Weeds, treatment of unwanted vegetation

Trial and comparison for glyphosate free weed treatment in Bristol parks and highway surfaces

Bristol City Council

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1. Introduction and background

The council has been approached by individuals and campaign groups calling for a ban on its use of *glyphosate* for the purposes of weed control and horticultural management . At the same time the Pesticide Action Network UK (PAN UK) launched a campaign for pesticide free towns and cities (PAN UK, 2016).

Glyphosate is a widely used systemic herbicide which acts to kill a whole plant, including its root, when applied to its foliage (Kristofferssen & Rask, 2012, p. 129; PSU, 2016).

In March 2015, the International Agency for Research on Cancer (IARC) report re-evaluated herbicide, glyphosate, carcinogenetic classification to group 2A as "probably carcinogenic to humans" (WHO, 2015). The evidence in humans came mostly from studies carried out on agricultural workers (Hortweek, 2015).

However, a subsequent peer-review of the IARC assessment in September 2016 concluded that glyphosate is "unlikely to pose a carcinogenic risk to humans" (Williams, et al., 2016). Other national and international organisations such as Food and Agricultural Organisation of the United Nations, FAO, and US environmental Protection Agency, EPA, have following the IARC report re-evaluated glyphosate status and found it unlikely to be carcinogenic (Appelby, 2016).

Prior to pending EU re-licensing of glyphosate in July 2016, the European Food Safety Authority (EFSA) also reviewed its glyphosates toxicological profile finding it "unlikely to pose a carcinogenic hazard to humans" (EFSA, 2015). The licence was renewed for 18 months only in wait of European Chemicals Agency (ECHA) evaluation. In March 2017 ECHA's Committee for Risk Assessment (RAC) *"concluded that the available scientific evidence did not meet the criteria to classify glyphosate as a carcinogen, as a mutagen or as toxic for reproduction"* (ECHA, 2017).

The Council's response has been to carry out research into alternatives to glyphosate and an assessment of the need for its use and to carry out a 12-month trial of an alternative method of weed control. The trial took place across all relevant land in Cotham ward and St Andrews Park.

2. Research questions

The aim of the trial is to research possibilities to further reduce synthetic herbicide use in public areas, concentrating specifically on glyphosate reductions. Answers to the following questions are sought:

- How affective is vinegar compared to glyphosate as an herbicide?
- How is the public responding to visual changes in parks and streets?
- What are the costs of alternative weed control?
- Will further reduction on herbicide application effect infrastructure?
- How and where can herbicide use be reduced without damage to infrastructure or increasing public concern?

3. Secondary research – Case study Sweden – alternative control of weeds on hard surface

The commonly available methods for weed control can be listed as prevention, chemical, thermal and mechanical treatments (Cederlund, 2016; EMR, 2015; Kristofferssen & Rask, 2012; Nielsen, et al., 2005; Cederlund, 2015; Kristofferssen & Rask, 2007; SKL, 2006). The alternatives for chemical weed control, such as thermal and mechanical, are 'contact' herbicides (not systemic as glyphosate) which affect only the visual parts of the plant, leaving the roots intact. A previous BCC report (BCC, 2016f; BCC, 2015) has covered both synthetic herbicides used in weed control and some alternative methods in detail. The report used research material available in English. This report will include studies available in other languages, as research available in English has been sparse (EMR, 2015, p. 2).

In Sweden, both railways and power transfer stations, where the protection of infrastructure is of national importance, are still using synthetic herbicides whereas most municipal authorities have severely restricted the use of synthetic herbicides. Over a ten year period, from 2006 to 2015, the Swedish University of Agricultural Sciences (SLU) has conducted research on weed control on behalf of Banverket (Swedish Rail Administration) testing various methods and their effects on railways. Methods such as hot foam and acetic acid spray have been tested (Henningsen, 2013; Cederlund, 2015).

Alternative Method – Hot Foam

The energy and water use for the hot foam method are high and operations speed slow, but compared with other thermal methods such as flaming, the method is found to be more versatile in difficult to reach areas (EMR, 2015, p. 7). 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 (Ascard, et al., 2007, p. 172; Cederlund, 2016, p. 24).

Figure 1 NCC Spuma hot foam treatment

The water use for hot foam method was estimated to be between 15,000 - 17,000 litres/ha, compared to 3000 litres/ha for acetic acid and 200 litres/ha for the tested glyphosate product. Working speed for truck mounted hot foam system was estimated to 1620m² per hour whereas when operated by hand the work output varied between 142 – 325m². The size of the water container also affects the working speed (Cederlund, 2015, p. 12).

Alternative Method – Acetic Acid

Acetic acid has also been tested in a railway environment. It was found to be effective at killing weeds at 12% concentration, but needed more treatment times and higher doses for acceptable weed removal levels when compared with synthetic, systemic herbicides. Although no effects were detected during the experiment, the possibility of the acid corroding rails and signal systems made Banverket abandon further experiments (Cederlund, 2016, pp. 38 - 39).

Alternative Method – Mechanical

The most commonly used alternative weed control on streets in Sweden is wire brushes with a side arm attachment (SKL, 2006, pp. 15 - 20). Parking restrictions in place for necessary winter snow clearance make it possible to get easy access for the sweepers in the summer.

Figure 2 Mechanical wire brush sweeper

4. Primary research – Rationale for weed spraying and costs

The Council's street cleansing contract covers the council's statutory duty to *"keep specified land clear of litter and refuse"* (Defra, 2006, p. 5), this includes litter collection. The duty covers both street and park land and was previously known as NI195, NI196. Weeds are not specifically mentioned but are understood to be included under detritus - *"dust, mud, soil grit, gravel, stones, rotted vegetation, twigs and alike"*. Bristol Centre is maintained to grade A* and the rest of the city to grade B as described on grading principles on cleanliness in amenity setting (Defra, 2006, p. 14).

The cost of the weed spraying work carried out by Bristol Waste Company (BWC) is embedded in the total value of street cleansing and cannot be accurately isolated. In 2016, weed control on the highway was carried out by BWC. In 2017, weed control will be the subject of a tender and will be delivered through a contractor.

BWC has sought prices costs for using both hot foam treatment and acetic acid treatment. The two contractors approached were not willing to consider hot foam treatment because the equipment is too large to be of use in restricted spaces deeming it not to be an effective treatment. They did not recommend the use of vinegar and were concerned that complaints about its 'smell' would harm their reputation.

However BWC previously estimated that the relative cost of each method is £60k per application for glyphosate, £216k per application for acetic acid and £392K per application for hot foam (Note: a considerable effort has been made to compare prices of acetic acid spray with use of glyphosate but it has proved too difficult to be sure we are comparing like with like in terms of outcome. BWC's estimate does this. What is clear is that the use of acetic acid and hot foam are always considerably more expensive than glyphosate.

5. The Glyphosate-free trial – Method and findings

Method:

The Council carried out a trial across all relevant land in Cotham ward and in St Andrews Park.

No glyphosate based products were used by the council or its contractors throughout the trial area on BCC owned and maintained land apart from invasive weed spraying. The trial was delivered to existing budgets for this work (BCC, 2016b). Three alternative methods for weed control were considered and priced. Acetic acid was chosen as an alternative control method (BCC, 2016c, p. 9; BCC, 2016g).

The trial involved monitoring the impact of not using glyphosate within the trial with other 'control' areas where weed control was continuing as normal. Monitoring took place on relevant streets, hard surfaces and green spaces.

The total trial area of Cotham ward is about 1 square kilometre (100ha). There is approximately 20km of highways roads in the ward. The trial started in March 2016 and the ward boundaries changed in May 2016. The trial follows largely the old boundaries.

The control routes were established by finding parks with similar path condition as Cotham Garden (a space within the trial area) and including surrounding streets. Existing road hierarchy system was used and road surface checks were done on google street view to select roads with similar characteristics in both trial and comparison areas. The sites were given a number to enable easier management of research material. The areas are divided in four routes of total of 9,639m (excluding parks). Route 1.0 was separated to two areas as some streets were added after the first visit. Route 2.0 was also separated as the weed treatment was carried out late and road surface conditions in route 2.2 (Easton) were worse than elsewhere thus causing a distortion in the scores.

Route 1.0: from Clifton Down Station to Cromwell Road, divided to:

> ***1.1 Cotham***; 2,016m of streets, three housing sites and two parks (Cotham Green and Redland Grove OS) from Whiteladies Road to Cheltenham Road
> ***1.2 Clifton and Ashley***; Total of 2,974m of streets and one park (St Andrews Park); Clifton East from Clifton Station to Whiteladies Road and Ashley from Cheltenham Road to Cromwell Road.

Route 2.0: from Lawrence Hill station to Stapleton Road divided in to (divided due to road surface conditions in 2.2):

> ***2.1 Lawrence Hill***; 1,071m of streets and one park (Gaunts Ham Park), from Lawrence Hill Station to Easton Way.
> ***2.2 Easton***; 878m of streets from Easton Road to Stapleton Road.

Route 3.0: streets on route to St George Park

Route 4.0: Road by Stapleton Road Station closed for traffic, not maintained

Both trial and control areas were visited once a month and a photographic record made.

The areas were assessed for weed levels using the method introduced in Defra report "Weeds" (EMR, 2015, pp. 18 - 23). The criterion was used to view the emerging differences between trial and comparison area. Weed complaints received by BWC have also been considered.

St George Park acted as a 'control' comparison site for St Andrews Park to add more horticultural features. For

Criteria			Score	Level	Description
Height mm	Weed diameter or legth mm	Joint covarage %			
<10	<50	<10	<3	1	No noticable weeds
10 to 50	50 to 100	0 to 20	4 to 6	2	Occational small weeds
50 to 100	100 to 150	20 to 30	7 to 9	3	Patchy weed growth with some flowering weeds
100 to 150	150 to 200	30 to 40	10 to 12	4	Numerous weeds, many flowering, view annoys or irritates public
150 to 200	200 to 300	40 to 50	13 to 15	5	Numerous large weeds, risk to slip or trip
>200	>300	>50	16 to 18	6	Numerous large weeds, many tall and flowering, cousing obstruction

Figure 3 Weed level scale and criteria

the parks the monitoring was concentrated on horticultural feature condition and visual amenity round obstacles in grass, such as park benches and bins. Possible public complaints have been taken into account.

Findings - Streets

Table below illustrates the differences between trial and comparison where 1.1, Cotham, is the trial area and the rest are control areas used for comparison.

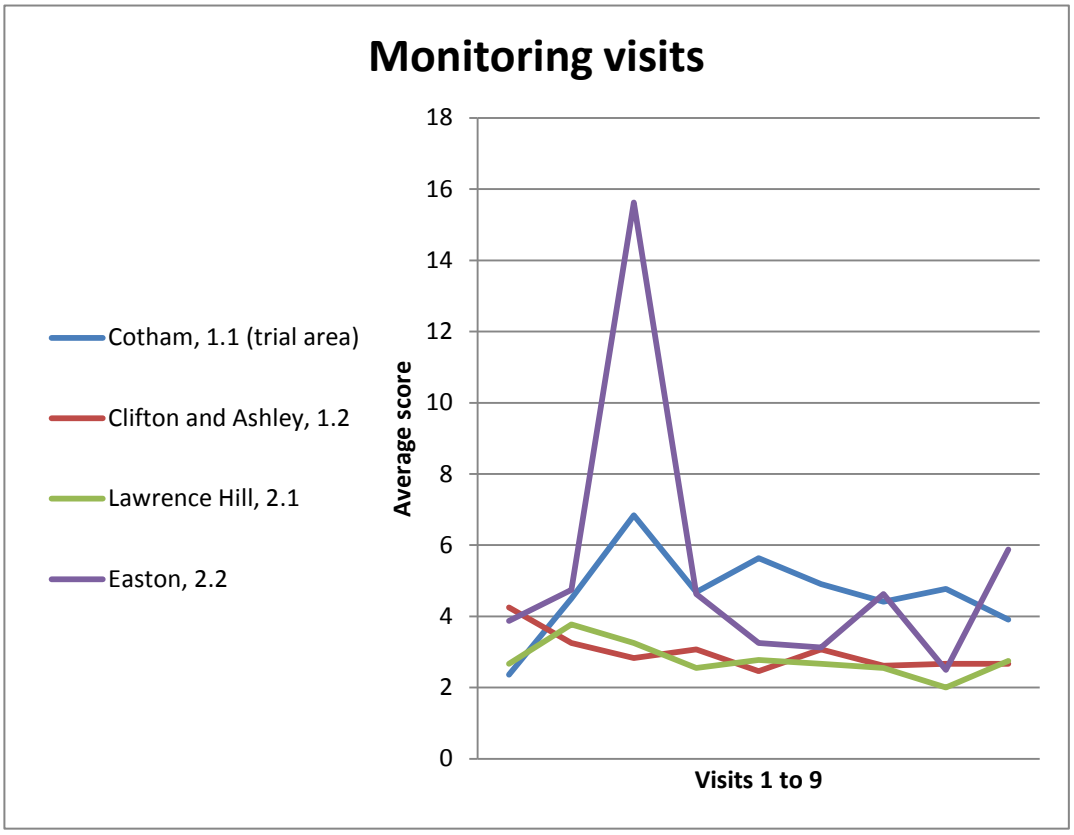

Figure 4 Average weed scores

The highest score recorded on a control area came from St Marks Road, Easton, where the herbicide spraying was carried out late in the season. After treatment, the score was more in line with other areas treated with glyphosate.

The score charts from Cotham trial area had two clear low score times, one after acetic acid treatment and one after hand weeding. Glyphosate treated areas score lower for longer after treatment. For the monitoring results it was the clearest difference between the trial and comparison areas. It shows the length of time the different methods were effective.

The monitored streets in the trial area had resident parking scheme in place whereas the comparison area did not with more parked cars as a result. Especially North Street in comparison area Ashley (1.2) was very busy making both sweeping and weed treatment tricky. On occasions it was difficult to find a gap wide enough between parked cars to walk through. It seemed to have resulted in difficulties for the spraying operations with missed weeds as a result.

The average scores for route Ashley (1.2) and Lawrence Hill (2.1) were good or acceptable throughout the monitoring period. Area Lawrence Hill (2.1) is seems more densely populated which might result on higher footfall and less weeds on the area. The jointing points between

hard surfaces were mostly weed free at all times apart from round street signs and furniture. There were no or few street trees in this area.

The tarmac quality, surface materials and late treatment time gave route Easton (2.2) some of the worst scores in earlier visits. The route can illustrate what the outcomes of no weed control could be. The area received most public complaints. The type of hard surfacing at St Marks in Easton was not present in any other monitored sites – the small paving's and large amounts of joints are a favorable growing surface for weeds. The placing of street furniture and other objects increased the weediness levels, as shown on Chelsey Road (Figure 5) with a parking area surrounded by trees and a cluster of street furniture preventing normal footfall. The parking area had empty, but still open tree pits and epicormic growth surrounding the trees. The area was sprayed later than most making the overall appearance very poor. However, one of the clearest differences between the trial and control areas was that the treatment time was clear to see. Once the area was treated its scores were comparable with the rest of the control area.

Figure 5 Easton, Chelsey Road

The streets on route 3.0 are grouped together being on the way to St George Park. Some of the route had newly resurfaced paths where the effects of good quality tarmac where clear to see. The new tarmac also covers the cracks between curb stones thus giving far less weeds.

Route 4.0 is a road closed to vehicle traffic next to Stapleton Road Station (Figure 6). It is owned by Network rail. As it doesn't seem to be on a regular weed control route, perennial species like brambles, nettles and sycamore samplings are present. Although the area was treated mechanically once during the monitoring period, it shows how the perennial weeds start to appear without weed control.

Figure 6 Stapleton Road Station

Althogether 367 complaints for street weeds were received of which 26 were in the trial or comparision areas giving 7 in Cotham, 11 in Easton and 8 in St George/Redland. No complaints were received from Ashley.

It is difficult to find distingushing any difference in the number of complaints between the trial and comparision areas.

Findings – Parks:

In parks in the trial area no alternative weed control was used. All herbicide use was ceased and normal maintenance work, such as shrub bed maintenance, path sweeping and grass cutting was continued as normal. In practise this meant that the so called "obstacle" and path spraying was not carried out. Obstacles mean anything in grass like lamp posts, trees, seats and fence lines, normally sprayed to ease the grass cutting operations and to maintain the traditional visual appearance.

Some of the paths in Cotham Gardens (Figure 7), one of the parks in the trial along with Redland Grove and St Andrews Park, were in very bad state with worn of tarmac surface and tree root damage. Tarmac quality is one of the major contributors for weediness levels and one of the most difficult to solve without the use of chemicals as if normal machine sweeping is used the tarmac will deteriorate even further.

Figure 7 Cotham Gardens path

The paths at the top part of Cotham Gardens were scheduled for resurfacing during the trial period. They needed to be treated for weeds which was not possible during the trial. The alternative would have been to cut out the areas affected, fill in with new sub-base and tarmac over. The additional cost for the 150m² area would have been £1356, about £9 per square metre.

Park entrance design and the installation techniques used for park furniture are playing part on weediness levels. Where the footfall is low, weeds will grow on a hard surface. Benches installed without a plinth are sprayed or strimmed underneath to stop the grass growth reaching the seat. Installation of concrete plinths would reduce weeding need. In the case of Redland Grove, volunteers cleared areas under the benches during the trial period.

Cotham Gardens also has fencing around its playground where grass was left untouched during the trial. Within the trial period the visual impact of this was minimal as the species growing in the base were mostly grasses. However in St Andrews Park the fenced areas had larger species mix and the visual impact was noticeably worse. With time the possibility of perennial woody species, like elder and buddleia, being established increases. In the short term the visual affect would be negative and in the long term damage to the fence may occur. The effects of no spray can also be seen in many walls round Bristol's parks.

It seems that leaving tree bases untreated (Figure 8) would be acceptable although attention needs to be paid to possible damage to trees from cutting operations. In some areas path edges have been sprayed in the 'old fashioned' way which can seem unacceptable to the modern eye, whereas in

Figure 8 St George Park long grass

other areas the visual impact of no spraying also seems unacceptable.

St Andrews Park was added to the trial at a later state to include horticultural features not present in Cotham Gardens, such as annual floral meadows. The annually seeded meadows require herbicide treatment prior to installation. For the trial period two areas were seeded with annual mixture and four areas with perennial mixture both without herbicide treatment. An other small area of floral meadow was intalled in existing grass also without treatment as a comparision. All areas in St Andrews had more weeds than before, but germination did happen and flowers apeared. It can also be stated that after six years of intalling floral meadows throughout bristol, that the existing seed bank and the amounts of time that the same spot has been used, play a crucial role in weedines levels. Amaranthus and docs have established themselves in one park to the level where a decision to move the meadow has been made.

Further notes:

For the 2016 season Bristol Waste Company (BWC) took the spraying contract in-house when previously it was contracted out. A new spraying application method was employed, Total Droplet Control (TDC), a method perceived to have less environmental impact with precision spraying, quicker drying times and less wind drift. It also turned out to be slower. BWC only completed one treatment in most areas, a change from two treatments the previous year.

With the short trial time it is impossible to say if or how the weed flora would change with different treatment methods. In both the control and trial areas, the weeds present later in the season were mostly tap rooted plants, such as taxarum ssp, and grasses.

The crews carrying out the weed control stated that the weeds started to regrow in acetic acid areas a quicker than elsewhere. As the outcome for the acetic acid was set to “as with glyphosate” hand weeding was carried out later in the season on some streets. Both statements are reflected in the score results.

An unexpected effect of the acetic acid on spraying equipment was that the acid is presumed to have damaged the spraying equipment nozzles. Most of the available equipment is made for synthetic herbicides and alternatives would have to be sought for future use.

During the short trial it was not possible to identify any long term impact to highway surfaces. The highways department states that the biggest deteriorating aspect on bitumen surfaces is UV radiation followed by heavy and frequent traffic. Little or no research has been available as to weeds affecting surfaces. There is available research on tree roots affecting surfaces and therefore it can be anticipated that if larger woody weeds get established, the infrastructure will get affected on the long term. The highways department carries out surface condition surveys and the resurfacing is carried out in about a ten year cycle subject to inspection.

6. Research questions – summary of findings

Question 1: How effective is vinegar compared to glyphosate as a herbicide?

The large trial areas, involvement of several operators, lack of infrastructure investment and use application methods may have affected trial results to some degree. However, clear differences between the methods can be shown, like the length of time before weeds started re-emerging. For acetic acid and hand weeding the weeds started to re-emerging within a month, the interval of monitoring times. On comparison sites, treated with glyphosate, the weedines scores stayed low for five to six months. This is reflected in secondary research material studied.

Acetic acid can be as effective as glyphosate in removing the surface appearance of weeds if used more frequently. However the cost becomes prohibitive.

Many Swedish municipalities have had a total ban or restrictions for synthetic chemical use since 1996. A study and guidance document has evaluated ten years of experiences from different councils of weed control without synthetic chemicals. It finds that the weed problem in places is now so severe and that either more resources is needed or long-term removal process of hard surfaces needs to be started (SKL, 2006, p. 3). The main reason for herbicide bans has been to protect groundwater. Other protective measures, such as recommendations not wash your car on the streets are also in place.

Question 2: How is the public responding to visual changes in parks and streets?

During the trial period only one weed treatment was completed with glyphosate resulting in some complaints. No guidelines have so far been used as for wished for outcomes of spraying or what is an acceptable level of weeds on streets. We know that the public does react to an increase in weeds on streets.

We can also assume that, as most authorities across the UK and Europe carry out some method of weed control, this is because of their impact on the attractiveness of an area and the public response to that.

Within parks, the trial-time of one year did not result in significant enough visual changes and therefore no increase in public concern. There was an increase in volunteering activity in Redland Grove, where benches have no base and weeds were starting to grow through. The grass was cut under benches by volunteers who also have been fundraising to install plinths for benches.

Question 3: What are the costs of alternative weed control?

As the trial was set up within the existing budgets it is considered the no extra costs should have occurred. However, the contractor did hand weed some of the trial area with an estimated additional cost of £1.06/linear[1] meter. Also the parks department had scheduled a path surfacing for Cotham gardens and would have incurred and increase of £9.04/m^2 if the work had been done.

The BWC estimations mentioned earlier indicate 3.6 times higher costs for acetic acid applications and 6.5 times higher costs for hot foam treatment. However, BWC was not able to

[1] Based on estimated weekly work increase for a crew of 2.
[2] Based on cutting out areas affected by weeds, filling new subbase opposed to just spraying.

get quotes for either of the alternative treatments for the coming season as the contractors asked did not deem the alternatives as viable options.

Question 4: Will further reduction on herbicide application effect infrastructure?

For the short period of the trial no structural damage was detected. Control route 4 indicates that with the increase in perennial weed composition and appearance of woody weed such as sycamore and buddleia the future damage is possible. Literature also talks about increased wind and water erosion in spots were weeds start to grow and estimates that the life span of a surface can be reduced. The time is depending of surface materials with can vary widely between countries. The Swedish study from 2006 after ten years of alternative weed control by municipalities recommends that the weed control efforts are greatly increased or start ripping out tarmac. The nationally important structures such as electricity substations and railroads have not introduced glyphosate bans as they have, despite efforts, not been able to find good enough substitute. The railways did find acetic acid good enough but the metal signal systems stopped future experiment although research did not show great corrosive effects on metal structures.

Question 5: How and where can herbicide use be reduced without damage to infrastructure or increasing public concern?

In parks the reductions can be made in so called obstacle spray resulting in high grass round trees and poles. It might be more difficult to exclude spraying all together round fence lines as woody weeds will emerge with time. It should however be possible to use sprays only every other or third year if high grass round bases is visually acceptable.

For the street scene hard surface it will be more difficult. Parked cars will restrict the introduction of a machine based approach and affect cost. Defra recommend longer contracts which would allow the contractors to invest in specialist machines, especially applicators that use technology to detect weeds and measured amounts of herbicide going down to greatly limit the amount of glyphosate used. There are areas where spraying is needed for both visual amenity and for protecting infrastructure.

7. Conclusions

Although synthetic herbicides are still widely used in domestic, agricultural and public space settings and are more effective than alternatives, the desire to protect water courses, stop the progress of resistant weeds and political pressure has led to restrictions of herbicide use in some European countries (Kristoffersen, et al., 2007, p. 370; Cederlund, 2016, p. 43).

Since the European Chemicals Agency (ECHSA) risk analysis dictating glyphosate as not carcinogenic the debate between industry and campaigners is still ongoing. For example, the Crop Protection Association states the following:

"Glyphosate is, and always has been safe. This ruling is another reminder this debate has never really been about safety, it has been hijacked and politicised to force a wider debate on modern agriculture. It's right that we're having that debate, but it's wrong to use health scares to get there." (Appleby, 2017).

…and one of the campaign organisations, Greenpeace, states the following:

"Echa has gone to great lengths to sweep all evidence that glyphosate can cause cancer under the carpet. The data vastly exceeds what's legally necessary for the EU to ban glyphosate, but Echa has looked the other way" (Neslen, 2017).

It can be difficult for the policy makers to decide a course of action with this divergence of views. However, the legal requirement for weed control on public areas, public perception and protection does require weed control to be carried out.

When deciding a method, all the environmental aspects of synthetic herbicides and alternative weed control methods should be considered. The costs and effectiveness of the alternative methods will also influence the choice. Removing glyphosate completely at the moment, especially on hard surfaces and in control of invasive weeds, is not the right option.

The Swedish SKF study recommends better understanding of how the alternatives work and deters from total ban of glyphosate. It also finds that after ten year of restrictions and bans the situation in places is so severe that either weed control needs to be increase severely or long term removal of hard surface needs to start (SKL, 2006, p. 3) The recommendation from "Weeds" for integrated pest control, using synthetic herbicides along with alternative weed control methods, seems like the best alternative for a way forward. Even then more work and investment is needed to choose an appropriate control, adapt the equipment and operators skills and evaluate the street environment for suitable methods. Also, as with glyphosate is not a suitable comparison. The acceptance levels of weeds needs agreeing instead and several methods will need to be used alongside each other to achieve acceptable weed control.

The recommendation for street scene is for BWC to find a progressive contractor and find out technologies of spraying with sensors etc. for best reductions. This would require longer-term contracts to allow the contractors to invest in appropriate machinery and be able to follow latest developments in the industry.

Parks will soon be testing newly licenced pelargonic acid along with other naturally occurring herbicides. The choices at the moment are acetic acid and pelargonic acid. This will require re-educating the spraying operators.

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Table of figures

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Figure 10 Route 1.1, Cotham

Figure 11 Route 1.2, Ashley

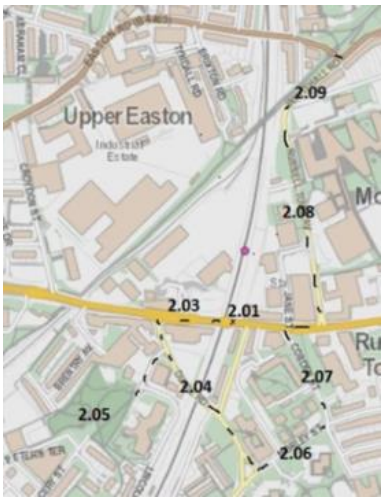

Figure 12 Route 2.1, Lawrence Hill

Figure 13 Route 2.2, Easton

Weed habits and common weeds

As most alternative weed control methods are contact affecting the need to recognize species and growth habits (Figure 14) becomes more important.

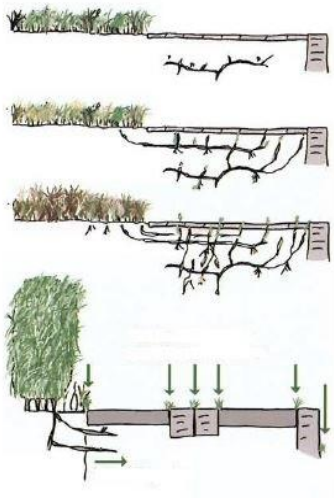

Figure 14 Weed growth habits on hard surface

The main two categories of weeds on hard surfaces are annuals, growing from seed, and perennials which can grow from root encroachment or seed. For a seed to germinate it needs nutrition, water, light and warmth. A millimeter size crack or joint is big enough for gathering dust particles and water to allow germination process to start. Curbs and other joints are the week points in a hard surface especially where footfall is low like house edge and round obstacles (Hein, 1990, p. 9). Some of the most common weeds on hard surface are annual meadow grass (Poa annua) along with other grasses, dandelion (Taxarum spp), and mosses (Bryophyta spp) (EMR, 2015, p. 10). Some fast growing tall weed species worth mentioning are willoherb (Chamaenerion angustigolium), sow thistle (Sonchus spp.) and horseweed (Conyza Canadensis) (Melander, et al., 2008, p. 8) all of which have been prominent in Bristol hard surfaces during monitoring. (See Appendix 1 for weeds).

The prevailing weeds have often they growth meristem below the hard surfaces and tolerate wear and tear (Rask, 2012, pp. 13 - 14). Besides the unkempt look of weeds on hard surfaces they can speed up the deterioration of the surface. The roots further brake down the surface allowing further erosion by wind and water (Kristofferssen & Rask, 2007, pp. 370 - 371).

Pictures of the most common weeds in trial:

C. angustifolium – willow herb

Sonchus spp. – sow thistle

Conyza canadensis - horseweed

Taxarum ssp – dandelion

Capsella bursa-pastoris, shepherd's purse

Senecio jacobaea - ragworth

Plantago ssp, Plantain

Poa annua - winter grass

Myosotis arvensis – field forget-me-not

Bryophytes ssp - mosses

Sagina procumbens L. - procumbent pearlwort

Arenaria serpyllifolia – thyme leaved sandworth