To illustrate this, many Swedish municipalities implemented a total ban or restrictions on the use of glyphosate and other herbicides since 1996. In 2006, reporting on 10 years of glyphosate restrictions, SKL reported that

'The situation is in several cases so critical that one must at the strategic decision level decide to either increase the resource allocation for sanitation and weed control, or start a long-term work to phase out hardened surfaces to reduce the resource-intensive area in the long run.'

(SKL 2006)

Consequently, SKL (2006) recommended that more research was required to better understand alternatives and find effective and sustainable control method substitutes for glyphosate before banning the use of this herbicide outright (SKL 2006).

5.3 Pavement weed control: sustainable approaches

Figure 5.1 summarises IPM sustainability considerations for the effective reduction of pavement weed populations. Further details of pros and cons of IPM weed control methods available to the UK amenity sector are provided in Figure 1.2.

To achieve more sustainable control of pavement weeds, Cardiff Council has considered its use of glyphosate within the context of IPM approaches. Total herbicide use has been reduced by the council through the sparing and targeted use of glyphosate, specifically:

- Improved herbicide efficacy by the inclusion of appropriate spray additives.
- Reduced herbicide application volumes, achieved by diluting the glyphosate-based herbicide product 166 times more than legal guidelines.
- Use of precision sensors to target actively growing weeds i.e., through the use of contractor Weed-IT machines (Figure 5.1).

Figure 5.1: Integrated Pest Management (IPM) approach for the sustainable management of pavement weeds control methods (SKL 2006, Kempenaar et al. 2007, Rask & Kristoffersen 2007, Fagot et al. 2011, De Cauwer et al. 2013, APSE 2019a, Kay pers comm. 2021, Mason pers comm. 2021, Phillips pers comm. 2021).

Control category	Desired effect	Approach
Cultural (preventative)	Prevent and/or minimise weed population growth	Weed growth can be limited, and control method application can be reduced on hard surface areas by changing the design of the surface and by selecting suitable materials and construction techniques. However, the conversion of surfaces will take a long time and incur high investment costs.
	Permit weed population growth in other areas	Set-aside areas of unmanaged land to which minimal/no control methods will be applied.
Physical (mechanical)	Bring weed population under control	Sweeping pavements regularly for maintenance will remove soil and other detritus, thereby reducing the chances of weed establishment and growth. However, sweeping is expensive, it can be difficult to coordinate sweeping with weed control operations and removal of soil and surface joint material (particularly in older urban areas) should be avoided. **Note:** sweeping is not included in Figure 1.2 as it is not defined as a standalone weed control method.
Chemical (herbicides)	Bring weed population under control	**Increase herbicide efficacy** Pavement weed control methods should be directed toward immature annual and perennial plants early in the growing season. This is because at this time, weeds have accumulated fewer resources from which to recover from control method application and control methods are therefore more likely to be successful.
		Reduce herbicide application volumes Herbicide use (mainly glyphosate) was reduced by 11–66 % compared to standard practice, with weed control levels maintained in the Netherlands. Cardiff Council's contractor (Complete Weed Control Ltd; CWC) has been applying glyphosate at low application volumes for some time, using a glyphosate-based product diluted 166 times lower than legal guidelines (0.00288 milligrams of active ingredient per litre).
		Use of precision sensors Precision sensors developed in agriculture can also be used in UK amenity settings. CWC uses the Weed-IT system (Appendix 1) to reduce herbicide usage (60-80 %) through precision targeting of active weed growth and avoid gully pots, drains etc. which are the principal points through which glyphosate-based herbicides may enter water infrastructure.
		Increase number of herbicide applications Counterintuitively, increasing treatment frequency using glyphosate-based herbicides is likely to reduce overall herbicide use through better management of the weed population. For example, increasing from two to three sprays means that successive treatments are targeting smaller, less mature plants and/or plants which have recovered from previous treatments; these weeds can be managed at lower application rates. Further, if weeds are controlled before they flower, any pollinator exposure to herbicides will be reduced.
Integrated Pest Management (IPM)	Bring weed population under control	Over time, approaches to weed management based on single control methods may run the risk of stimulating herbicide resistance in pavement weeds. However, the pressure imposed on pavement weed populations by herbicides that may lead to resistance development is much smaller in the amenity sector than in agriculture because: - Fewer weeds are sprayed - Weeds are sprayed less often - Weed may be larger (deep-rooted) and not killed outright by herbicide application Wider integration may be possible in the future once effective and sustainable alternatives are identified; it is important that it is not done 'for the sake of it'. For example, application of ineffective alternatives followed by glyphosate application doubles treatment mileage, reducing the environmental and economic sustainability of weed control.

5.4 What happens if we do nothing?

Within the one-year timeframe of the Cardiff Council Trial, council staff observed some local residents in the untreated areas of the city beginning to undertake their own management of pavement weeds. In this specific case, it was likely that residents had been using hot water to control the weeds, but the use of bleach, salt and diesel have been reported by other local government organisations in Wales. Not only are bleach, salt and diesel unregistered products (i.e., they cannot legally be used for weed control), they are also non-specific, meaning that a lot must be used to kill weeds. Further, salt and diesel are persistent compounds that are toxic to most forms of life, despite being 'natural' in origin (Adam and Duncan, 1999; Sobhnaian et al., 2011). Possible increasing and widespread use of these chemicals is likely to result in greater environmental burdens and risks posed to environmental and public health and safety (APSE 2021a).

Given these concerns, it is notable that some local government organisations are beginning to recommend a range of DIY weed control methods to reduce herbicide use. However, these recommendations are not evidence-based and have the potential to pose risks to public safety and the environment. To minimise environmental and societal risks associated with weed control methods and enhance their sustainability, it is suggested that professional use should be the preferred option for the safe maintenance of infrastructure assets.

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6. Summary statements

6.1 Report statement: herbicide regulation

The European Union (EU) Pesticide Reduction Strategy was developed in response to public concern and medical evidence demonstrating the harmful effects of pesticides on human and wildlife health. This legal framework (which the UK currently remains a part of) is the most stringent and comprehensive strategy in place worldwide for the sustainable use of pesticides (including herbicides; Hillocks 2012, Hillocks 2013, Kudsk & Mathiassen 2020). Since introduction of the strategy, around 75 % of herbicides used in Europe before 1993 have been withdrawn from the market with this process continuing to the present day. While this ongoing work is important, it is also essential that further herbicide withdrawals do not outpace development of alternative (effective) control measures (i.e., how and where do we strike the balance; Hillocks 2012, Hillocks 2013).

Hazards, such as herbicides are something that can cause harm, while a risk is the chance, high or low, that a hazard (e.g. pesticides) will actually cause somebody harm. Currently, there a highly contentious debate between:

- Those who advocate a precautionary (preventative) approach to pesticide regulation, where potential hazard is viewed as a benchmark for pesticide removal and
- Those who hold the view that the risk of harm posed by pesticides is effectively managed through strict regulation of use (Hillocks, 2013).

Regardless of the position held by the reader, it is very important to note that there are serious concerns regarding approval based upon hazard: a product may be potentially hazardous, though there is little risk to health or environment from a chemical, if correctly used (Hillocks, 2012). Assessment of potential hazard is also frequently complex and subjective and there is no clear definition of hazard, or scientific definitions of some hazard criteria (e.g., endocrine disruptors; Hillocks, 2012; Hillocks, 2013). Further, consideration of the significant benefits conferred through pesticide use are often omitted, particularly in the smaller amenity and horticultural sectors (Hillocks, 2012; Jones and Eastwood, 2019).

6.2 Report statement: glyphosate controversy and sustainability

The widespread use of herbicides (and pesticides more widely) has been debated since the 1960's. However, the publication of an International Agency for Research on Cancer (IARC) report in 2015 which found that glyphosate was 'probably carcinogenic to humans' (Group 2A) sparked intense debate worldwide, specifically around the safe use of glyphosate-based herbicides (Guyton et al. 2015). Glyphosate is considered to be one of the least toxic and environmentally safe herbicides in use and all other regulatory agencies have asserted that glyphosate is safe to use, including the European Food Safety Authority (EFSA), the European Chemicals Agency (ECHA), the Joint Meeting on Pesticide Residues of FAO and WHO, in addition to the United States (US) EPA and the Australian, Canadian and New Zealand pesticide authorities (Kniss 2017, Neal & Senesac 2018, Kudsk & Mathiassen 2020).

There are two key differences which may go some way to explaining the differences in the findings of IARC and EFSA:

1. IARC only assessed reports published in scientific journals, while EFSA also considered confidential research done by the manufacturers.
2. EFSA only assesses the active ingredient i.e., glyphosate, whereas IARC assessed reports on glyphosate and formulated commercial products (Kudsk & Mathiassen 2020).

However, regardless of any differences in safety evaluation, some countries have moved to limit the use of this herbicide, while others work toward an outright ban on use. In part, such government restrictions on glyphosate use are in response to:

- Ongoing scientific debate around the widespread use of glyphosate in agriculture;
- Difficulties associated with translating carcinogenicity research into appropriate public health policies and recommendations for risk management and
- Court rulings in the United States (US) which awarded multi-million dollar damages to citizens who claimed that the long-term use of glyphosate has caused them to develop cancer (The Lancet Oncology 2016, Duke 2017, Andreotti et al. 2018).

In short, ongoing scientific debate, and perhaps more importantly United States (US) court rulings have driven increasingly cautious government decision-making and led many users to reconsider glyphosate's safety as well as the possibility of legal action being taken against them. However, these decisions are somewhat independent of scientific evidence of the risks and hazards posed by the use of glyphosate (Neal & Senesac 2018).

In the UK 95 % of PPPs (percentage of a.i. by mass) applied are herbicides (Wynn et al. 2014, fera 2016). Application of glyphosate in the UK totals around 2 million kilos per year, constituting approximately 25 % of total herbicide use (Kudsk & Mathiassen 2020). While agriculture accounts for approximately 90 % of use (fera 2016), the amenity sector accounts for just 8-10 % of the total amount of herbicide applied in the UK (much of this will be glyphosate-based). However, it is important to note that while agriculture can switch to other effective synthetic herbicides, the amenity sector cannot because the market for such products is relatively small, while the cost of re-registration continues to grow. Manufacturers are consequently reluctant to re-register products for 'minor use', despite these products being essential for maintaining efficacy and profitability of operation within the amenity sector (Hillocks 2012). Therefore, once such products are removed from sale they are likely to be lost forever, regardless of whether the alternative control methods that replace them perform as effectively.

At present, there are few safe and truly sustainable alternatives to glyphosate, with many alternative weed control methods and herbicide products delivering far less effective weed control along with larger environmental and economic costs (Kniss 2017, Neal & Senesac 2018). Examples of alternative herbicides based on naturally occurring chemicals such as acetic acid, pelargonic acid and other 'natural oils' are largely ineffective and in many cases prohibitively expensive (APSE 2020, APSE 2021a, APSE 2021b). Further, some are more toxic than the synthetic herbicides which they are replacing and operators must therefore carefully avoid contact with the skin or eyes, and avoid inhaling fine sprays (Neal & Senesac 2018). Also, of the weed control methods which are comparable to glyphosate in their ability to control weeds, these are often much more expensive and/or environmentally damaging than the targeted use of glyphosate.

In short, there is no 'magic bullet' for weed control in any sector of the economy and each control method comes with its own set of drawbacks. So, it is essential to consider all of the positives and negatives of each control method, rather than deciding on what the 'ideal' weed control method is and working back from this position. To restate, in order that weed control methods are adopted sustainably, they must:

- Be less costly than the alternatives.
- Involve (comparatively) low levels of investment or financial requirements.
- Create little risk or uncertainty (i.e., they are evidence-based).
- Have well-defined control and management timeframes, provided by evidence-based research (Wynn et al. 2014).

6.4 Report statement: impact of weed control methods on pollinators

There is a current focus on the negative impacts of herbicides on pollinators and other bugs (invertebrates), particularly in the agricultural sector (Lundin et al. 2021). Also, it has been suggested that herbicides (glyphosate in particular) are having negative effects on microorganisms in the soil (soil biota; Kepler et al. 2020) and larger animals such as invertebrates via a number of mechanisms, such as reduced invertebrate movement and a reduction in beneficial gut flora (Gaupp-Berghausen et al. 2015, Motta et al. 2018). Further research has identified direct toxicity of herbicide products against Honey bees (*Apis mellifera*), though this research suggests that it is the co-formulants (also termed adjuvants, spreaders etc.) which are toxic, as opposed to the glyphosate molecule itself (Straw et al. 2021).

However, the evidence for these impacts at the landscape scale remains blurred even for the scientific community. For example, Kepler et al. (2020) found no evidence that glyphosate increased the relative abundance of soil pathogens, while the experiments of Gaupp-Berghausen et al. (2015) and Motta et al. (2018) were small to conclude effects (extrapolate) at the landscape scale. In the case of the Straw et al. (2021), experiments tested herbicide products available to the public on Bumble bees (*Bombus* spp.). Here the results suggested that it was not the herbicide itself killing bees, but the other co-formulants in the spray. Quite reasonably Straw et al. (2021) conclude that use of such products in agricultural and urban settings should be carefully considered; the author agrees and adds that herbicides and other non-chemical control methods in general should be undertaken by trained professionals, as opposed to the public.

While there is a growing body of predominantly laboratory-based research investigating lethal and non-lethal effects of pesticides on a range of organisms, there is surprisingly little research into the impacts of non-chemical control methods, which may be equally damaging to wildlife in agricultural settings (Vincent et al. 2003, Lundin et al. 2021). For example, while the application of steam to control the Colorado beetle (*Leptinotarsa decemlineata*) is ineffective, the steam applied will kill other invertebrates in the treated area. Further, other methods (e.g. trenches) which are technically and environmentally acceptable, are impractical, costly and carbon intensive relative to the use of effective pesticides (Vincent et al. 2003). Vincent et al. (2003) also note that successful implementation of physical control methods tends to occur in postharvest situations i.e., once the plant is removed from the field.

These considerations raise two key questions:

1. Can the findings of agricultural research be transferred directly to our understanding of the impacts of pavement weed control methods, and herbicides in particular, on pollinators?
2. Are alternative weed control methods applied in urban areas equally damaging to pollinators as the application of herbicides?

In response to the first question, the use of herbicides to control pavement weeds involves herbicide spot treatments directly to growing plants, with herbicides being applied 1-3 times per year. In contrast, agricultural herbicide application may involve blanket sprays of different herbicides made several times throughout the year, depending on the crop being grown. Therefore, the scale of herbicide use is entirely different and so too are the impacts of the use of herbicides on pollinators, if only due to the relative product volumes used in the agricultural and amenity sectors, respectively. In short, we must be careful about generalising the impacts of herbicides on pollinators across economic sectors, particularly where the negative impacts are being debated and the cost of losing effective herbicides such as glyphosate are so great.

With respect to the second question, presently, the impacts of non-chemical weed control methods in agriculture have not been measured scientifically (Vincent et al. 2003, Lundin et al. 2021) and this is also the case in the amenity sector. However, there is an assumption that a reduction in herbicide use will automatically lead to increased biodiversity as non-chemical control methods and/or IPM systems do not have negative impacts on biodiversity: this assumption remains to be measured (quantified). From a common-sense perspective, it is likely that the application of lethal heat (flame, hot water, foam) and mechanical damage (metal brushes) to plants and animals will cause immediate death, in contrast with debated sub-lethal effects of herbicides on these organisms (APSE 2020, City of York Council 2022, Corbett pers comm. 2021). Another key consideration is that effective and regular weed management counterintuitively reduces pollinator exposure to any weed control method as flowers are less likely to be produced, reducing the attraction of weeds to pollinators.

To summarise, in 2020 the scientific journal Science published a letter entitled *'Support Austria's glyphosate ban'* (Peng et al. 2020), based on the idea that alternative weed control methods such as root exudates, crop rotation or mulching can replace, like-for-like, the use of glyphosate. In response Pergl et al. (2020) published a response to this article entitled *'Don't throw the baby out with the bathwater – ban of glyphosate use depends on context'*. In the response published in the scientific journal NeoBiota, the authors argued that:

'risks associated with using this herbicide on a large scale exist, but on a small scale, such as in invasive plant control, glyphosate has an important role and is not easy to replace. Therefore, the context and scale need to be taken into account when applying such bans.'

(Pergl et al. 2020)

This concept of scale and proportion are also key to sustainable pavement weed control. Without supporting experiments to determine the efficacy and sustainability of alternative control methods, removing glyphosate as a weed control tool is likely to result in difficult situations such as those reported in Sweden by SKL (2006), where:

'The situation is in several cases so critical that one must at the strategic decision level decide to either increase the resource allocation for sanitation and weed control, or start a long-term work to phase out hardened surfaces to reduce the resource-intensive area in the long run.'

(SKL 2006)

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Appendix 1 - Equipment, products and materials

Foamstream® machine (Weedingtech™ Ltd., London, UK)

Brief technical specifications:

- Foamstream® machine L12
- Small lance used
- Water and foam mix leaves nozzle at 98 °C

The combined heater unit and water tank is mounted on the rear of a vehicle and driven to the site. Water is heated and mixed with a biodegradable foam which is applied through a lance onto the weeds or area being treated. The foam helps concentrate the heat onto the plant by reducing heat loss to the atmosphere. To kill plants, a minimum temperature of 58 °C is required (Weedingtech n.d., Bristol City Council 2017).

WEED-IT (Weed Economical Eradication Detection – Intelligent Technology) machine

Brief technical specifications:

- WEED-IT is a computer controlled herbicide application system specifically designed for use on hard surface areas.
- The system consists of a shrouded spraying head mounted on the front of a purpose-built, articulated carrier vehicle.
- Within the shrouded head are sensor units and spray nozzles. Sensor units detect the presence of weeds and trigger the appropriate spray nozzles to apply accurately the correct amount of herbicide just to those weeds and their immediate surroundings (CWC n.d.).

Monsanto Amenity Glyphosate XL - product label

March 2017

LABEL

H - Herbicide

MONSANTO AMENITY GLYPHOSATE XL

A foliar applied translocated herbicide for the control of emerged weeds in industrial and amenity situations, in forestry and on hard surfaces.

Degraded by micro-organisms*microbes in the soil.

A soluble concentrate containing 360 g/l glyphosate, present as 41.6 w/w of the isopropylamine salt of glyphosate

The (COSHH) Control of Substances Hazardous to Health Regulations may apply to the use of this product at work

MAPP Number: 17997

Contents ℮ 5 litres

PROTECT FROM FROST

Not for reformulation or repackaging
No licence is granted under any patent

® Monsanto 2017
Lot number/production date

The Voluntary Initiative

This label has been produced according to the Crop Protection Association Voluntary Initiative (VI) guidance.

Page 1

March 2017

FRONT LABEL

MONSANTO AMENITY GLYPHOSATE

A soluble concentrate containing 360 g/l glyphosate present as (41.6% w/w) of the isopropylamine salt of glyphosate

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Tel: (01954) 717575 - Technical Enquiries
E-mail: technical.helpline.uk@monsanto.com
Website: www.monsanto-ag.co.uk

In case of emergency day or night, telephone National Chemical Emergency Centre: (01865) 407333

IMPORTANT INFORMATION

FOR PROFESSIONAL USE ONLY AS AN INDUSTRIAL/AMENITY/FORESTRY HERBICIDE

Crops/situations:
Natural surfaces not intended to bear vegetation, permeable surfaces overlying soil, hard surfaces;
Amenity vegetation;
Forest nursery, forest (weed control, stump application and chemical thinning).

Maximum individual dose: }
Maximum number of treatments: } Full details are given in
Latest time of application: } the attached leaflet
Other specific restrictions: } (see Crop Specific information - marked #)

READ THE LABEL BEFORE USE. USING THIS PRODUCT IN A MANNER THAT IS INCONSISTENT WITH THE LABEL MAY BE AN OFFENCE. FOLLOW THE CODE OF PRACTICE FOR USING PLANT PROTECTION PRODUCTS.

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BACK & BASE LABEL

SAFETY PRECAUTIONS

Operator protection

Engineering control of operator exposure must be used where reasonably practicable in addition to the following personal protective equipment:

*WEAR SUITABLE PROTECTIVE GLOVES when handling the concentrate or handling contaminated surfaces.

*WEAR SUITABLE PROTECTIVE GLOVES AND RUBBER BOOTS when applying by hand-held controlled droplet application. (CDA) equipment.

*WEAR SUITABLE PROTECTIVE CLOTHING (COVERALLS). SUITABLE PROTECTIVE GLOVES AND RUBBER BOOTS when applying by hand-held weed wiper.

** However, engineering controls may replace personal protective equipment if a COSHH assessment shows they provide an equal or higher standard of protection.*

WHEN USING DO NOT EAT DRINK OR SMOKE.
WASH HANDS AND EXPOSED SKIN before eating and drinking and after work.

Environmental protection

Do not contaminate water with the product or its container. Do not clean application equipment near surface water. Avoid contamination via drains from farmyards and roads.

Storage and disposal

KEEP AWAY FROM FOOD, DRINK AND ANIMAL FEEDINGSTUFFS.
KEEP OUT OF REACH OF CHILDREN.
KEEP IN ORIGINAL CONTAINER, tightly closed, in a safe place.
RINSE CONTAINER THOROUGHLY by using an integrated pressure rinsing device or manually rinse three times. Add washings to sprayer at time of filling and dispose of safely. Triple rinsed containers may be disposed of as non-hazardous waste.

Medical advice

Medical guidance is available on a 24 hour basis by telephoning the National Chemical Emergency Centre on 01865 407333 or for doctors, from the National Poisons Information Service on 08448920111

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DIRECTIONS FOR USE

IMPORTANT: This information is approved as part of the Product Label. All instructions within this section must be read carefully in order to obtain safe and successful use of this product.

Warnings

EXTREME CARE SHOULD BE TAKEN TO AVOID SPRAY DRIFT AS THIS CAN SEVERELY DAMAGE NON TARGET PLANTS.
DO NOT MIX, STORE OR APPLY MONSANTO AMENITY GLYPHOSATE XL IN GALVANISED OR UNLINED STEEL CONTAINERS OR SPRAY TANKS.
DO NOT leave spray mixtures in tank for long periods and make sure tanks are WELL VENTED.

Restrictions

A period of at least 6 hours and preferably 24 hours rain free must follow application of Monsanto Amenity Glyphosate XL.

Do not spray onto weeds which are naturally senescent, or where growth is impaired by drought, high temperatures, a covering of dust, flooding or frost at, or immediately after application, otherwise poor control may result.

Do not spray in windy conditions as drift onto desired crops or vegetation could severely damage or destroy them.

After application, large concentrations of decaying foliage, stolons, roots or rhizomes should be dispersed or buried by thorough cultivation before crop drilling.

Applications of lime, fertilizer, farmyard manure and pesticides should be delayed until 5 days after application of Monsanto Amenity Glyphosate XL.

Weeds controlled

Monsanto Amenity Glyphosate is a foliar acting herbicide which controls annual and perennial grasses and most broad-leaved weeds when used as directed. It is important that all weeds are at the correct growth stage when treated, otherwise some re-growth may occur and this will need re-treatment.

Apply Monsanto Amenity Glyphosate herbicide once grasses and broad-leaved weeds have emerged and they have ACTIVELY GROWING green leaves.

- PERENNIAL GRASSES must have a full emergence of healthy, green leaf. (Common Couch, for example, becomes susceptible at the onset of tillering and new rhizome growth commences which usually occurs when plants have 4-5 leaves, each with 10-15cm of new growth)
- PERENNIAL BROAD-LEAVED WEEDS are most susceptible around the flowering stage.
- ANNUAL GRASSES AND BROAD-LEAVED WEEDS should have at least 5 cm of leaf, or 2 expanded true leaves respectively.
- OTHER SPECIES recommendations for specific Areas of Use are given in the Recommendation Tables, pages 6 and 7
- This product will not give an acceptable level of control of Horsetails (*Equisetum arvense*) - repeat treatment will be necessary.

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Following Crops

Upon soil adsorption the herbicidal properties of Monsanto Amenity Glyphosate XL are lost permitting the drilling of crops 48 hours after application. Planting of trees, shrubs etc may take place 7 days after application. Grass seed may be sown from 5 days after treatment.

#Crop specific Information

COMPLIANCE WITH THE FOLLOWING CONDITIONS OF USE AND ALL SAFETY PRECAUTIONS MARKED* IS A LEGAL REQUIREMENT

Crops/situations:	Maximum individual dose (litres product/ hectare):
Natural surfaces not intended to bear vegetation, permeable surfaces overlaying soil, hard surfaces	5.0
Amenity vegetation	5.0
Forestry, forest nursery: • Weed control	5.0

Other specific restrictions:

The maximum individual dose must not exceed 22.5g/l glyphosate for hydraulic knapsack sprayers

When applying through rotary atomisers the spray droplet spectra produced must be of a minimum Volume Median Diameter (VMD) of 200 microns

Weed wipers may be used in any crop where the wiper or chemical does not touch the growing crop

For weed wiper applications, the maximum concentrations must not exceed the following:

Weed wiper Mini	1:2 dilution with water }	Refer to weed wiper guidance under
Other wipers	1:1 dilution with water }	'Mixing & Spraying' section

READ THE LABEL BEFORE USE. USING THIS PRODUCT IN A MANNER THAT IS INCONSISTENT WITH THE LABEL MAY BE AN OFFENCE. FOLLOW THE CODE OF PRACTICE FOR USING PLANT PROTECTION PRODUCTS.

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RECOMMENDATION TABLES

AREA OF USE	TARGET WEED/USAGE	CROP/SITUATION	WEED INFESTATION	APPLICATION RATE l/ha	WATER VOLUME	APPLICATION TIMING AND GUIDANCE
NATURAL SURFACES NOT INTENDED TO BEAR VEGETATION PERMEABLE SURFACES OVERLYING SOIL RAILWAY BALLAST	Vegetation management	Including roadsides, paths and along fences & total weed control on industrial sites	Annual weeds	[illegible]	Hydraulic sprayers: 80-250 l/ha or Rotary atomisers* water volumes 40 l/ha or hand held equipment See Mixing & Spraying section	Use areas include: Clearing up weedy ground prior to planting or sowing and as a directed spray in ornamental plantings Hydraulic sprayers, rotary atomisers or weed wipers may be used DO NOT USE IN OR ALONGSIDE HEDGEROWS DO NOT USE UNDER POLYTHENE OR GLASS
			Perennial grasses and broad-leaved weeds	[illegible]		
Hard surfaces [illegible]	Vegetation management	Including roadsides, paths concrete and alongside walls	Annual weeds	[illegible]	Hydraulic sprayers 80-250 l/ha or Rotary atomisers* water volumes 40 l/ha or hand held equipment See Mixing & Spraying section	Apply this product carefully. Ensure spraying takes place only when weeds are actively growing (normally March to October) and is confined only to visible weeds including those in the 30cm swath covering the kerb edge and road gulley – do not overspray drains
			Perennial grasses and broad-leaved weeds	[illegible]		
AMENITY VEGETATION	Vegetation management	Areas of semi natural or ornamental vegetation including trees. Areas of bare soil around ornamental plants or areas intended for ornamental planting or clearance of allotments	Annual weeds	[illegible]	[illegible]	Hydraulic sprayers, rotary atomisers or weed wipers may be used DO NOT USE IN OR ALONGSIDE HEDGEROWS DO NOT USE UNDER POLYTHENE OR GLASS
			Perennial grasses and broad-leaved weeds	[illegible]		

* Rotary atomisers may be used at a water volume of 40 l/ha. Ensure droplet diameter falls within the range 200-300 microns

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Forestry weed control

Monsanto Amenity Glyphosate XL can be used for site preparation and for weed control in planted out trees

AREA OF USE	TARGET WEEDS/USAGE	WEED INFESTATION	APPLICATION RATE L/HA	WATER VOLUME	APPLICATION TIMING & GUIDANCE
Forestry Pre-planting	Arable land planting, replanting & grassland areas	Annual weeds	[illegible]	Hydraulic sprayers 80-250 l/ha or rotary atomisers 40 l/ha*	All tree species may be planted 7 days or more after treatment *Where rotary atomisers are used their droplet diameter must fall within the range 200-300µm
		[illegible] weeds	[illegible]		
Forestry Post planting (directed) in conifers & broad-leaved trees	[illegible]	[illegible]	4.0	Knapsack 200-250 l/ha or [illegible] apply as a concentration of 1 part Monsanto Amenity Glyphosate XL to 2 parts water (see Mixing & Spraying section)	It is ESSENTIAL to use a TREE GUARD for all applications made in the growing season Treat bracken after frond tips are unfurled but before senescence [illegible] All other woody weeds are treated June August before leaf senescence (but after new growth of crop has hardened)

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Mixing and spraying

Monsanto Amenity Glyphosate XL mixes readily with water and can be applied in spray volumes ranging from 80-400 l/ha using tractor mounted, knapsack, rotary atomisers and hand-held sprayers. Specialised application equipment such as weed wipers and spot gun applicators may be used where indicated

Correctly calibrate all sprayers under field or use conditions prior to application.

a) Tractor mounted and powered sprayers

These should be capable of applying accurately 80-400 l/ha within a pressure range of 1.5-2.5 bars (20-35 psi).

Half fill the spray tank with clean water, start gentle agitation, and then add the correct amount of Monsanto Amenity Glyphosate XL. Top up the tank with water to the required level. To avoid foaming do not use top tank agitation. Use of a defoamer may be necessary.

All applications using hydraulic sprayers (including knapsack sprayers) to be as 'MEDIUM' or 'COARSE' spray quality (BCPC definition).

Medium Volume application (150-300 l/ha)
Avoid high water volumes (>300 l/ha) which may lead to run off from the treated vegetation, resulting in reduced control. Low drift nozzles such as air induction and pre-orifice types producing a medium or coarse spray (BCPC definition) should be used to minimise the risk of drift.

Low Volume Application (minimum 80 l/ha)
Low volume application can be achieved by reducing pressure and the appropriate nozzle selection. Low drift nozzles which produce a medium spray quality (BCPC definition) should be used to minimise the risk of drift.

b) Knapsack sprayers

Recommended delivery range is 80 - 300 l/ha. Half fill the spray tank with clean water, add the correct amount of Monsanto Amenity Glyphosate XL and top up with water. Fill according to best practice as given on the CPA's Voluntary Initiative website (www.vountaryinitiative.org.uk)

When used at a walking speed of 1 m/sec to apply a swath of 1 m width, most knapsack sprayers fitted with a Hypro AN 0.6-AN2.4 or similar nozzle deliver approximately 200 l/ha spray volume (or 10 l per 500 m²). To apply 5.0 l/ha of MONSANTO AMENITY GLYPHOSATE XL, therefore, use 50ml of product for each 2 litres of spray liquid required. Similarly, knapsack sprayers fitted with low volume nozzles such as D/0.23/1 - D/0.68/1 typically deliver approximately 100 l/ha spray volume. To apply 5.0 l/ha MONSANTO AMENITY GLYPHOSATE XL in this case, use 100ml of product for each 2 litres of spray liquid required.

c) Rotary Atomisers

Tractor mounted boom sprayers and hand-held machines are suitable for use in some situations to apply a minimum spray volume of 40 l/ha.

When rotary atomisers are used to apply Monsanto Amenity Glyphosate XL ensure that the droplet diameter falls within the range 200-300 microns for all uses.

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Stir the correct amount of Monsanto Amenity Glyphosate XL to control the particular target species into the sprayer bottle half filled with clean water. Top up with water, close the top and shake gently to ensure good mixing.

Do not tank mix Monsanto Amenity Glyphosate XL when using rotary atomiser sprayers.

d) Weed Wipers

For ropewick applicators use a concentration of 1 part Monsanto Amenity Glyphosate XL to 2 parts of water and add a water-soluble dye if required. Care should be taken to avoid dripping onto wanted vegetation.

For new generation weed wipers, use 1 part Monsanto Amenity Glyphosate XL to 10 or 20 parts of water or as directed by manufacturer's instructions or as directed by manufacturer's instructions.

e) Spot Gun Applicators

Spot gun applicators are for the treatment of individual weeds.
Apply 5 ml of spray to target weed, using a narrow cone TG-3 or TG-5 nozzle.

Spot Diameter (metres)	Amount of Monsanto Amenity Glyphosate XL (ml) per 5 litres spray solution for targeted dosages of:		
	3.0 l/ha	4.0 l/ha	5.0 l/ha
0.3	20	28	35
0.6	85	110	140

Compatibility

Do not tank mix Monsanto Amenity Glyphosate XL with adjuvants, pesticides or fertilisers except as advised by Monsanto. For up to date information on compatible products contact Monsanto UK Limited (tel: 01954 717575)
For hydraulic sprayers: maintain continuous agitation when using Monsanto Amenity Glyphosate XL in tank mixture.

For knapsack sprayers: mix thoroughly and use immediately when using Monsanto Amenity Glyphosate XL in tank mixture.

COMPANY ADVISORY INFORMATION

This section is not part of the Product Label under the Plant Protection Products Regulations 1995 and provides additional advice on the product.

General information

Monsanto Amenity Glyphosate XL herbicide is a foliar acting herbicide with broad-spectrum activity. It is taken up by foliage and translocated to underground roots, rhizomes and stolons, providing control of both annual and perennial grasses and broad-leaved weeds. Monsanto Amenity Glyphosate XL is rapidly adsorbed onto particulate matter in soils and water and is quickly degraded by the micro-organisms present in soil and aquatic bottom sediments. Upon adsorption, the herbicidal properties of Monsanto Amenity Glyphosate XL are lost, permitting drilling of crops within 48 hours of application. When used as directed, any water subjected to Monsanto Amenity Glyphosate XL spray drift may be used immediately for irrigation purposes. Until degraded, the active ingredient in Monsanto Amenity Glyphosate XL, glyphosate, is practically immobile in soils and is, therefore, unlikely to contaminate groundwater.

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To maximise the safe use of Monsanto Amenity Glyphosate XL to operator, consumer and environment, the label recommendations and the DEFRA/HSC/NAW publication "Code of Practice for Using Plant Protection Products" of January 2006, should be adhered to.

Symptoms on the weeds

Symptoms of treatment are generally first seen 7-10 days, or longer (if growth is slow), after spraying. These take the form of leaf reddening followed by yellowing and are usually quicker to appear on grasses than on broad-leaved weeds. Reaction of nettles is slow.
Effects of weather

See Directions for Use (Restrictions).

Monsanto Amenity Glyphosate will remain efficacious at low but not freezing temperatures however the onset of symptoms will be delayed.

A covering of dew may reduce efficacy where run-off occurs.
Reduced control is likely where weed growth is impaired by natural senescence, drought, high temperature, a covering of dust, flooding or severe/prolonged frost of, or immediately after, application.
Weed resistance strategy

There is low risk for the development of weed resistance to Monsanto Amenity Glyphosate XL. There are no known cases of weed resistance to glyphosate in UK.
Strains of some annual weeds (e.g. Black-grass, Wild oats and Italian Ryegrass) have developed resistance to herbicides which may lead to poor control. A strategy for preventing and managing such resistance should be adopted. This should include integrating herbicides with a programme of cultural control measures. Guidelines have been produced by the Weed Resistance Action Group and copies are available from the HGCA, CPA, your distributor, crop adviser or product manufacturer (Monsanto).

Growers are encouraged to implement a weed resistance strategy based on (a) Good Agricultural Practices and (b) Good Plant Protection Practices by:

- Following label recommendations
- The adoption of complimentary weed control practices
- Minimising the risk of spreading weed infestations
- The implementation of good spraying practice to maintain effective weed control
- Using the correct nozzles to maximise coverage
- Application only under appropriate weather conditions
- Monitoring performance and reporting any unexpected results to Monsanto UK Ltd (01954 717575)

General Cautions

Take extreme care to avoid drift, particularly when using near or alongside hedgerows. The use of low drift nozzles such as 'air induction' and 'pre-orifice' nozzles are recommended.

After application, large concentrations of decaying foliage, stolons, roots or rhizomes should be dispersed or buried by thorough cultivation before crop drilling.

New Generation Weed Wipers
Logic Contact 2000
Carier Rollmaster
Allman Ecowipe

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Rotowiper (UK) Ltd
C-Dax™ Eliminator
Weedswiper™

Sprayer Maintenance
Ensure the sprayer is in good working order and replace damaged, worn or malfunctioning parts before use. Carry out maintenance according to the instructions of the sprayer manufacturer.

Sprayer Hygiene

It is essential to thoroughly clean out spray tanks, pumps and pipelines and nozzle or disc assemblies, with a recommended detergent cleaner, between applying this product and other pesticides to avoid contamination from pesticide residues. Traces of Monsanto Amenity Glyphosate XL left in the equipment may seriously damage or destroy crops sprayed later.

Calibration

All sprayers should always be calibrated before use. This is essential when nozzles are changed or if a different dose of product is to be applied.

Unused Spray Mixture

Once Monsanto Amenity Glyphosate XL has been diluted in the spray tank, it should be used as soon as possible. However, if unexpected delays occur the diluted spray can be safely stored. Agitate well before use. Storage for longer than 3 days may result in reduced efficacy.

Disposal

Follow the guidance on the disposal of surplus spray solution, tank washings, concentrate and containers as given in section 5 of the DEFRA/HSC/NAW publication "Code of Practice for Using Plant Protection Products", January 2006.

Environmental Information Sheet

An Environmental Information Sheet for this product is available from the CPA's Voluntary Initiative website (www.voluntaryinitiative.org.uk)

Material Safety Data Sheet

A material safety data sheet for this product is available on request (telephone 01954 717575) or can be downloaded from the Monsanto website:
www.monsanto-ag.co.uk

Trade Mark References

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Monsanto does not warrant that the purchase or use of equipment mentioned in this document will not infringe any patent or trade mark registration

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Monsanto Amenity Glyphosate XL - material safety data sheet (MSDS)

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Monsanto Amenity Glyphosate XL | Version: 1.0 | Effective date: 03/02/2017

MONSANTO Europe S.A./N.V.
Safety Data Sheet
Commercial Product

1. PRODUCT AND COMPANY IDENTIFICATION

1.1. **Product identifier**
Monsanto Amenity Glyphosate XL
1.1.1. **Chemical name**
Not applicable for a mixture.
1.1.2. **Synonyms**
None.
1.1.3. **CLP Annex VI Index No.**
Not applicable.
1.1.4. **C&L ID No.**
Not available
1.1.5. **EC No.**
Not applicable for a mixture.
1.1.6. **REACH Reg. No.**
Not applicable for a mixture.
1.1.7. **CAS No.**
Not applicable for a mixture.

1.2. **Product use**
Herbicide

1.3. **Company/(Sales office)**
MONSANTO Europe S.A./N.V.
Haven 627, Scheldelaan 460, B-2040
Antwerp, Belgium
Telephone: +32 (0)3 568 51 11
Fax: +32 (0)3 568 50 90
E-mail: safety.datasheet@monsanto.com

1.4. **Emergency numbers**
Telephone: Belgium +32 (0)3 568 51 23

2. HAZARDS IDENTIFICATION

2.1. **Classification**
2.1.1. **Classification according to Regulation (EC) No. 1272/2008 [CLP], National classification: U.K.**
Not classified as dangerous.
Hxxx Not applicable.

2.2. **Label elements: U.K.**
Labelling according to Regulation (EC) No. 1272/2008 [CLP]
Hazard pictogram/pictograms: U.K.
Not Applicable
Signal word: U.K.
Not applicable.
Hazard statement/statements: U.K.

Hxxx Not applicable.

Precautionary statement/statements: U.K.

P234 Keep only in original container

Supplemental hazard information: U.K.

EUH401 To avoid risks to human health and the environment, comply with the instructions for use.

2.3. Other hazards

0% of the mixture consists of ingredient/ingredients of unknown acute toxicity.

0% of the mixture consists of ingredient/ingredients of unknown hazards to the aquatic environment

2.3.1. Potential environmental effects

Not expected to produce significant adverse effects when recommended use instructions are followed.

2.4. Appearance and odour (colour/form/odour)

Pale yellow /Liquid / Odourless

Refer to section 11 for toxicological and section 12 for environmental information.

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.1 Substance: Not applicable.

3.2 Mixture: Yes.

Composition/information on ingredients

Components	CAS No.	EC No.	EU Index No. / REACH Reg. No. / C&L ID No.	Concentration	Classification
Isopropylamine salt of glyphosate	[illegible]	[illegible]	[illegible]	[illegible]	Aquatic Chronic - Category 2; H411; [e]
Quaternary [illegible] compound			[illegible]	[illegible]	Skin corrosion/irritation - Category 2; Eye damage/irritation - Category 1; Aquatic Chronic - Category 3; H315, 318, 412
Water and minor formulating ingredients			[illegible]	[illegible]	[illegible]

Active ingredient

Isopropylamine salt of N-(phosphonomethyl)glycine; {Isopropylamine salt of glyphosate}

Full text of classification code: See section 16.

4. FIRST AID MEASURES

Use personal protection recommended in section 8.

4.1. Description of first aid measures

4.1.1. Eye contact

Immediately flush with plenty of water. Continue for at least 15 minutes. If easy to do, remove contact lenses. If there are persistent symptoms, obtain medical advice.

4.1.2. Skin contact

Take off contaminated clothing, wristwatch, jewellery. Immediately wash affected skin with plenty of water. Wash clothes and clean shoes before re-use.

4.1.3. Inhalation

Remove to fresh air.

4.1.4. Ingestion

Rinse mouth thoroughly with water. Remove particles from mouth. Immediately offer water to drink. Do NOT induce vomiting unless directed by medical personnel. If symptoms occur, get medical attention.

4.2. Most important symptoms and effects, both acute and delayed

4.2.1. Potential health effects

Likely routes of exposure: Skin contact, inhalation, eye contact, ingestion

Eye contact, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.

Skin contact, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.

Inhalation, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.

Single ingestion: Not expected to produce significant adverse effects when recommended use instructions are followed.

4.3. Indication of any immediate medical attention and special treatment needed

4.3.1. Advice to doctors

This product is not an inhibitor of cholinesterase.

4.3.2. Antidote

Treatment with atropine and oximes is not indicated.

5. FIRE-FIGHTING MEASURES

5.1. Extinguishing media

5.1.1. Recommended: Water, foam, dry chemical, carbon dioxide (CO2)

5.2. Special hazards

5.2.1. Unusual fire and explosion hazards

Minimise use of water to prevent environmental contamination. Environmental precautions: see section 6

5.2.2. Hazardous products of combustion

Carbon monoxide (CO), Phosphorus oxides (PxOy), nitrogen oxides (NOx), Ammonia (NH3)

5.3. Advice for firefighters

Self-contained breathing apparatus. Equipment should be thoroughly decontaminated after use.

5.4. Flash point

Does not flash.

6. ACCIDENTAL RELEASE MEASURES

Use handling recommendations in Section 7 and personal protection recommendations in Section 8.

6.1. Personal precautions

Use personal protection recommended in section 8.

6.2. Environmental precautions

Minimise spread. Keep out of drains, sewers, ditches and water ways. Notify authorities.

6.3. **Methods for cleaning up**
Absorb in earth, sand or absorbent material. Dig up heavily contaminated soil. Refer to section 7 for types of containers. Collect in containers for disposal. Flush residues with small quantities of water. Minimise use of water to prevent environmental contamination.

Refer to section 13 for disposal of spilled material.

7. HANDLING AND STORAGE

7.1. **Precautions for safe handling**
Good industrial practice in housekeeping and personal hygiene should be followed. Avoid contact with eyes. When using do not eat, drink or smoke. Wash hands thoroughly after handling or contact. Wash contaminated clothing before re-use. Thoroughly clean equipment after use. Do not contaminate drains, sewers and water ways when disposing of equipment rinse water. Refer to section 13 of the safety data sheet for disposal of rinse water.
Emptied containers retain vapour and product residue. FOLLOW LABELLED WARNINGS EVEN AFTER CONTAINER IS EMPTIED.

7.2. **Conditions for safe storage, including any incompatibilities**
Compatible materials for storage: stainless steel, fibreglass, plastic, glass lining
Incompatible materials for storage: galvanised steel, unlined mild steel, see section 10.
Minimum storage temperature: -5 °C
Maximum storage temperature: 35 °C
Keep out of reach of children. Keep away from food, drink and animal feed. Keep container tightly closed in a cool, well-ventilated place. Keep only in the original container. Minimum shelf life: 2 years.

7.3. **Specific end use(s)**
Not applicable.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1. **Control parameters**

Airborne exposure limits

Components	Exposure Guidelines
Isopropylamine salt of glyphosate	No specific occupational exposure limit has been established.
Quaternary ammonium compound	No specific occupational exposure limit has been established.
Water and minor formulating ingredients	No specific occupational exposure limit has been established.

8.2. **Exposure controls**
Engineering controls
No special requirement when used as recommended.
Eye protection:
No special requirement when used as recommended.
Skin protection:
If repeated or prolonged contact: Wear chemical resistant gloves. Chemical resistant gloves include those made of waterproof materials such as nitrile, butyl, neoprene, polyvinyl chloride (PVC), natural rubber and/or barrier laminate.
Respiratory protection:
No special requirement when used as recommended.

When recommended, consult manufacturer of personal protective equipment for the appropriate type of equipment for a given application.

9. PHYSICAL AND CHEMICAL PROPERTIES

These physical data are typical values based on material tested but may vary from sample to sample. Typical values should not be construed as a guaranteed analysis of any specific lot or as specifications for the product.

9.1 **Information on basic physical and chemical properties**

Colour/colour range:	Pale yellow
Form:	Liquid
Odour:	Odourless
Odour threshold:	No data.
Physical form changes (melting, boiling, etc.):	
Melting point:	Not applicable
Boiling point:	Not available.
Flash point:	Does not flash.
Explosive properties:	No explosive properties
Auto ignition temperature:	460 °C
Self-accelerating decomposition temperature (SADT):	No data
Oxidizing properties:	Not available.
Specific gravity:	1.167 @ 20 °C / 4 °C
Vapour pressure:	No significant volatility; aqueous solution.
Vapour density:	Not applicable.
Dynamic viscosity:	24.9 mPa s @ 20 °C
Kinematic viscosity:	Not available.
Density:	1.167 g/cm3
Solubility:	Water: Soluble
pH:	5.0 @ 10 g/l
Partition coefficient:	log Pow: < -3.2 @ 25 °C (Glyphosate)

9.2 **Other information**

Evaporation rate:	No data.

10. STABILITY AND REACTIVITY

10.1. **Reactivity**
Reacts with galvanised steel or unlined mild steel to produce hydrogen, a highly flammable gas that could explode.

10.2. **Chemical stability**
Stable under normal conditions of handling and storage.

10.3. **Possibility of hazardous reactions**

Reacts with galvanised steel or unlined mild steel to produce hydrogen, a highly flammable gas that could explode.

10.4. Conditions to avoid
None.

10.5. Incompatible materials
Incompatible materials for storage: galvanised steel, unlined mild steel, see section 10.
Compatible materials for storage: see section 7.2.

10.6. Hazardous decomposition products
Hazardous products of combustion: see section 5.

11. TOXICOLOGICAL INFORMATION

This section is intended for use by toxicologists and other health professionals.

11.1. Information on toxicological effects

Classification according to Regulation (EC) No. 1272/2008 [CLP]
Acute oral toxicity: Based on available data classification criteria are not met.
Acute dermal toxicity: Based on available data classification criteria are not met.
Acute inhalation toxicity: Based on available data classification criteria are not met.
Skin corrosion/irritation: Based on available data classification criteria are not met.
Eye corrosion/irritation: Based on available data classification criteria are not met.
Skin sensitization: Based on available data classification criteria are not met.
Respiratory sensitization: Based on available data classification criteria are not met.
Mutagenicity: Based on available data classification criteria are not met.
Carcinogenicity: Based on available data classification criteria are not met.
Reproductive/Developmental Toxicity: Based on available data classification criteria are not met.
Specific Target Organ Toxicity - Single Exposure: Based on available data classification criteria are not met.
Specific Target Organ Toxicity - Repeated Exposure: Based on available data classification criteria are not met.
Aspiration hazard: Based on available data classification criteria are not met.

Most important symptoms and effects, both acute and delayed
Potential health effects
Likely routes of exposure: Skin contact, inhalation, eye contact, ingestion
Eye contact, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.
Skin contact, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.
Inhalation, short term: Not expected to produce significant adverse effects when recommended use instructions are followed.
Single ingestion: Not expected to produce significant adverse effects when recommended use instructions are followed.

Data obtained on product and components are summarized below.

Acute oral toxicity
Rat, LD50 (Method: OECD 401): > 2 000 mg/kg body weight
Slightly toxic.
Acute dermal toxicity

Rat, LD50: > 2 000 mg/kg body weight
Skin irritation
Rabbit, number of animals unknown, OECD 404 test:
Non-irritant
Eye irritation
Rabbit, number of animals unknown, OECD 405 test:
Non-irritant
Skin sensitization
Guinea pig, Negative.
No skin sensitization

N-(phosphonomethyl)glycine; {glyphosate acid}

Genotoxicity
Not genotoxic.

Carcinogenicity
Not carcinogenic in rats or mice.
Reproductive/Developmental Toxicity
Developmental effects in rats and rabbits only in the presence of significant maternal toxicity.
Reproductive effects in rats only in the presence of significant maternal toxicity.

12. ECOLOGICAL INFORMATION

This section is intended for use by ecotoxicologists and other environmental specialists.

Data obtained on product and components are summarized below.

12.1 Toxicity

Aquatic toxicity, fish
Rainbow trout (Oncorhynchus mykiss):
Acute toxicity, 96 hours, LC50: > 100 mg/L.
Aquatic toxicity, invertebrates
Water flea (Daphnia magna):
Acute toxicity, 48 hours, EC50: > 100 mg/L.
Aquatic toxicity, algae/aquatic plants
Green algae (Scenedesmus subspicatus):
Acute toxicity, 72 hours, ErC50 (growth rate): 54.5 mg/L.
Green algae (Scenedesmus subspicatus):
Acute toxicity, 72 hours, NOEC (growth rate): 4.8 mg/L.

12.2 Persistence and degradability
No data.

12.3 Bioaccumulative potential
Refer to section 9 for partition coefficient data.

12.4 Mobility in soil
No data.

12.5 Results of PBT and vPvB assessment

Not a persistent, bioaccumulative or toxic (PBT) nor a very persistent, very bioaccumulative (vPvB) mixture

12.6 Other adverse effects
Not expected to produce significant adverse effects when recommended use instructions are followed.

12.7 Additional information
If available, data obtained on similar products and/or on components are summarized below.

N-(phosphonomethyl)glycine; (glyphosate acid)

Avian toxicity
Bobwhite quail (Colinus virginianus):
Acute oral toxicity, single dose, LD50: > 3.851 mg/kg body weight
Arthropod toxicity
Honey bee (Apis mellifera):
Oral, 48 hours, LD50: 100 µg/bee
Honey bee (Apis mellifera):
Contact, 48 hours, LD50: > 100 µg/bee
Bioaccumulation
Bluegill sunfish (Lepomis macrochirus):
Whole fish: BCF: < 1
No significant bioaccumulation is expected
Dissipation
Soil, field:
Half life: 2 - 174 days
Koc: 884 - 60.000 L/kg
Adsorbs strongly to soil
Water, aerobic:
Half life: ~ 7 days

13. DISPOSAL CONSIDERATIONS

13.1. Waste treatment methods

13.1.1. Product
Follow all local/regional/national/international regulations on waste disposal. Follow current edition of the General Waste, Landfill, and Burning of Hazardous Waste Directives; and the Shipment of Waste Regulation. Keep out of drains, sewers, ditches and water ways. According to the manufacturer self-classification, following Regulation (EC) No. 1272/2008 [CLP], the product can be disposed as a non-hazardous industrial waste. Disposal in a waste incinerator with energy recovery is recommended.

13.1.2. Container
Follow all local/regional/national/international regulations on waste disposal, packaging waste collection/disposal. Follow current edition of the General Waste, Landfill, and Burning of Hazardous Waste Directives; and the Shipment of Waste Regulation. Do NOT re-use containers. Triple or pressure rinse empty containers. Pour rinse water into spray tank. Properly rinsed container can be disposed as a non hazardous industrial waste. Store for collection by approved waste disposal service. Recycle if appropriate facilities/equipment available. Recycle the non-hazardous container only when a proper control on the end use of the recycled plastic is possible. Suitable for industrial grade recycling only. Do NOT recycle plastic that could end in any human or food contact application. This package meets the requirements for energy recovery. Disposal in a incinerator with energy recovery is recommended.

Use handling recommendations in Section 7 and personal protection recommendations in Section 8.

14. TRANSPORT INFORMATION

The data provided in this section is for information only. Please apply the appropriate regulations to properly classify your shipment for transportation.

ADR/RID
14.1 **UN No.:** Not applicable.
14.2 **Proper Shipping Name (Technical Name if required): Not regulated for transport under ADR/RID Regulations.**
14.3 **Transport hazard class: Not applicable.**
14.4 **Packing Group:** Not applicable.
14.5 **Environmental hazards: Not applicable.**
14.6 **Special precautions for the user:** Not applicable.

IMO
14.1 **UN No.:** Not applicable.
14.2 **Proper Shipping Name (Technical Name if required): Not regulated for transport under IMO Regulations**
14.3 **Transport hazard class: Not applicable.**
14.4 **Packing Group:** Not applicable.
14.5 **Environmental hazards: Not applicable.**
14.6 **Special precautions for the user:** Not applicable.
14.7 **Transport in bulk according to Annex II of MARPOL 73/78 and the IBC Code:** Not applicable

IATA/ICAO
14.1 **UN No.:** Not applicable.
14.2 **Proper Shipping Name (Technical Name if required): Not regulated for transport under IATA/ICAO Regulations**
14.3 **Transport hazard class: Not applicable.**
14.4 **Packing Group:** Not applicable.
14.5 **Environmental hazards: Not applicable.**
14.6 **Special precautions for the user:** Not applicable.

15. REGULATORY INFORMATION

15.1. Safety, health and environmental regulations/legislation specific for the substance/mixture
SP1 Do not contaminate water with the product or its container.

15.2. Chemical Safety Assessment
A Chemical Safety Assessment per Regulation (EC) No. 1907/2006 is not required and has not been performed.
A Risk Assessment has been performed under Regulation EC 1107/2009.

16. OTHER INFORMATION

The information given here is not necessarily exhaustive but is representative of relevant, reliable data.
Follow all local/regional/national/international regulations.
Please consult supplier if further information is needed.
This Safety Data Sheet has been prepared following the Regulation (EC) No. 1907/2006 (Annex II) as last amended by Regulation (EC) No. 2015/830
|| Significant changes versus previous edition.
In this document the British spelling was applied.

Classification of components

MONSANTO Europe S.A./N.V. — Page: 10 / 10
Monsanto Amenity Glyphosate XL — Version: 1.0 — Effective date: 03/02/2017

Components	Classification
Isopropylamine salt of glyphosate	Aquatic Chronic - Category 2 H411 Toxic to aquatic life with long lasting effects
Quaternary ammonium compound	Skin corrosion/irritation - Category 2 Eye damage/irritation - Category 1 Aquatic Chronic - Category 3 H315 Causes skin irritation H318 Causes serious eye damage H412 Harmful to aquatic life with long lasting effects
Water and minor formulating ingredients	Not classified as dangerous

Endnotes
{a} EU label (manufacturer self-classification)
{b} EU label (Annex I)
{c} EU CLP classification (Annex VI)
{d} EU CLP (manufacturer self-classification)

Full denomination of most frequently used acronyms. BCF (Bioconcentration Factor), BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), EC50 (50% effect concentration), ED50 (50% effect dose), I.M. (intramuscular), I.P. (intraperitoneal), I.V. (intravenous), Koc (Soil adsorption coefficient), LC50 (50% lethality concentration), LD50 (50% lethality dose), LDLo (Lower limit of lethal dosage), LEL (Lower Explosion Limit), LOAEC (Lowest Observed Adverse Effect Concentration), LOAEL (Lowest Observed Adverse Effect Level), LOEC (Lowest Observed Effect Concentration), LOEL (Lowest Observed Effect Level), MEL (Maximum Exposure limit), MTD (Maximum Tolerated Dose), NOAEC (No Observed Adverse Effect Concentration), NOAEL (No Observed Adverse Effect Level), NOEC (No Observed Effect Concentration), NOEL (No Observed Effect Level), OEL (Occupational Exposure Limit), PEL (Permissible Exposure Limit), PII (Primary Irritation Index), Pow (Partition coefficient n-octanol/water), S.C. (subcutaneous), STEL (Short-Term Exposure Limit), STOT SE (Specific Target Organ Toxicity, Single Exposure), STOT RE (Specific Target Organ Toxicity, Repeated Exposure), TLV-C (Threshold Limit Value-Ceiling), TLV-TWA (Threshold Limit Value - Time Weighted Average), UEL (Upper Explosion Limit)

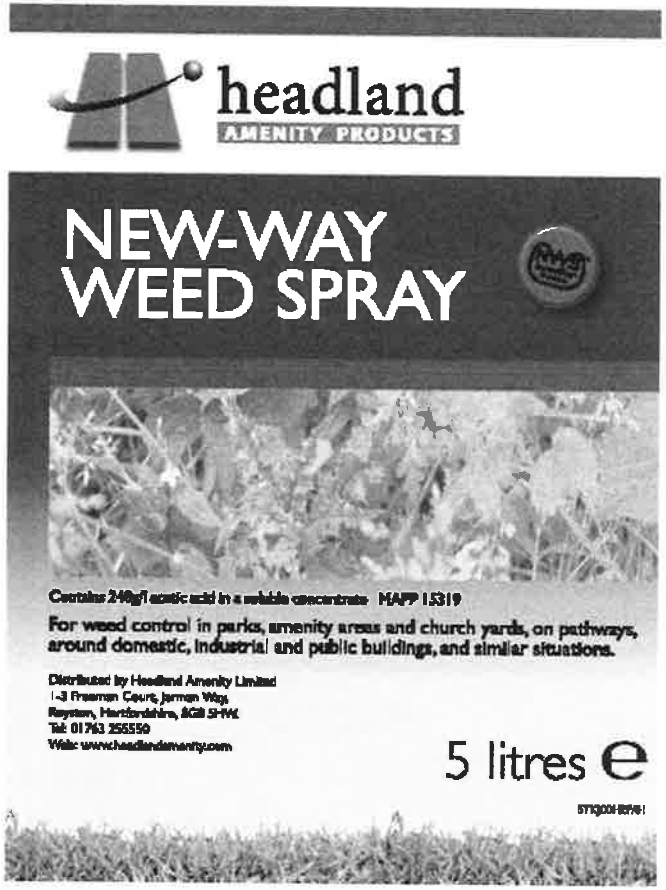
> Although the information and recommendations set forth herein (hereinafter "Information") are presented in good faith and believed to be correct as of the date hereof, MONSANTO Company or any of its subsidiaries makes no representations as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for the purposes prior to use. In no event will MONSANTO Company or any of its subsidiaries be responsible for damages of any nature whatsoever resulting from the use of or reliance upon information. NO REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR OF ANY OTHER NATURE ARE MADE HEREUNDER WITH RESPECT TO INFORMATION OR TO THE PRODUCT TO WHICH INFORMATION REFERS.

Safety Data Sheet (SDS) Annex

Chemical Safety Report:
Read and follow label instructions.

000000063347 — End of document

New-Way Weed Spray - product label


headland
AMENITY PRODUCTS
NEW-WAY
WEED SPRAY
Contains 240g/l acetic acid in a soluble concentrate MAPP 15319
For weed control in parks, amenity areas and church yards, on pathways, around domestic, industrial and public buildings, and similar situations.
Distributed by Headland Amenity Limited
1-3 Freeman Court, Jarman Way,
Royston, Hertfordshire, SG8 5HW.
Tel: 01763 255550
Web: www.headlandamenity.com
5 litres e


headland
NEW-WAY WEED SPRAY
5 Litres e
Distributed by Headland Amenity Limited, 1-3 Freeman Court, Jarman Way, Royston, Hertfordshire, SG8 5HW. Tel: 01763 255550 Web: www.headlandamenity.com
Contains Alcohol ethoxylate, C13 EC 931-138-8; Acetic acid 240g/l EC 200-580-7 MAPP 15319
For weed control in parks, amenity areas and church yards, on pathways, around domestic, industrial and public buildings, and similar situations.
The Control of Substances Hazardous to Health (COSHH) Regulations may apply to the use of this product at work.
DANGER
P312 Immediately call a POISON CENTER/doctor.
IMPORTANT INFORMATION
FOR USE ONLY AS A PROFESSIONAL HERBICIDE AND MOSSKILLER
Situations: Natural surfaces not intended to bear vegetation. Permeable surfaces overlying soil. Hard surfaces.
Maximum individual dose: 25 ml product per m².
Maximum number of treatments: 6 per year.
Other specific restrictions: A minimum interval of 7 days must be observed between applications.
READ THE LABEL BEFORE USE. USING THIS PRODUCT IN A MANNER THAT IS INCONSISTENT WITH THE LABEL MAY BE AN OFFENCE. FOLLOW THE CODE OF PRACTICE FOR USING PLANT PROTECTION PRODUCTS.
SAFETY PRECAUTIONS
Operator protection
Environmental protection
Storage & Disposal
DIRECTIONS FOR USE
Areas of use
Application
Mixing
Weather
After spraying
Subsequent planting
Care of equipment

New-Way Weed Spray - material safety data sheet (MSDS)

headland

SAFETY DATA SHEET
NEW-WAY WEED SPRAY

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1. Product identifier

Product name	NEW-WAY WEED SPRAY
Product number	PST012/5

1.2. Relevant identified uses of the substance or mixture and uses advised against

Identified uses	As a horticultural/industrial herbicide and mosskiller

1.3. Details of the supplier of the safety data sheet

Supplier	Headland Amenity Ltd 1-3 Freeman Court Jarman Way Royston Hertfordshire SG8 5HW +44 (0)1763 255550 sds@headlandamenity.com
Contact person	Wendy Johnson

1.4. Emergency telephone number

Emergency telephone	+44 (0)1763 255550 (09.00 - 17.00 GMT Monday - Friday)
National emergency telephone number	111

SECTION 2: Hazards identification

2.1. Classification of the substance or mixture

Classification (EC 1272/2008)

Physical hazards	Not Classified
Health hazards	Skin Irrit. 2 - H315 Eye Dam. 1 - H318
Environmental hazards	Not Classified

2.2. Label elements

Hazard pictograms

Signal word	Danger
Hazard statements	H315 Causes skin irritation. H318 Causes serious eye damage.

NEW-WAY WEED SPRAY

Supersedes date 24/09/2019

Precautionary statements	P280 Wear protective gloves/ protective clothing/ eye protection/ face protection P302+P352 IF ON SKIN: Wash with plenty of water. P305+P351+P338 IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. P310 Immediately call a POISON CENTER/ doctor. P332+P313 If skin irritation occurs: Get medical advice/ attention. P362+P364 Take off contaminated clothing and wash it before reuse.
Supplemental label information	EUH401 To avoid risks to human health and the environment, comply with the instructions for use.
Contains	ACETIC ACID

2.3. Other hazards

SECTION 3: Composition/information on ingredients

3.2. Mixtures

ACETIC ACID			**24% (240g/l)**
CAS number: 64-19-7	EC number: 200-580-7	REACH registration number: 01-2119475328-30-XXXX	
Classification Flam. Liq. 3 - H226 Skin Corr. 1A - H314 Eye Dam. 1 - H318			

ALCOHOL ETHOXYLATE, C13		**3-10%**
CAS number: 69011-36-5	EC number: 500-241-6	
Classification Aquatic Chronic 3 - H412		

The Full Text for all R-Phrases and Hazard Statements are Displayed in Section 16.

SECTION 4: First aid measures

4.1. Description of first aid measures

Inhalation	Remove person to fresh air and keep comfortable for breathing. Get medical attention if symptoms are severe or persist.
Ingestion	Rinse mouth thoroughly with water. Get medical attention if symptoms are severe or persist.
Skin contact	Take off contaminated clothing and wash it before reuse. Wash skin thoroughly with soap and water. Get medical attention if symptoms are severe or persist after washing.
Eye contact	Remove any contact lenses and open eyelids wide apart. Rinse immediately with plenty of water. Get medical attention immediately. Continue to rinse.

4.2. Most important symptoms and effects, both acute and delayed

Inhalation	Irritating to respiratory system.
Ingestion	Irritates mucous membranes in mouth and gastrointestinal tract.
Skin contact	Redness.
Eye contact	Eye contact may result in deep caustic burns, pain, tearing and cramping of the eyelids. Risk of serious damage to eyes. Loss of sight.

NEW-WAY WEED SPRAY

4.3. Indication of any immediate medical attention and special treatment needed

Specific treatments	Treat symptomatically.

SECTION 5: Firefighting measures

5.1. Extinguishing media

Suitable extinguishing media	The mixture is not classified as flammable. Use fire-extinguishing media suitable for the surrounding environment.
Unsuitable extinguishing media	Do not use water jet as an extinguisher, as this will spread the fire.

5.2. Special hazards arising from the substance or mixture

Specific hazards	Product decomposes in fire and may release toxic gases such as carbon monoxide and hydrocarbons.

5.3. Advice for firefighters

Protective actions during firefighting	Move containers from fire area if it can be done without risk. Avoid breathing fire gases or vapours.
Special protective equipment for firefighters	Wear positive-pressure self-contained breathing apparatus (SCBA) and appropriate protective clothing.

SECTION 6: Accidental release measures

6.1. Personal precautions, protective equipment and emergency procedures

Personal precautions	Wear suitable protective equipment, including gloves, goggles/face shield, respirator, boots, clothing or apron, as appropriate.

6.2. Environmental precautions

Environmental precautions	Do not discharge onto the ground or into water courses.

6.3. Methods and material for containment and cleaning up

Methods for cleaning up	Wipe up with an absorbent cloth and dispose of waste safely. Absorb in vermiculite, dry sand or earth and place into containers.

6.4. Reference to other sections

Reference to other sections	For personal protection, see Section 8. For waste disposal, see Section 13.

SECTION 7: Handling and storage

7.1. Precautions for safe handling

Usage precautions	Use only in well-ventilated areas.
Advice on general occupational hygiene	Eye wash facilities and emergency shower must be available when handling this product. Wash hands thoroughly after handling.

7.2. Conditions for safe storage, including any incompatibilities

Storage precautions	Keep out of the reach of children. Keep away from food, drink and animal feeding stuffs. Store in a cool and well-ventilated place.

7.3. Specific end use(s)

SECTION 8: Exposure controls/Personal protection

8.1. Control parameters

Occupational exposure limits

ACETIC ACID

NEW-WAY WEED SPRAY

Long-term exposure limit (8-hour TWA): WEL 10 ppm 25 mg/m³ vapour
Short-term exposure limit (15-minute): WEL 20 ppm 50 mg/m³ vapour
WEL = Workplace Exposure Limit.

ACETIC ACID (CAS: 64-19-7)

DNEL	Workers - Inhalation; Short term local effects: 25 mg/kg Workers - Inhalation; Long term local effects: 25 mg/kg General population - Dermal; Short term local effects: 25 mg/kg General population - Inhalation; Long term local effects: 25 mg/kg
PNEC	- Fresh water; 3.06 mg/l - Sediment (Freshwater); 11.4 mg/kg - Soil; 0.478 mg/kg - STP; 85 mg/l

8.2. Exposure controls

Eye/face protection	Use approved safety goggles or face shield. Personal protective equipment for eye and face protection should comply with European Standard EN166.
Hand protection	Wear protective gloves. Butyl rubber. To protect hands from chemicals, gloves should comply with European Standard EN374.
Other skin and body protection	Wear protective clothing. Boots.
Hygiene measures	Wash hands thoroughly after handling. Do not eat, drink or smoke when using this product. Remove contaminated clothing and protective equipment before entering eating areas.
Respiratory protection	If ventilation is inadequate, suitable respiratory protection must be worn. Gas filter, type E. Respiratory protection must conform to one of the following standards: EN 136/140/145.
Environmental exposure controls	Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation.

SECTION 9: Physical and chemical properties

9.1. Information on basic physical and chemical properties

Appearance	Liquid
Colour	Colourless
Odour	Characteristic
Odour threshold	No information available.
pH	pH (concentrated solution): 3.19
Melting point	No information available.
Initial boiling point and range	100oC
Flash point	No information available.
Evaporation rate	No information available.
Evaporation factor	No information available
Flammability (solid, gas)	No information available
Upper/lower flammability or explosive limits	No information available.

NEW-WAY WEED SPRAY

Vapour pressure	No information available
Vapour density	No information available
Relative density	1.065
Solubility(ies)	Miscible with water
Partition coefficient	No information available
Auto-ignition temperature	No information available
Decomposition Temperature	No information available
Viscosity	372 mPa s @ °C
Explosive properties	No information available
Oxidising properties	Does not meet the criteria for classification as oxidising

9.2. Other information

SECTION 10: Stability and reactivity

10.1. Reactivity

Reactivity	Strong reducing agents. Strong oxidising agents. Strong alkalis.

10.2. Chemical stability

Stability	Stable at normal ambient temperatures and when used as recommended

10.3. Possibility of hazardous reactions

Possibility of hazardous reactions	No potentially hazardous reactions known

10.4. Conditions to avoid

Conditions to avoid	None known

10.5. Incompatible materials

Materials to avoid	Strong reducing agents. Strong oxidising agents. Strong alkalis.

10.6. Hazardous decomposition products

Hazardous decomposition products	Thermal decomposition or combustion may liberate carbon oxides and other toxic gases or vapours.

SECTION 11: Toxicological information

11.1. Information on toxicological effects

Toxicological information on ingredients.

ACETIC ACID

Acute toxicity - oral

Acute toxicity oral (LD_{50} mg/kg)	3,310.0
Species	Rat
ATE oral (mg/kg)	3,310.0

Acute toxicity - inhalation

NEW-WAY WEED SPRAY

Acute toxicity inhalation (LC_{50} vapours mg/l)	40.0
Species	Rat
ATE inhalation (vapours mg/l)	40.0

ALCOHOL ETHOXYLATE, C13

Acute toxicity - oral

Acute toxicity oral (LD_{50} mg/kg)	2,000.9
Species	Rat
ATE oral (mg/kg)	2,000.9

SECTION 12: Ecological information

12.1. Toxicity

Ecological information on ingredients.

ACETIC ACID

Acute aquatic toxicity

Acute toxicity - fish	LC_{50}, 96 hours: 300.82 mg1, Freshwater fish LC_{50}, 96 hours: 300.82 mg1, Marinewater fish LC_{50}, 21 days: 52.2 mg/l, Oncorhynchus mykiss (Rainbow trout) NOEC, 21 days: 34.3 mg/l, Oncorhynchus mykiss (Rainbow trout)
Acute toxicity - aquatic invertebrates	EC_{50}, 48 hours: >300.82 mg/l, Daphnia magna NOEC, 21 days: 31.4 mg/l, Daphnia magna
Acute toxicity - aquatic plants	EC_{50}, 72 hours: >300.82 mg/l, Skeletonema costatum
Acute toxicity - microorganisms	NOEC, 16 hour: 1150 mg/l, Pseudomonas putida

ALCOHOL ETHOXYLATE, C13

Acute aquatic toxicity

Acute toxicity - fish	LC_{50}, 96 hour: 2.5 mg/l, Brachydanio rerio (Zebra Fish) EC_{20}, 30 days: 1.097 mg/l, Pimephales promelas (Fat-head Minnow)
Acute toxicity - aquatic invertebrates	EC_{50}, 48 hours: 1.5 mg/l, Daphnia magna EC_{50}, 21 days: 0.74 mg/l, Daphnia magna
Acute toxicity - aquatic plants	ErC20, 72 hours: 0.979 mg/l, Desmodesmus subspicatus ErC50, 72 hours: 2.5 mg/l, Scenedesmus subspicatus NOEC, 72 hours: 1.7 mg/l, Scenedesmus subspicatus
Acute toxicity - microorganisms	EC_{50}, 3 hours: 140 mg/l, Activated sludge EC_{50}, 16.9 hours: > 10g , Pseudomonas putida

12.2. Persistence and degradability

Persistence and degradability The product is biodegradable

12.3. Bioaccumulative potential

NEW-WAY WEED SPRAY

Bioaccumulative potential	Bioaccumulation is unlikely.
Partition coefficient	No information available.

12.4. Mobility in soil

Mobility	The product contains at least one substance with low soil mobility.

12.5. Results of PBT and vPvB assessment

Results of PBT and vPvB assessment	This product does not contain any substances classified as PBT or vPvB.

12.6. Other adverse effects

SECTION 13: Disposal considerations

13.1. Waste treatment methods

General information	Avoid discharge to drain or surface water. Collect spills and waste in closed, leak-proof containers for disposal at the local hazardous waste site.

SECTION 14: Transport information

14.1. UN number

UN No. (ADR/RID)	2790
UN No. (IMDG)	2790
UN No. (ICAO)	2790
UN No. (ADN)	2790

14.2. UN proper shipping name

Proper shipping name (ADR/RID)	ACETIC ACID SOLUTION
Proper shipping name (IMDG)	ACETIC ACID SOLUTION
Proper shipping name (ICAO)	ACETIC ACID SOLUTION
Proper shipping name (ADN)	ACETIC ACID SOLUTION

14.3. Transport hazard class(es)

ADR/RID class	8
ADR/RID classification code	C3
ADR/RID label	8
IMDG class	8
ICAO class/division	8
ADN class	8

Transport labels

14.4. Packing group

ADR/RID packing group	III
IMDG packing group	III

NEW-WAY WEED SPRAY

ICAO packing group	III
ADN packing group	III

14.5. Environmental hazards

Environmentally hazardous substance/marine pollutant
No.

14.6. Special precautions for user

EmS	F-A, S-B
ADR transport category	3
Emergency Action Code	•2R
Hazard Identification Number (ADR/RID)	80
Tunnel restriction code	(E)

14.7. Transport in bulk according to Annex II of MARPOL and the IBC Code

SECTION 15: Regulatory information

15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture

EU legislation	Product Registration Number: MAPP 15319.

15.2. Chemical safety assessment

A chemical safety assessment has been carried out.

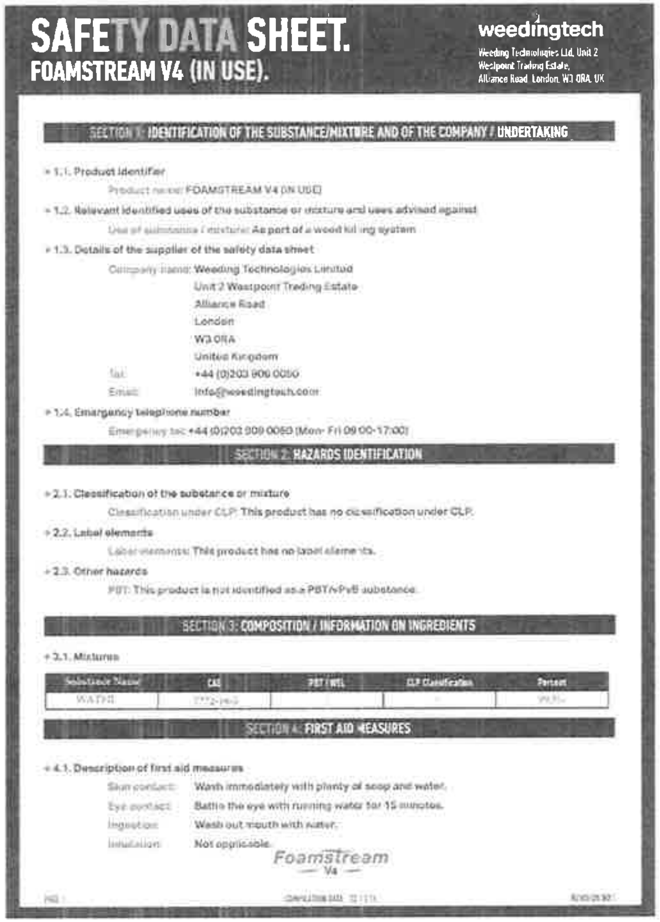
SECTION 16: Other information

Revision comments	Section 2.2 'Supplemental label information' updated. Section 12.6 'Other adverse effects' updated. Supplier company address updated. Emergency contact details updated.
Revision date	24/03/2021
Revision	5
Supersedes date	24/09/2019
Hazard statements in full	H226 Flammable liquid and vapour. H314 Causes severe skin burns and eye damage. H315 Causes skin irritation. H318 Causes serious eye damage. H412 Harmful to aquatic life with long lasting effects.

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process. Such information is, to the best of the company's knowledge and belief, accurate and reliable as of the date indicated. However, no warranty, guarantee or representation is made to its accuracy, reliability or completeness. It is the user's responsibility to satisfy himself as to the suitability of such information for his own particular use.

Foamstream® - product label

Foamstream® - material safety data sheet (MSDS)



SAFETY DATA SHEET.
FOAMSTREAM V4 (IN USE).

weedingtech
Weeding Technologies Ltd, Unit 2
Westpoint Trading Estate,
Alliance Road, London, W3 0RA, UK

SECTION 1: IDENTIFICATION OF THE SUBSTANCE/MIXTURE AND OF THE COMPANY / UNDERTAKING

1.1. Product identifier

Product name: FOAMSTREAM V4 (IN USE)

1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of substance / mixture: As part of a weed killing system

1.3. Details of the supplier of the safety data sheet

Company name: Weeding Technologies Limited
Unit 2 Westpoint Trading Estate
Alliance Road
London
W3 0RA
United Kingdom
Tel: +44 (0)203 909 0050
Email: info@weedingtech.com

1.4. Emergency telephone number

Emergency tel: +44 (0)203 909 0050 (Mon- Fri 09:00-17:00)

SECTION 2: HAZARDS IDENTIFICATION

2.1. Classification of the substance or mixture

Classification under CLP: This product has no classification under CLP.

2.2. Label elements

Label elements: This product has no label elements.

2.3. Other hazards

PBT: This product is not identified as a PBT/vPvB substance.

SECTION 3: COMPOSITION / INFORMATION ON INGREDIENTS

3.1. Mixtures

Substance Name	CAS	PBT / WEL	CLP Classification	Percent
WATER	[illegible]		-	[illegible]

SECTION 4: FIRST AID MEASURES

4.1. Description of first aid measures

Skin contact: Wash immediately with plenty of soap and water.
Eye contact: Bathe the eye with running water for 15 minutes.
Ingestion: Wash out mouth with water.
Inhalation: Not applicable.

Foamstream V4

SECTION 4: FIRST AID MEASURES (CONTINUED)

+ 4.2. Most important symptoms and effects, both acute and delayed
  - Skin contact: There may be mild irritation at the site of contact.
  - Eye contact: There may be irritation and redness.
  - Ingestion: There may be irritation of the throat.
  - Inhalation: No symptoms.
  - Delayed / immediate effects: Immediate effects can be expected after short-term exposure.
+ 4.3. Indication of any immediate medical attention and special treatment needed
  - Immediate / special treatment: Not applicable.

SECTION 5: FIRE-FIGHTING MEASURES

+ 5.1. Extinguishing media
  - Extinguishing media: Suitable extinguishing media for the surrounding fire should be used. Use water spray to cool containers.
+ 5.2. Special hazards arising from the substance or mixture
  - Exposure hazards: None identified.
+ 5.3. Advice for fire-fighters
  - Advice for fire-fighters: Fire fighters should wear protective clothing and breathing apparatus as appropriate.

SECTION 6: ACCIDENTAL RELEASE MEASURES

+ 6.1. Personal precautions, protective equipment and emergency procedures
  - Personal precautions: Refer to section 8 of SDS for personal protection details. Turn leaking containers leakside up to prevent the escape of liquid.
+ 6.2. Environmental precautions
  - Environmental precautions: Contain the spillage using bunding.
+ 6.3. Methods and material for containment and cleaning up
  - Clean-up procedures: Absorb into dry earth or sand. Transfer to a closable, labelled salvage container for disposal by an appropriate method.
+ 6.4. Reference to other sections
  - Reference to other sections: Refer to section 8 of SDS.

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SECTION 7: HANDLING AND STORAGE

+ 7.1. Precautions for safe handling
  - Handling requirements: Avoid direct contact with the substance. Ensure there is sufficient ventilation of the area.
+ 7.2. Conditions for safe storage, including any incompatibilities
  - Storage conditions: Store in a cool, well ventilated area. Keep container tightly closed.
  - Suitable packaging: Must only be kept in original packaging.

SECTION 8: EXPOSURE CONTROLS / PERSONAL PROTECTION

+ 8.1. Control parameters
  - Workplace exposure limits: No specific control limits available
+ 8.2. Exposure controls
  - Engineering measures: Ensure there is sufficient ventilation of the area.
  - Respiratory protection: Not usually required. Use in well ventilated areas and avoid formation of spray or aerosols.
  - Hand protection: Protective gloves.
  - Eye protection: Tightly fitting safety goggles. Ensure eye bath is to hand.
  - Skin protection: Protective clothing.
  - Environmental: No special requirement

SECTION 9: PHYSICAL AND CHEMICAL PROPERTIES

+ 9.1. Information on basic physical and chemical properties

State:	Liquid.	Flash point°C:	No data available.
Colour:	Pale yellow.	Autoflammability°C:	No data available.
Odour:	Characteristic odour.	Relative density:	No data available.
Evaporation rate:	Negligible	VOC g/l:	No data available.
Oxidising:	Non-oxidising (by EC criteria)	Melting point/range°C:	No data available.
		upper:	No data available.
Solubility in water:	Miscible	Part.coeff. n-octanol/water:	No data available.
Viscosity:	No data available.	Vapour pressure:	No data available.
Boiling point/range°C:	No data available.	pH:	No data available.
Flammability limits %: lower:	No data available.		

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SECTION 10: STABILITY AND REACTIVITY

+ 10.1. Reactivity

Reactivity: Stable under recommended transport or storage conditions.

+ 10.2. Chemical stability

Chemical stability: Stable under normal conditions.

+ 10.3. Possibility of hazardous reactions

Hazardous reactions: Hazardous reactions will not occur under normal transport or storage conditions.

Decomposition may occur on exposure to conditions or materials listed below.

+ 10.4. Conditions to avoid

Conditions to avoid: Heat.

+ 10.5. Incompatible materials

Materials to avoid: Strong oxidising agents. Strong acids.

+ 10.6. Hazardous decomposition products

Haz. decomp. products: May release fumes of carbon monoxide and carbon dioxide if heated to decomposition.

SECTION 11: TOXICOLOGICAL INFORMATION

+ 11.1. Information on toxicological effects

Toxicity values: This product is not considered to be acutely toxic.

+ 11.2. Symptoms / routes of exposure

Skin contact:	There may be mild irritation at the site of contact.
Eye contact:	There may be irritation and redness.
Ingestion:	There may be irritation of the throat.
Inhalation:	No symptoms.
Delayed / immediate effects:	Immediate effects can be expected after short-term exposure.
Other information:	Not applicable.

SECTION 12: ECOLOGICAL INFORMATION

+ 12.1. Toxicity

Ecotoxicity values: Not expected to be toxic in the environment.

+ 12.2. Persistence and degradability

Persistence and degradability: Biodegradable

+ 12.3. Bioaccumulative potential

Bioaccumulative potential: No bioaccumulation potential

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SECTION 12: ECOLOGICAL INFORMATION (CONTINUED)

+ 12.4. Mobility in soil

Mobility: Readily absorbed into soil.

+ 12.5. Results of PBT and vPvB assessment

PBT identification: This product is not identified as a PBT/vPvB substance.

+ 12.6. Other adverse effects

Other adverse effects: Negligible ecotoxicity.

SECTION 13: DISPOSAL CONSIDERATIONS

+ 13.1. Waste treatment methods

Disposal operations: Dispose of in accordance with local regulations.

Disposal of packaging: Clean with water. Dispose of as normal industrial waste.

SECTION 14: TRANSPORT INFORMATION

Transport class: This product does not require a classification for transport.

SECTION 15: REGULATORY INFORMATION

+ 15.1. Safety, health and environmental regulations/legislation specific for the substance or mixture

Specific regulations:

- Proposition 65 (California)- None of the ingredients is listed
- TSCA (USA): All ingredients are listed
- EPA (Washington): Foamstream does NOT need registration under FIFRA

SECTION 16: OTHER INFORMATION

Other information: This safety data sheet is prepared in accordance with Commission Regulation (EU) No 2015/830.

* indicates text in the SDS which has changed since the last revision.

Legal disclaimer: The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. This company shall not be held liable for any damage resulting from handling or from contact with the above product.

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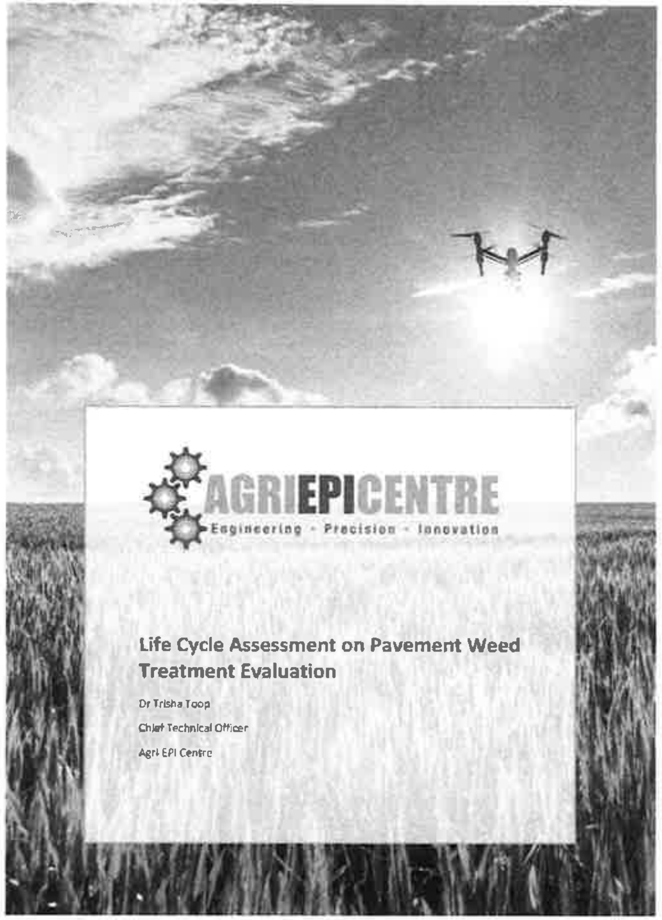
COMPILATION DATE: 22/11/19

Appendix 2 - LCA report

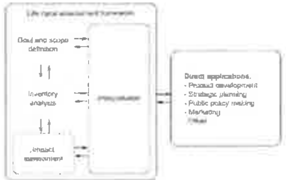


Contents

1. INTRODUCTION

Life Cycle Assessment (LCA) is a structured, comprehensive and internationally standardised method. It quantifies all relevant emissions and resources consumed and the related environmental and health impacts and resource depletion issues that are associated with the entire life cycle of any goods or services ("products").

The framework used to conduct a LCA is shown in Figure 1. This shows the stages of an LCA and the direct applications of the results



The LCA detailed in this report has been conducted to the international standards in LCA ISO 14040 and 14044 (Arvanitoyannis, 2008). And uses best practice outlined in the International Reference Life Cycle Data System (ILCD) which was developed to provide guidance for consistent and quality assured Life Cycle Assessment data and studies (European Commission - Joint Research Centre, 2010)

An evaluation of the efficacy of different pavement weed control methods was undertaken across the City of Cardiff by Advanced Invasives for Cardiff Council. Full details of the methodology and results can be found in that report. As part of the evaluation three different weed control treatments were evaluated all inputs of the treatment were measured and this data was be used for calculations in this LCA

There have been studies on weed treatment techniques in amenity areas done previously but none have applied a full LCA done by an independent expert on the treatment systems in this study to assess the environmental impacts of the different methods

2. GOAL OF THE STUDY

The goal of the study is to compare the weed treatments tested in the study to determine which has the lowest environmental impacts. Therefore, a comparative LCA will be completed on all three treatments tested in the study conducted with primary usage data provided by Advanced Invasives

This study will be presented to Cardiff Council for decision making on pavement weed treatments. A peer review has been undertaken externally by Dr Sophie Hocking (Department of Biosciences, Swansea University) on the study which allows for this use following ISO guidelines.

The intended audience for this LCA is weed control specialists within Advanced Invasives who have experience of accessing LCA results and members of Cardiff Council who have not. Therefore, methodologies for non-expert distribution have been followed so normalisation and weighting of results will not be used. This LCA report should be used in conjunction with the weed control trial report in which the methodology for the trial and data collection is detailed.

3. SCOPE OF THE STUDY

Functional unit

The function of the products in this study are to treat pavements for weed control. The functional unit was determined as 1 km of pavement treated. The efficacy of treatment is assessed in a report that preceded the completion of the LCA. The functional unit quantifies the amount of each product used to give weed control to an equal efficacy.

System boundaries

All inputs into the production of the treatments have been included in the system along with the inputs into the production of tap water which was used by many of the treatments. Petrol and diesel use have been included where used in the treatment system. Production of equipment used to apply the products and transport to the treatment site has not been included. A general system boundary is shown in Figure 2.

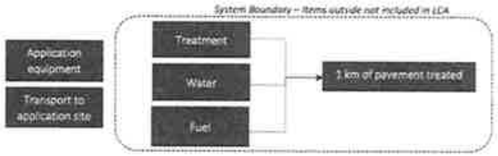


Figure 2 – General system boundary

The Ecoinvent database 3 in Simapro release 9.3.0.3 was used to in all aspects of the LCA.

Where possible European data was used for the inputs into the process with global data only selected when that was not available.

This LCA was conducted in 2022 using the data available for production, use, emissions and waste scenarios available at that time in Ecoinvent and Simapro. The LCA will need to be updated regularly to capture changes and to keep the results current. This particularly important if product formulations or usage changes.

Allocation is embedded into the database on the following principles. The system model 'allocation, recycled content' or 'cut-off' is based on the approach that primary production of materials is always allocated to the primary user of a material. If a material is recycled, the primary producer does not receive any credit for the provision of any recyclable materials. The consequence is that recyclable materials are available burden-free to recycling processes and secondary (recycled) materials bear only the impacts of the recycling processes. Also, producers of wastes do not receive any credit for the recycling or re-use of products resulting out of any waste treatment.

Assumptions and limitations

Information on the treatments and their constituents were gained from product information printed on product packaging and MSDS sheets.

Further clarification on product composition was requested in the case if Foamstream but no further information was gained from the manufacturer. Due to being unable to get an exact composition of the product Rapeseed oil was used as the reference product for the LCA as information obtained indicated that this was the majority constituent. Other items such as plant husks are also referenced but not included as no details as to the amounts in the product could be obtained. This omission in the data will result a very small underestimation of the emissions for this treatment and further modelling would be recommended if more product details could be obtained.

Standard Ecoinvent database data was used for all other products based on the information provided by the manufacturer.

Impact categories and impact assessment method

ReCiPe 2016 Midpoint (H) V1.04 / World (2010) (Hierarchist) method was used to calculate the Impact categories which are as shown below in Table 1.

Table 1 – Impact categories used in LCA as calculated by ReCiPe 2016 Midpoint (H) V1.04 / World (2010) H method

Impact category	*Unit*
Global warming	kg CO2 eq
Stratospheric ozone depletion	kg CFC11 eq
Ionizing radiation	kBq Co-60 eq
Ozone formation, Human health	kg NOx eq
Fine particulate matter formation	kg PM2.5 eq
Ozone formation, Terrestrial ecosystems	kg NOx eq
Terrestrial acidification	kg SO2 eq
Freshwater eutrophication	kg P eq
Marine eutrophication	kg N eq
Terrestrial ecotoxicity	kg 1,4-DCB
Freshwater ecotoxicity	kg 1,4-DCB
Marine ecotoxicity	kg 1,4-DCB
Human carcinogenic toxicity	kg 1,4-DCB
Human non-carcinogenic toxicity	kg 1,4-DCB
Land use	m2a crop eq
Mineral resource scarcity	kg Cu eq
Fossil resource scarcity	kg oil eq
Water consumption	m3

Normalisation and weighting

Due to the target audience for the LCA no allocation or weighting was used in the production of the results.

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4. LIFE CYCLE INVENTORY ANALYSIS

Process flowcharts

Detailed process flows are shown in the figures below for all treatments.

The process flow for the Glyphosate treatment used is shown in Figure 3.

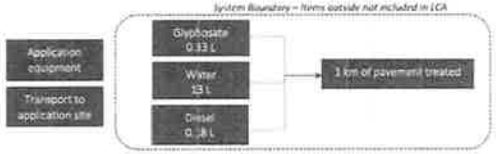

Figure 3 - Process flow for Glyphosate treatment used to treat 1 km of pavement

The process flow for the New Wave treatment is shown in Figure 4.

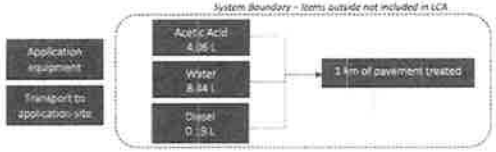

Figure 4 - Process flow for New Wave treatment used to treat 1 km of pavement

The process flow for the Foamstream treatment is shown in Figure 5.

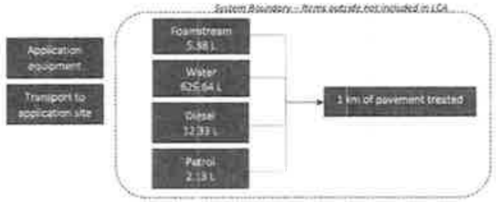

Figure 5 - Process flow for Foamstream treatment used to treat 1 km of pavement

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Data

Primary data was collected as part of the trial conducted by Advanced Invasives on all treatments. Aggregated data was provided to Agri-EPI Centre to use for the LCA along with raw data for reference and query if needed.

Clarification was sought from the data provider to ensure that an accurate representation of the treatments was being made and all figures used were checked by Advanced Invasives prior to inclusion in the LCA and were reviewed during the peer review process. The figures used to calculate the emissions are shown in Table 2.

Table 2 – [illegible]

Control Method	Product Use L/km	Water Use L/km	Diesel Use L/km	Petrol Use L/km
Glyphosate	0.33	13.00	0.18	0.00
New Wave	4.06	8.44	0.18	0.00
Foamstream	5.37	629.64	12.33	2.13

5. Results

The results of the LCA are as follows in this section. A direct comparison was made between all treatments on km of pavement treated, the results of which are shown in Figure 6.

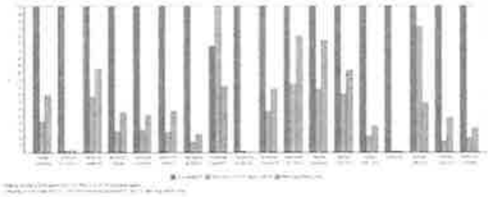

Figure 6 - [illegible]

It can be seen from above that Foamstream has higher environmental impacts in all impact categories calculated except for freshwater eutrophication.

The details of the environmental impacts for the weed treatments tested are shown in Table 3 below. All impacts relate back to the functional unit of 1 km of pavement treated.

Table 4 – Results from comparison of pavement weed treatments environmental impacts

Impact category	Unit	Monsanto Amenity Glyphosate XL	New-Way Weed Spray	Foamstream®
Global warming	kg CO2 eq	3.725906632	6.920265219	17.62954775
Stratospheric ozone depletion	kg CFC11 eq	0.00	3.71233E-06	0.000219686
Ionising radiation	kBq Co-60 eq	0.333211153	0.499734199	0.870118201
Ozone formation, Human health	kg NOx eq	0.008903155	0.01745232	0.064022231
Fine particulate matter formation	kg PM2.5 eq	0.00736806	0.0123352	0.048506821
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.009142212	0.0186019	0.066531821
Terrestrial acidification	kg SO2 eq	0.014106715	0.02609239	0.215053388
Freshwater eutrophication	kg P eq	0.005180359	0.002346239	0.003780149
Marine eutrophication	kg N eq	0.000345545	0.000150603	0.059807027
Terrestrial ecotoxicity	kg 1,4-DCB	16.26066476	25.29477007	58.13958006
Freshwater ecotoxicity	kg 1,4-DCB	0.250487795	0.427871658	0.534874363
Marine ecotoxicity	kg 1,4-DCB	0.31026383	0.554566163	0.72170849
Human carcinogenic toxicity	kg 1,4-DCB	0.167244915	0.236177538	0.421593391
Human non-carcinogenic toxicity	kg 1,4-DCB	4.463951492	7.370060901	41.27578609
Land use	m2a crop eq	0.101314072	0.127103301	33.33581954
Mineral resource scarcity	kg Cu eq	0.064759475	0.025142473	0.075130588
Fossil resource scarcity	kg oil eq	1.337191228	4.259576156	18.29370741
Water consumption	m3	0.104360548	0.186825836	1.133128599

The process flow of Foamstream was further investigated to determine the major factors contributing to its environmental impacts and are shown in Figure 7.

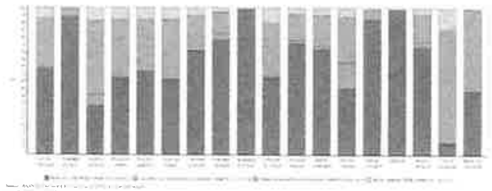

Figure 7 – Processes contribution to impacts for Foamstream

As there is no one contributing factor no further investigation was made at this stage.

6. CONCLUSIONS

The goal of the study was to compare the three pavement weed treatments detailed in the work done by Advanced Invasives for Cardiff Council. Data was collected in a detailed, systematic way which allowed for accurate calculation of the amount of product used to treat 1 km of pavement for treatment type.

As shown in Figure 6 and Table 3, Foamstream has higher environmental impacts in all categories calculated except for that of freshwater eutrophication in which Monsanto Amenity Glyphosate had a higher impact.

The conclusions that can be made from these results is that both Monsanto Amenity Glyphosate and New Wave weed treatments have an overall lower environmental impact than Foamstream; and the treatment that has the lowest overall environmental impact is Monsanto Amenity Glyphosate.

The results from the impact assessment were not surprising given the higher number of inputs into the Foamstream system. Further information from the manufacturers on the overall composition of the treatment would give more accurate results. A conservative approach was taken on how to determine the composition of the product from information that was available and this will have resulted in an underestimation of the environmental impact. If further information becomes available at a later date it is recommended that the LCA be recalculated.

The results above are comparable to those found in a similar study of weed treatments for controlling weeds on hard surfaces (Department for Environment, Food and Rural Affairs, 2015). They found that freshwater impacts were the only ones that Glyphosate were higher than those of non herbicide approaches. They had an integrated treatment approach which makes direct comparison of figures difficult but the findings were comparable in general.

The conclusions from the LCA are that overall Monsanto Amenity Glyphosate has less environmental impact than the other treatments in this study. However, these are not stand alone results and this report should be used in conjunction with the full study compiled by Advanced Invasives. (Arvanitoyannis, 2008)

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References

Arvanitoyannis, I. (2008). ISO 14040: Life Cycle Assessment (LCA) - Principles and Guidelines. ISO/TC 207/SC 5 Life cycle assessment.

Department for Environment, Food and Rural Affairs. (2015). *Development of zero and minimal herbicide regimes for controlling weeds on hard surfaces and determining their emissions.* East Malling: Department for Environment, Food and Rural Affairs.

European Commission - Joint Research Centre. (2010). *Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Provisions and Action Steps.* Luxembourg: Publications Office of the European Union.

Appendix 3 - Details of all monitoring sites

Six monitoring sites were identified in each of the three evaluation wards (total = 18), with a further six untreated control monitoring sites across the City of Cardiff (overall total = 24). Monitoring sites for each evaluation ward and the untreated control monitoring sites included two:

- Main thoroughfare routes
- Representative residential street routes
- Residential street routes in close proximity to an open space/parkland

All monitoring sites are provided in the Figures below, together with monitoring site route distances.

Route type	Street name	Route distance (m)
Main thoroughfare A	Cathedral Road (Dogo Street to Berthwin Street)	81
Main thoroughfare B	Cowbridge Road (Market Road to Llandaff Road)	120
Residential street A	Despenser Place (Beauchamp Street to Clare Street)	78
Residential street B	Sneyd Street (Kings Road to Plasturton Avenue)	90
Residential street + open space/parkland A	Despenser Gardens (Beauchamp Street to Clare Street)	80
Residential street + open space/parkland B	Plasturton Gardens (Plasturton Place to Plasturton Avenue)	141

Figure: Riverside Ward monitoring sites, showing route type, street names and route distances (m).

Route type	Street name	Route distance (m)
Main thoroughfare A	Colchester Avenue (Scholars Drive to Fforrd Nowell)	116
Main thoroughfare B	Penylan Road (Ty-Draw Road to Boleyn Walk)	118
Residential street A	Amesbury Road (Blenheim Road to Waterloo Road)	93
Residential street B	Baron's Court Road (Dorchester Avenue to Hampton Court Road)	178
Residential street + open space/parkland A	Waterloo Gardens (Waterloo Road to turning point)	133
Residential street + open space/parkland B	Sandringham Road (Trafalgar Road to Grenville Road)	81

Figure: Penylan Ward monitoring sites, showing route type, street names and route distances (m)

Route type	Street name	Route distance (m)
Main thoroughfare A	Heol Glandulais (Clos Nant Y Cor to Sindercombe Close)	95
Main thoroughfare B	Heol Pontprennau (Kenmare Mews to Youghal Close)	96
Residential street A	Speedwell Close	119
Residential street B	Idencroft Close	75
Residential street + open space/parkland A	Cottingham Drive	108
Residential street + open space/parkland B	High Bank	45

Figure: Pontprennau & Old St Mellons Ward monitoring sites, showing route type, street names and route distances (m).

Route type	Ward	Street name	Route distance (m)
Main thoroughfare A	Llanedeyrn	62-82 Llanedeyrn Road + Bro Edern	79
Main thoroughfare B	Fairwater	Plas-Mawr Road (Clos-Y-Nant to Poplar Road)	108
Residential street A	Ely	Moore Road (Windsor Clive Primary to Moore Close)	105
Residential street B	Trowbridge	58-66 Coleford Drive	105
Residential street + open space/parkland A	Splott	23-57 Whitaker Road	105
Residential street + open space/parkland B	Rhiwbina	42-62 Ty Wern Road	105

Figure: Untreated control monitoring sites confirmed across the City of Cardiff, showing route type, ward, street names and route distances (m).