Holistic weed control practice for urban storm water catchments. Global trends, methods, limitations and cost benefits

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This paper cites scientific research into weed management practices from around the globe to evaluate their benefits and limitations. In order to protect ecosystems, that WSUD intends to facilitate, there is an increasing range of non chemical and organic weed control methods that are being used and trialed to mitigate herbicide residues in storm water. Life cycle costs, carbon footprint, downstream effects & risk assessment of a range of weed control methodologies are considered in order to evaluate their comparative costs and benefits. These findings allow us to present a weed management methodologies matrix as a reference point for discussion on planning and budgeting for sustainable weed management to mitigate herbicide residues in urban storm water.

I. Introduction

Weed control is necessary in urban storm water catchments as weeds cause several problems (Rask & Kristoffersen, 2007). Weeds can cause damage to public assets such as footpaths, paved areas and road surfaces by breaking up asphalt and opening up cracks (Holgersen, 1994; Schroedr, 1994). Weeds and moss contribute to slip hazards on footpaths. Weeds accumulate debris, particulate, vegetation & sediment at their base and create an environment for harboring seed, perpetuating further weed establishment. This accumulation of residues can impede storm water run-off or be trans-located by storm events into the storm water system and contribute to sedimentation and weed establishment downstream. Established weeds can impede vision of traffic when in the proximity of kerbs, channels and traffic islands. There is a general view that weeds in footpaths and the streetscape creates a perception of a city in decline.

"Conventional" weed control in the urban areas since the late 1970's has been carried out with herbicides, dominantly glyphosate products. (Ramwell, 2006). Glyphosate (the active constituent in Roundup) is the worlds most used chemical at 650,000 tonnes in 2011 and estimated to increase by 800% by 2025. (Friends of the Earth Europe 2011) Urban areas are substantially designed to facilitate surface runoff, rapid infiltration and mitigate flooding. Public assets within urban storm water catchments which are regularly treated with herbicide, mainly glyphosate, include kerbs, gutters, footpaths, streets & WSUD installations. Glyphosate is removed easily from asphalt and concrete. Ramwell, 2006 demonstrated 35% loss of applied glyphosate to storm water in two studies. 80% of loss occurred in first few mm of rainfall leading to contamination of storm water, sewage systems and groundwater (e.g. Allender 1991; Ramwell et al 2002; Skark et al 2004).

A study of glyphosate and aminomethyl phosphonic acid (AMPA) transfer in the Orge watershed (France) (Botta F et al 2009) showed annual glyphosate estimated load was 1.9 kg/year downstream from agricultural zone and 179.5 kg/year at the catchment outlet from the urban zone. This result suggested that the contamination of this basin by glyphosate was essentially from urban origin and contributed 94 times as much as the agriculture area upstream.

Puijker et al (2004) calculated that the cost of treating water to remove pesticides, by the combined Dutch water companies, amounted to almost €92 million (Rask & Kristoffersen, 2007).

Glyphosate, once claimed to be safe enough to drink, is increasingly being found to have bio-accumulative effects in mammals, has been found in 60 – 100% of urine samples taken in populations across Europe (Sewell 2013) found in mothers breast milk in the US (Honeycutt et al 2014). Roundup, the worlds most used herbicide, has been shown to by 125 times more toxic to humans than its glyphosate active principle (Mesnage et al, 2014).

In this paper the reader is provided with a brief overview of the non chemical weed management apparatus which have become available in the last 5 years. The results of desktop research into the current available studies, web-based information, as well as the authors own experience with ‘on the ground’ weed management have been collated into a table which starts to compare management considerations such as efficacy, carbon footprint, cost and environmental impact of the nominated methods. An extract of this table is presented. Finally, there are some concluding remarks.

Thermal and mechanical weed management alternatives

A. Mechanical

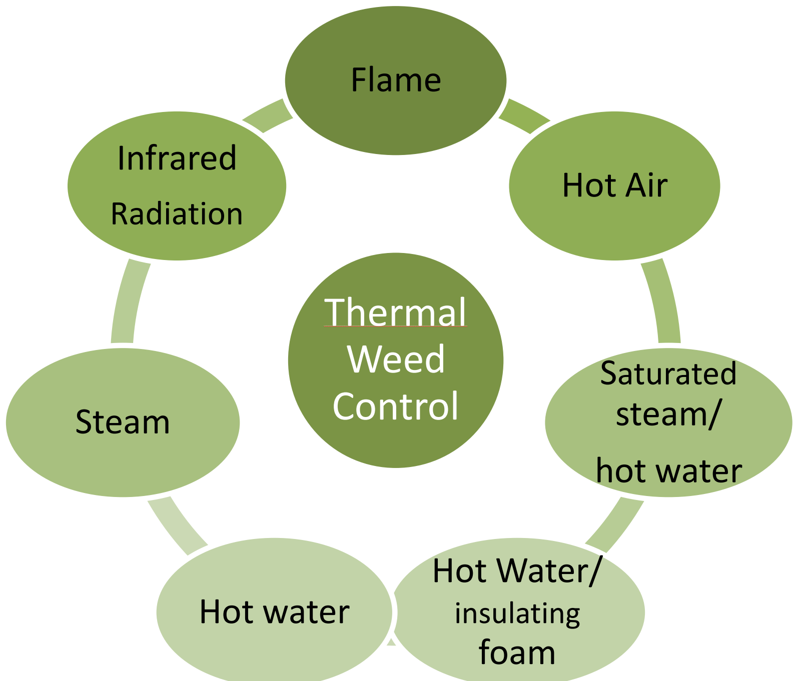
Mechanical methods of weed control for paved surfaces include brushing, whipper-snipping (weed whacking/ brush cutting), hand weeding. Thermal weed control methods include flaming, hot air, radiant heat, hot water, hot foam and saturated steam. Weed brushes are a specialist piece of equipment mounted to mobile plant produced by companies that specialize in cleaning apparatus such as Karcher, Nilfisk, Koti, Kersten, Ecobrush, Weedbrush. Whipper Snippers are manually operated hand held units which are readily available from grounds and garden care outlets. Mechanical weed control has the disadvantage of removing the above ground parts of weed only. Weeds by their nature are adapted to grazing and regenerate quickly from the meristematic cells at the plants crown or from the apical cells of leaves and shoots. Mechanical weed control also has been shown to damage assets, brushes causing additional wear and tear on paved surfaces (Lefevre et al 2001; Wood, 2004) and potentially damage tree assets eg whipper snipper girdling of trunks.

In the last 10 years there has been significant development of a number of varieties of thermal weed control.

B. Thermal

Earliest documented patents for thermal weed control date back to the 1920’s when steam trains in Australia were fitted with pipes to divert locomotive steam to distribution pipes directing hot water to vegetation growing on the rock ballast under the tracks. The advent of herbicides in the 1940’s saw this technology almost disappear until the early 1990’s when a mobile method and apparatus for controlling vegetation using hot water was patented (Newson R J, PCT/NZ93/00035). In the last 10 years there has been significant development of a number of varieties of thermal weed control.

Thermal weed control options can be broadly classed into two categories. Hot Dry and Hot Wet.



C. Hot Dry

Hot Dry includes flame, hot air and radiant heat. Flame and radiant heat tend to be more portable, use LPG / propane but do not penetrate into the crown of the plants efficiently, often requiring more frequent interventions. Exposed flame weeders pose significant fire risk in dry conditions and on mulches, and cannot be used on rubber soft fall, rubber paving, near litter, debris or irrigation lines and fittings.

Hot air weed control extracts hot air from a flame source directing it onto vegetation such as the Zacho: Turbo Weed Blaster. Hot air has very high energy consumption. Radiant Flame units direct flame heat, under the protection of a shroud, onto a ceramic or metal surface in close to proximity of vegetation. Units can be hand held, trolley or vehicle mounted available from HOAF NL, Sunburst OR, USA. Hand held LPG/ propane flame burners are an often used alternative, mainly for small or difficult to access areas.

D. Hot Wet

Hot wet weed control apparatus are mainly of the hot water, hot foam and saturated steam embodiments. Wet steam, such as the Canadian Greensteam ® (no longer in production) and HOAF 'greensteam' overcome some of the fire risk of open flame but produce too little volume of wet stream to provide commercial viability (Authors personal experience). The superior control of weeds by hot wet methods over hot dry is due to moisture enabling more rapid transfer of lethal heat into cell structure than dry heat. Deeper penetration into meristematic cells is experienced and residual heat in the surface soil is enough to provide some control of seed bank. (Hansson & Ascard 2004, Kristoffersen et al 2007).

There have been improved methods of heating water by a number of manufacturers in Europe, USA and Australia. Development of hydraulic controlled machine mounted applicator heads by Wave in NL and Empas Gmbh increases speed and area of application in accessible open paved areas such as parks, footpaths, streets and lanes. Use of infra-red weed detection by Wave NL reduces water and energy consumption. Heated foam, formed by mixing a heated aqueous solution of water, surfactant and hot air, first patented in 1995 (Rajamannan A.H.J US5,575,111 Filed 28 Sept,1995) has been further developed by Weeding Technologies Ltd, GB. Heated foam has been demonstrated to expose plant tissue to heat for a longer period increasing efficacy when compared to hot water. Saturated steam, created by increasing the boiling point of heated water under pressure to approximately 115 - 120C and then depressurising in a depressurising nozzle assembly in close proximity to vegetation delivers a mixture of saturated steam and hot water at 100C to the weeds. (Aus Patent 2004320467 P.Musten, D.Parkin, J.Winer).

Global incidence of pesticide and herbicide prohibition and reduction.

In a growing number of countries use of glyphosate and other herbicides and pesticides have been regulated against. By example the EU Water Framework Directive (WFD) orders local authorities at water catchment level to reach a ‘good quality’ of the water by the end of 2015, which by definition requires mitigation of pesticide residues. The Netherlands after 10 years of research and trials has banned the use of herbicide at Municipality level from January 2015 (The Sustainable Pulse, 2014). The cities Grobbendonk, Hasselt and Ghent in Belgium have banned the use of pesticides in Parks, streets and cemeteries. Local authorities in Denmark have signed a voluntary agreement to totally phase out herbicides in urban areas. Switzerland has banned the use of herbicides on roofs, balconies, streets and squares. Ninety (90) provinces across Canada have banned the use of herbicides for amenity horticulture including vegetation management in streets and public open space. New York State has banned the use of all pesticides in schools, San Francisco has banned the use of herbicides in the catchment of the Bay area. In France, Ségolène Royal, the Minister of Ecology, is leading debate to have all chemicals banned in parks, schools and public places.

Weed management considerations

There is a requirement upon managers responsible for vegetation management to consider environmental and economic targets. In States and regions where regulatory authorities have not banned the use of herbicides, managers work within municipal or organisational policies to decide on the weed methodologies to employ. Increasingly in Australia, municipalities are adopting policies which include commitments to carbon emission reduction and least toxic weed and pest management. (For examples see City of Sydney Pesticide Notification Plan (PNP), Warringah Council Environmental Sustainability Strategy 2012).

The management considerations include, carbon emissions (CE), whole of life cycle analysis (LCA), water consumption, health and safety for operators, health and safety for community, ecological/ environmental impacts and cost.

A determinant in the frequency of weed control interventions is the presentation standard required of the asset. For example a footpath in a pedestrian shopping precinct may have a requirement to have < 2% weed cover at any time, whereas a suburban footpath in a residential area may be permitted to have <10% weed cover with no weeds more than 50mm in height.

Carbon emissions CE.

Carbon emissions are a measure of the CO and CO_2 emitted in the course of a product's life cycle.

Barber, 2009 estimated the total CE of glyphosate to be 28 kg/ Litre in its production, formulation and packaging. Kristoffersen & Rask et al 2007 determined the relative energy consumption of 5 various non-chemical weed treatments used on traffic islands over a number of treatments. R. Lal in his paper *Carbon emissions from farm operations* 2004 cites 0.63 as the emission coefficient for LPG/kg. The author has documented production rates and fuel consumption for saturated steam weed control. Table gives some comparisons of the CE of 7 weed management tools.

Table 1. Carbon emissions (CE) of some non-chemical alternatives and glyphosate

		Capacity (m2/h)	Energy kW h h-1	working width cm	Treatment per annum (5)	mean dose kg gas ha	Mean dose per year	CE/kg a.i (1)
Flames	HOAF	320-350	61.4-67.2	50	8	150	1200	94.5
Hot air	Zacho	350-400	150.1 -171.5	65	8	335	2680	211.1
Steam	Danstream	250-300	52.2 -62.6	50	8	163	1304	102.7
Hot Water	Waipuna	200	79.9	20	4	312	1240	196.6
Brushes	DUKS FM-BS			50	4			0.0
Saturated steam (4)	Steamwand SW900	350-520		50	4	105	419	65.9
Glyphosate (2)					3			>75.6 (3)

(Kristoffersen, 2007) reported all fields shaded in grey.
(1) CE coefficient of 0.63/kg propane (R.Lal 2004)
(2) Barber 2009 calculated glyphosate CE 28kg/L
(3) Nufarm Roundup Biactive label states Active Constituent of glyphosate 360g/L. Rate per Ha of Roundup Biactive is 2-3L. Average 2.5L/Ha x 360g = 0.9kg with a CE of 28 kg/L = CE 25.2 Kg/Ha,(3 x p.a = 75.6) this does not include CE of applicator pump or the carrying vehicle. Barber also does not include transport of the Roundup from point of manufacture (China) to the end user or the post consumed disposal of the toxin drum. CE does not include calculation for the surfactant and other non disclosed additives which make up the Roundup formulation.
(4) Data for saturated steam is data supplied by the author recorded whilst undertaking weed control for a municipal council on terrain that the author considers comparable to segmental paving areas of the Kristoffersen study.
(5) Treatment frequencies are for Danish growing season of Kristoffersen study.

Table 2. Urban Weed Management Methodologies Matrix

		Chemical Spray	Mechanical	Thermal					
		Glyphosate based	Weed brush	Flame	Saturated Steam & hot water	Hot Water Foam	Hot Water	Radiant	Hot air
Application	Contact	Y	Y	Y	Y	Y	y	Y	Y
	Systemic	Y							
	Pre-emergent				Potentially	Potentially			
Effect	Above ground	Y	Y	Y	Y	Y	y	Y	Y
	Meristematic crown	Y			Y	Y	y		Y
	Roots	Y							
	Seed bank		Spreads	Potentially germinates seeds					
Efficacy	overall	High	Low	Moderate	High	High	High	Moderate	Moderate
Surface types	Paved	Y	Y	Y	Y	Y	y	Y	Y
	Notes		Reduces surfaces life						
	Gravelled	Y		Y	Y	Y	y	Y	Y
	Mulched	Y		Not advised spot treat	Y	Y	y	Not advised	
	Turfed								
	Rubberised	Y			Y	Y	y		
Location suitability	Footpaths	Y		Y	Y	Y	y	Y	Y
	Kerbs/ Gutters	Y	Y	Y	Y	Y	y	Y	Y
	Playgrounds	N			Y	Y	y		
	Street tree pits	?		Y	Y	Y	y	Y	Y
	Pedestrian plazas	?	Y	Y	Y	Y	y	Y	Y
	Creek lines	?		caution	Y	Y	y		
	Ephemeral	?		caution	Y	Y	y		
Frequency PA	Typical - SE Aust	4 - 8	10 - 14	10-14	6 - 8	7 - 8	8-9	10-14	10-14
Noise	Nuisance rating	Nil - Low	High	Nil	Moderate	Moderate	Moderate	Low	Low
Accessibility	Very Good, Good, Poor	VG	Poor	VG	Good	Good	Good	Poor	Poor
CO2 emissions	CE/kg Ha	25.2		94	66	unavail	196	unavail	211
Human harm potential	Poisoning - operator	High	NIL	NIL	NIL	Low	Low	NIL	NIL
	- public	Mod	NIL	NIL	NIL	NIL	NIL	NIL	NIL
	Physical -	Low	Low	Mod	Mod	Mod	Mod	Mod	Low

	operator								
	- public	Low	Low	Low	Low	Low	Low	Low	Low
Environmental harm potential	Off target spp	High	NIL	Mod	Low	Low	Low	Low	Low
	Residual	High	NIL	NIL	NIL	NIL	NIL	NIL	NIL
	Stormwater pollution	High	NIL	NIL	NIL	NIL	NIL	NIL	NIL
	Bio accumulation	High	NIL	NIL	NIL	NIL	NIL	NIL	NIL
	Fauna	High	NIL	Low	Low	Low	Low	Low	Low
Public notification Required		Yes	NO	NO	NO	NO	NO	NO	NO
Economic Efficiency		Low Cost	High Cost	High Cost	Med Cost	High Cost	High Cost	High Cost	High Cost

Table 2 is an extract of a more detailed urban weed management methodologies matrix developed by the author. Much of the classification and rudimentary values are the author’s subjective assessment based on knowledge and experience in the field. The intention of the table is to create a platform for discussion and be a handy reference point for managers to refer when evaluating the options. The Table may also generate questions and hypothesis for further research projects, for instance, does thermal weed control germinate seed banks thereby reducing future weed control activity after regular first year treatment.

It is not possible to determine meaningful comparative dollar value costs for the various methods of control for a general publication. There are too many variable factors which play a role in the frequency of application required. For example in the Leichhardt municipality, an inner suburban area of Sydney, NSW, Australia treatment frequencies using saturated steam vary from 6 – 8 times per annum, yet in Freemantle WA similar streets are treated only 2-3 times due to the climatic differences. Climatic conditions, soil type, weed population profile, weed seed sources, weed resistance to mode of action, vehicular & pedestrian traffic, street cleansing activities, surface drainage, ground water and visual amenity requirements all affect weed density, vigour and ultimately the frequency of intervention and cost per annum.

Concluding Remarks

There is a growing body of evidence concluding that herbicides and specifically glyphosate are not safe for our environment and pose significant risk to aquatic ecosystems, potable water supplies and human health. Samsell and Sanef, (2013) found that '*Glyphosate, contrary to being essentially nontoxic, may in fact be the most biologically disruptive chemical in our environment'.* There is a global trend emerging of decision makers and regulators opting for chemical reduction and alternative technologies. This has been a catalyst for development of a new generation of thermal, mechanical and 'organic' weed control technologies that have improved upon predecessors.

Glyphosate is easily removed from hard surfaces by even small amounts of rainfall. There are costs associated with this translocation of glyphosate into waterways and potable water supplies. In the Netherlands it was calculated to have cost the water companies €92 million to remove the pesticides. (Puijker et al, (2004)) The majority of municipalities in Australia take a low cost, weed management with herbicide option, therefore passing on the consequential costs of the translocation of their herbicides onto other agencies such as the water authorities, NPWS, and the State government.

Weed control using one mode of action will result in plant resistance. There are over 430 unique cases of herbicide resistant weeds globally (www.weedscience.org). There are a range of alternative modes of action that will provide weed management to a presentation of < 2% weed coverage.

It is suggested that to manage weeds sustainably the following principles should be applied.

1. Design to reduce weeds through pavement selection and competitive planting.
2. Design for and specify presentation standards, therefore the level of tolerance for weeds dictates the level of intervention, which allows budgets to be allocated on a presentation requirement.
3. Identify no chemical spray areas which have runoff potential within potable water catchments.

4. Identify socially and environmentally sensitive no chemical spray areas within urban communities i.e schools, playgrounds, shopping centres, parks
5. Adopt a variety of modes of action such as brushing/ sweeping away of debris & sediment that creates seed banks before spring, followed up with thermal weed control. Over time some species may persist which can be treated with an alternative mode of action such as an 'organic approved' vinegar, pelargonic acid or pine oil.
6. Keep records of weed management practices, what worked, what didn't, duration between treatments, weather records and the changes in weed populations over time.
7. Weed management without chemicals or utilising alternatives will have higher per sq.m costs which should be budgeted for. There will however be substantial savings of the hidden costs associated with chemical weed control.

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