ON SITE LANDFILL LEACHATE TREATMENT: INVESTIGATIONS INTO ECONOMICAL AND ENVIRONMENTAL SUSTAINABLE SYSTEMS FOR NORTHERN IRELAND

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Abstract

This paper presents the potential for the Swedish Laqua® system to be used as a sustainable method for on-site landfill leachate management in Northern Ireland, specifically the potential to use locally sourced filter materials from Northern Ireland as part of the filter system. Four carbon containing ashes and four types of peat were tested over a 24 hours period by a shaking test with untreated landfill leachate. Considering the results of this screening test, and the economical and sustainable supply of filter materials, one combination of ash and peat was selected to be column tested. Column testing with artificial leachate containing 7 organic pollutants (3 PAHs and 4 PCBs) and 9 inorganic pollutants showed that locally sourced filter materials effectively removed both organic and inorganic pollutants. A subsequent column test with landfill leachate for 13 weeks demonstrated it was feasible to apply the Laqua® system with economical locally sourced filter materials.

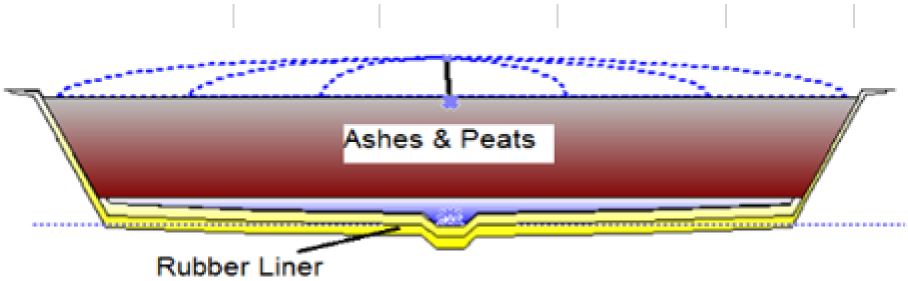
Keywords

Artificial leachate, Carbon-Containing Ash, Filter treatment, Landfill leachate, Peat, Wastewater treatment

Introduction

In the 21st century we are becoming an increasingly ‘throw-away society’; consuming produce and generating significant volumes of waste materials for disposal immediately after use. For example, many mothers in the UK no longer wash baby nappies, instead using disposable products which are ultimately destined for landfill. These products are not just made of simple materials such as paper, but also contain complex materials that include polymers, adhesives, dyes and perfumes. While there is some public concern about these waste materials entering landfill and polluting the soil, there may be less concern or knowledge about the dissolved pollutants that may leave the landfill via leachate. Over time, waste material decomposes producing leachate which has to be managed and treated to prevent it from entering ground water sources. Without proper treatment of the leachate, it can pollute not only around landfills, but also rivers, lakes and the ocean.. However, even after a landfill site has been closed to further waste, the treatment of leachate is often required for decades.In 2015, there were approximately 30 authorised landfill sites in Northern Ireland which were estimated to handle 1.4 million tonnes of municipal waste a year (NIEA, 2015). According to Met Office data (Met Office, 2017) rainfall in Northern Ireland ranges between 800 – 2000 mm per annum, and subsequent ground water replenishment can result in large volumes of leachate being generated on landfill sites. On-site, the landfill leachate receives primary treatment to reduce the levels of Biological Oxygen Demand and Ammonia and adjust the pH/acidity, before being transferred to waste water treatment facilities for further treatment before final safe discharge to the environment. One Northern Irish landfill site recorded their leachate volume to be up to 40,000m^3 per year, equivalent to transportation of three water tankers per day (110m^3 /day). So, it is easy to estimate the high economic costs solely for leachate transportation, let alone the additional costs of the final leachate treatment. In Sweden, some commercial landfill sites have introduced an "on-site landfill leachate management" system named Laqua®. The Laqua® system and methodology is a simple filter-based system where leachate is filtered through a mixed layer of specific peats and ashes to remove potential contaminants (Figure 1).

Figure 1. Laqua® system: Leachate is filtered through a mixture of layered ashes and peats



This study investigated the potential for the Swedish Laqua® system to be used as a sustainable method for on-site landfill leachate management in Northern Ireland, specifically the potential to use locally sourced filter materials from Northern Ireland as part of the filter system.

Materials

A range of filter media resources were obtained from several sources across Northern Ireland and the Republic of Ireland. A range of peat materials were sourced along with a selection of combustion ashes from a number of coal-fired power stations; a waste material or by-product. Approximately 200L landfill leachate, were collected from an authorised landfill site before primary treatment. The leachate was stored at 4°C until its use.

Analysis of leachate

Municipal Solid Waste (MSW) landfill leachate has a very complex composition and usually contains a large number of organic and inorganic pollutants. In addition, the leachate's character is influenced by factors such as rainfall volume, landfill composition and speed of decomposition. A batch of leachate collected on 5 December 2016 was analysed for various parameters, including organic pollutants and inorganic pollutants. A range of general properties, including pH, conductivity, ammonium-nitrogen, nitrite and nitrate nitrogen and a biological toxicity test were also measured.

Table1. General properties of leachate collected on 5 December 2016

pH	conductivitiy (μS/cm)	NO2 + NO3-N (mg/l)	NH4-N (mg/l)
7.18	1825	3.77	81

A biological toxicity test was carried out using *Artemia salina* (Svensson, et al, 2005). *Artemia salina* has a high tolerance for chloride ions and therefore it is suitable to measure the toxicity of leachate. *Artemia salina* was hatched in artificial seawater and 48-52 hours after hatching, was added to five concentrations of leachate (48%, 71%, 83%, 89% and 95%) leachate. After 24 hours, the immobility of the *Artemia salina* was measured and compared with that in artificial sea water. "Immobility" was defined as no movement for more than 10 seconds. Reliability of this assessment as a quality control was carried out with 100ppm potassium dichromate as a reference material.

The results are in Table 2. *Artemia salina* had less influenced on this leachate until 71% leachate concentration (20μl of artificial sea water and atresia, 300μl of leachate and 100μl of artificial sea water) but more than 83% volume ratio *Artemia salina* showed dramatically high immobility. According to microscopic observation, *Artemia salina* were stuck into sludges and killed. Therefore leachate for toxicity test were filtered with 0.7μm glass syringe filter to remove sludge.

Table2. Biological toxicity test of leachate collected on 5 December 2016

Leachate volume ratio in a test well (%)	Artemia immobility (%)
0	3
48	1
71	5
83	53
89	87
95	95

Organic pollutants

The leachate consisted of solid sludge and liquid. Extraction with dichloromethane was carried out filtered and unfiltered leachate to examine sludge's influence.

They were analysed by a mass spectrometry for a range of organic contaminants, 62 pesticides, 24 polycyclic aromatic hydrocarbons (PAHs) and 7 polychlorinated biphenyls (PCBs). Two pesticides and 14 PAHs were detected in the unfiltered samples whilst lower levels of one of the pesticides and two of the PAHs were detected in the filtered leachates. (Table 3) This suggests that the majority of the compounds are associated with the particulate matter (solids / sludge) in the leachate samples.

Table 3. Screening test for pesticides, PCBs and PAHs - positive identifications indicated by a tick. Where a compound was detected in the both filtered and unfiltered a double tick indicated much higher levels were found in that sample

Pesticide	Unfiltered	filtered
Chlorpyriphos	✓✓	✓
Pendimethalin	✓	
PCBs		
PCB 101		
PCB 118		
PCB 138		
PCB 153		
PCB 180		
PCB 28		
PCB 52		
PAHs		
Naphthalene	✓✓	✓
Phenanthrene	✓	
Anthracene	✓	✓
Fluoranthene	✓	
Pyrene	✓	
Benzo (a) Anthracene	✓	
Chrysene	✓	
Benzo (b) Fluoranthene	✓	
Benzo (k) Fluoranthene	✓	
Benzo (j) Fluoranthene	✓	
Benzo (a) Pyrene	✓	
Indeno (123,cd) Pyrene	✓	
Benzo (ghi) Perylene	✓	
Dibenzo (a,e) Pyrene	✓	

Inorganic pollutants

Filtered and unfiltered leachate samples were acid digested and measured by ICP-OES (Agilent Technologies 5100) in order to determine and compare concentrations of inorganic pollutants.

Filtration of the leachate reduced the concentration of many of the elements, including cadmium, chromium, nickel, lead, copper, zinc and iron; suggesting that these pollutants are associated with the particulate material similar to the organic pollutants (Table 4).

Table 4. ICP analysis on unfiltered leachate and filtered leachate

metal	Cd	Ni	Pb	Cu	Mn	Zn	Fe	K	Na	Ca
unit	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l	mg/l	mg/l	mg/l
Unfiltered leachate	*9.46*	*46.9*	*16.4*	*31.6*	*491*	*525*	*73.7*	*45.8*	*82.1*	*130*
Filtered leachate	ND	13.9	1.16	8.62	444	33.7	0.069	48.7	85.4	129

Filter materials screening (24 hour shaking test)

The initial screening of the potential filter materials involved a 24 hour extraction test with leachate to assess the potential to reduce contaminants.

Since high carbon-containing ashes (Svensson, B.M. et al, 2005) showed good potential as filter materials, carbon concentration was measured by combustion analysis (LECO). Fly ash from a coal power station (Ash 2) was the highest content. Ash 1 and 3 were similar content but sourced from different combustion power stations. Biochar was added to the screening test to examine the effect of a high carbon containing product produced via pyrolysis.

Peats were selected from 4 different mining areas and production processes. All the peats contained high moisture except for Peat 3 which was a more fibrous peat. The materials are summarised in Table5.

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Table 5. Ashes and Peats for filter materials screening

Name	Information	Carbon contant %
Ash 1	Grate/Clinker ash	18.0
Ash 2	Fly ash	34.1
Ash 3	Fine Powder ash	17.2
Biochar	Processed at 650°C	45.0
Name	**Information**	**Dry matter (%)**
Peat 1	Fuel peat	28.1
Peat 2	Peat fibre shredded	71.2
Peat 3	Fuel peat	29.0
Peat 4	Horticulture peat less than 10mm	30.9

Screening test method

The screening test method was a modified version of British standard BS EN 12457-2:2002. Four individual peats and 4 individual ashes, and 16 peat/ash mixtures were shaken for 24 hours with untreated leachate at a ratio of 10L/kg. Various mixtures of peat and ash were made up using a peat to ash ratio of 3:1 (v/v). The individual materials and the mixes (10g) were weighed into 250ml plastic bottles and shaken with 100mls of leachate using an orbital shaker at 200rpm for 24 hours. The processed leachates were centrifuged at 3600rpm for 10 minutes then filtered through Whatman No.40 filter paper. A standard mix supplied by Laqua Treatment AB, Sweden, was also included in the screening test for comparison.

The filtered treated leachate was measured for pH and conductivity. The concentrations of nitrite,nitrate and ammonium nitrogen were determined by a colorimetric method.

Biological toxicity tests, simplified to 71% and 95% of leachate composition, were also carried out for all the filtrates.

Table 6. 24 hours shaking test results on general properties

Filter material	pH	conductivitiy (μS/cm)	NO2 + NO3-N (mg/l)	NH4-N (mg/l)	71% leachate immobility %	95% leachate immobility %
Leachate	7.18	1825	3.77	81.0	69	100
Leachate (method blank)	7.65	1811	2.30	81.5	21	93
Standard mix	7.55	2930	4.35	61.5	19	96
Potential Materials						
Ash 1	7.92	1929	1.97	79.5	15	96
Ash 2	7.69	2260	2.38	73.1	35	98
Ash 3	11.65	2780	3.44	67.0	17	100
Biochar	10.07	17760	3.82	30.0	100	100
Peat 1	7.22	875	2.07	52.4	48	100
Peat 2	6.38	550	2.80	25.2	63	99
Peat 3	7.46	730	3.39	40.8	60	100
Peat 4	7.54	602	3.29	31.3	62	100
Potential Mixes						
Ash1+ Peat 1	7.30	1417	1.92	69.3	31	100
Ash1+ Peat 2	7.84	1484	2.02	64.6	25	100
Ash1+ Peat 3	7.62	1438	3.07	66.5	22	95
Ash1+ Peat 4	7.87	1589	2.55	68.9	8	92
Ash 2 + Peat 1	7.23	1346	2.06	66.2	2	97
Ash 2 + Peat 2	7.16	1493	2.33	61.3	16	99
Ash 2 + Peat 3	7.17	1414	2.86	64.2	52	100
Ash 2 + Peat 4	7.61	1641	2.80	67.1	36	97
Ash 3 + Peat 1	7.60	2280	4.14	71.5	10	100
Ash 3 + Peat 2	7.95	2710	4.09	61.3	14	100
Ash 3 + Peat 3	7.84	2410	4.94	66.2	22	100
Ash 3 + Peat 4	8.12	2470	4.22	64.3	15	100
Biochar + Peat 1	8.32	5550	4.00	43.1	100	100
Biochar + Peat 2	8.25	8420	3.71	7.1	100	100
Biochar + Peat 3	8.25	6540	4.51	17.3	100	100
Biochar + Peat 4	7.56	1365	4.82	64.9	12	100

Shaking leachate with ash and the biochar material alone effectively removed colour from the leachate indicating the possible absorbance of certain organics. The Biochar had some effect on reducing the level of NH_4-N while other ashes had little effect on the NH_4-N concentration in the leachate. The ashes also increased the conductivity, possibly due to the high conductive salts or carbons which might have eluted from ash. The ashes also showed their potential to reduce the toxicity of the leachate.

The biological toxicity results also showed that the peats were less effective than the ashes, despite the low NH_4-N concentrations. However, they were effective in reducing the conductivity and NH_4-N concentration in the leachate (Table 6).

The peat and ash mixtures varied in effectiveness depending on each characteristic. Mixes using peat 4 showed relatively good performance for all the general properties. Ash 3 showed similar characteristics to the standard Laqua mix. These results show that there is potential for locally sourced materials to act as a filter to reduce/remove contaminants. The peat/ash mixture is crucial for the filtration system as essentially the peat will remove metal contaminants and the ash will remove the organic contaminants.

Table 7. 24 hours shaking test results on metal analysis

Filter material	As (µg/l)	Cd (µg/l)	Cr (µg/l)	Pb (µg/l)	Cu (µg/l)	Mn (µg/l)	Zn (µg/l)	Fe (mg/l)	K (mg/l)	Na (mg/l)	Ca (mg/l)
Leachate	<5.0	1.50	<50.0	18.4	18.6	473	142	21.6	46.6	80.4	127
Leachate (method blank)	<5.0	<0.5	<50.0	<3.0	8.62	444	33.7	0.069	48.7	85.4	129
Standard mix	<5.0	<0.5	<50.0	<3.0	6.48	18.0	13.9	0.010	66.0	85.2	466
Potential Materials											
Ash 1	5.57	<0.5	<50.0	<3.0	<3.0	77.0	10.0	0.008	56.2	88.0	114
Ash 2	30.4	1.15	<50.0	<3.0	<3.0	116	39.8	ND	64.2	102	301
Ash 3	6.89	<0.5	164	<3.0	<3.0	<15.0	<10.0	0.009	38.9	72.1	434
Biochar	<5.0	<0.5	<50.0	<3.0	6.33	76.0	10.9	ND	3008	578	11.0
Peat 1	<5.0	<0.5	<50.0	<3.0	7.13	55.0	<10.0	1.14	27.8	62.7	13.3
Peat 2	<5.0	<0.5	<50.0	<3.0	18.2	<15.0	12.0	1.54	14.7	43.6	1.83
Peat 3	<5.0	<0.5	<50.0	<3.0	8.52	40.0	<10.0	0.644	22.2	55.6	3.69
Peat 4	<5.0	<0.5	92.7	<3.0	16.0	22.0	18.1	1.32	18.0	45.4	1.27
Potential Mixes											
Ash1+ Peat 1	<5.0	<0.5	<50.0	<3.0	6.18	163	14.6	0.676	40.8	77.2	61.9
Ash1+ Peat 2	<5.0	<0.5	<50.0	<3.0	9.32	56.0	11.0	0.468	40.5	82.8	46.0
Ash1+ Peat 3	<5.0	<0.5	<50.0	<3.0	6.24	271	13.3	0.194	42.1	81.6	72.6
Ash1+ Peat 4	5.90	<0.5	<50.0	<3.0	7.13	107	11.4	0.087	44.4	83.4	87.5
Ash 2 + Peat 1	17.2	<0.5	<50.0	<3.0	10.8	197	19.7	0.303	43.2	83.5	74.1
Ash 2 + Peat 2	211	<0.5	<50.0	4.30	16.0	74.0	43.4	0.735	44.2	91.7	35.6
Ash 2 + Peat 3	75.5	<0.5	<50.0	<3.0	8.77	269	15.0	0.285	44.5	86.2	59.1
Ash 2 + Peat 4	134	<0.5	<50.0	<3.0	6.50	155	32.7	0.099	50.6	94.4	91.0
Ash 3 + Peat 1	8.95	<0.5	<50.0	<3.0	<3.0	124	<10.0	0.054	41.3	77.8	197
Ash 3 + Peat 2	40.0	<0.5	<50.0	<3.0	<3.0	99.0	<10.0	0.054	43.1	84.2	199
Ash 3 + Peat 3	21.2	<0.5	<50.0	<3.0	<3.0	<15.0	<10.0	0.030	42.5	79.3	138
Ash 3 + Peat 4	45.3	<0.5	<50.0	<3.0	<3.0	54.0	<10.0	0.051	43.5	82.5	172
Biochar + Peat 1	39.6	<0.5	<50.0	<3.0	20.1	137	41.7	0.420	1388	224	22.7
Biochar + Peat 2	<5.0	<0.5	67.5	<3.0	16.9	113	33.0	0.318	2049	335	14.7
Biochar + Peat 3	12.1	<0.5	7.46	<3.0	36.2	119	29.4	0.075	1580	253	13.2
Biochar + Peat 4	<5.0	<0.5	<50.0	<3.0	15.9	78.0	20.2	0.066	1978	323	12.4

As shown in Table 7, the concentrations of copper, zinc and iron decreased after filtration. Concentration of manganese and alkali metals were not changed by paper filtration.

Although the ashes are effective in reducing the concentration of heavy metals such as copper, manganese, zinc and iron, it is evident that they also elute arsenic and calcium. However, according to the experience of Laqua treatment AB, the arsenic concentration produced from the ash in the initial stage of treatment will reduce after a number of weeks as the filter material becomes conditioned. Because this is only 24 hours shaking test, it was not unexpected to see an increase of arsenic from young ash material.

The biochar also reduced heavy metal concentrations and although it did not elute arsenic it produced high concentrations of potassium and sodium. Carbons in ashes and carbon in biochar seemed to have different effects on leachate treatment.

Peats were effective in reducing alkali and alkali-earth metals, as well as heavy metals.

The mixtures of ashes and peats reduced both heavy metals and alkali, alkali-earth metals.

As organic pollutants only the PAHs and PCBs were determined for 24 hours shaking test. Briefly, PAHs and PCBs were extracted from the leachate samples as follows: 100ml aliquots of each treatment were transferred in duplicate to separating funnels, 50ml aliquots of dichloromethane (DCM) were added to each separating funnel and the mixture shaken for 1min and allowed to separate before the lower DCM layer was run off into a conical flask. This was repeated with two further aliquots of DCM which were combined with the first extraction and dried over anhydrous sodium sulphate. The dried DCM fraction was filtered through Whatman No 1 filter paper into turbovap tubes and this was concentrated to 0.5ml under nitrogen at 35˚c.This was transferred with hexane washings to 10ml glass tubes and dried under nitrogen at room temperature before re-suspension in 1ml hexane for analysis by Agilent 7000 series GC-MS/MS (PCBs) and Agilent 5973 inert GC-MS (PAHs).

Organic pollutants were all lower than detection limits for all 24 hours shaking samples.

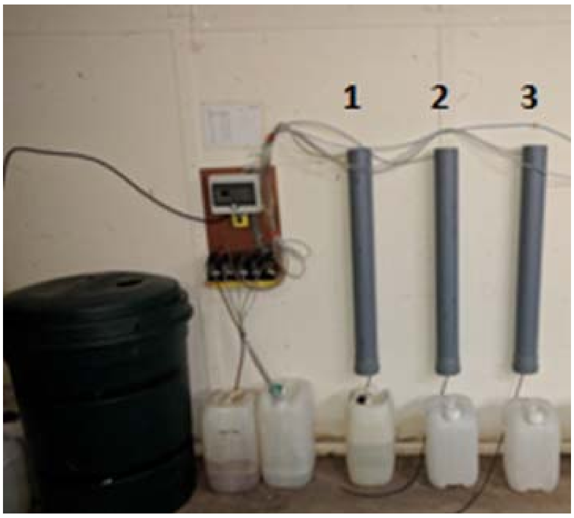
Filter material screening (column test)

The 24 hour screening test, was used to select the combinations of ash and peat for the column tests. The column test was designed to simulate filtration conditions at a landfill site. Untreated leachate was filtered through these column, at a flow rate of about 1 litre / day for thirteen weeks, with samples being collected weekly for analysis.

Test equipment

The columns were 1.2 metre in length with a diameter of 100mm and connected to timer controlled peristaltic pumps. (Figure 2) The columns were filled to a depth of 100cm with the different filter materials (homogenous mixes of ash and peat) before being compressed to a depth of approximately 80cm. Leachate was stored in a 90 litre container and mixed well once a day to help keep particulate matter in suspension. Every seven days, 300 ml filtrate was collected over an 8 hour period for analysis.

Figure 2. Column test equipment designed by Laqua Treatment AB, Sweden.



Selection of filter materials

Filter materials for the column test were selected using the results of the 24 hour shaking test and also the material's availability for up-scaling in the future.

Peat 4 was selected for a potential filter mix, mainly due to the 24 hour shaking test results (Table 6) and also because this peat is a readily available commercial grade horticultural peat.

The biochar was ruled out as it produced high concentrations of potassium and sodium, and high biological toxicity.

All the ashes tested produced similar results from the 24 hour shaking test.

Finally Ash 3 and Peat 4 were selected as a filter mixture and prepared in a ratio of 1 to 4 (v/v).

Column 1 was prepared using the standard mix supplied by Laqua Treatment. AB.

Column 2 and Column 3 were prepared using the locally sourced ash and peat mixture (Ash 3 and Peat 4). Columns 1 and 2 were then treated with landfill leachate and Column 3 was treated with an artificial leachate.

Artificial Leachate

In order to investigate the performance of the filter material quantitatively, an artificial leachate was designed and prepared to include a mixture of standard organic and inorganic pollutants at typical levels in landfill leachate. The artificial leachate was prepared (Table 8) to include nine inorganic and seven organic pollutants (PAHs and PCBs) and was then filtered through column 3 instead of actual leachate from a landfill site for a period of 4 weeks.

Table 8. Artificial leachate composition

Organic pollutants	
Polycyclic aromatic hydrocarbons (PAHs)	
Phenanthrene	2ng/ml
Benzo(a)anthracene	2ng/ml
Benzo(a)pyrene	2ng/ml
Polychlorinated biphenyls (PCBs)	
PCB101	1ng/ml
PCB118	1ng/ml
PCB28	1ng/ml
PCB52	1ng/ml
Inorganic pollutants	
Arsnic	40ng/ml
Cadmium	40ng/ml
Lead	40ng/ml
Copper	40ng/ml
Chromium	80ng/ml
Nickel	80ng/ml
Zinc	200ng/ml
Manganese	400ng/ml
Iron	20μg/ml

Results of the treatment of artificial leachate with local filter materials

As the artificial leachate was prepared using 0.5M nitric acid standard solution, the pH was much lower than the landfill leachate. The *Artemia salina* used for the biological toxicity test is very vulnerable to acidic conditions so it was not possible to perform this test. (JOHN MONASH science school , 2014) However, after treatment through the column, the pH was almost neutral at around pH7 with no impact on the *Artemia salina.* General properties are summarised in Table 9.

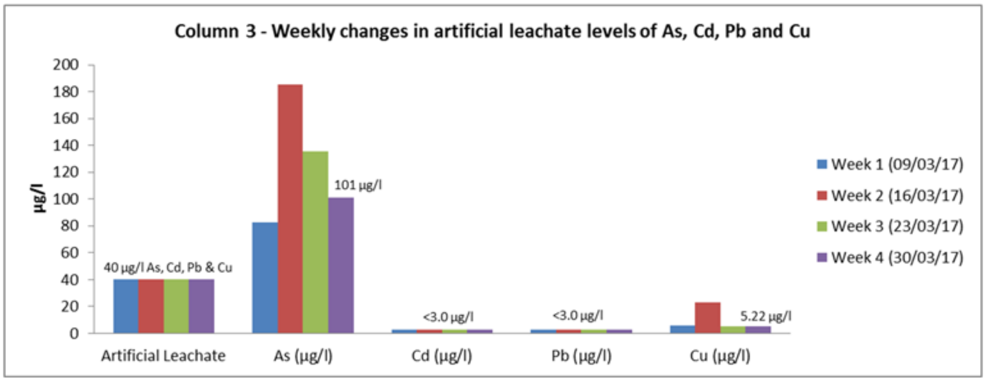
Table 9. General properties of artificial leachate treatment

	pH	Conductivity (mS/cm)	N-NH4 (mg/L)	Biological toxicity immobility (%) in 95% leachate solution
Untreated artificial leachate	2.86	0.73	6.1	100
1 Week	7.01	4.86	13.2	24
2 Week	7.21	1.44	7.1	35
3 Week	7.33	1.03	6.7	27
4 Week	7.22	0.77	7.1	20

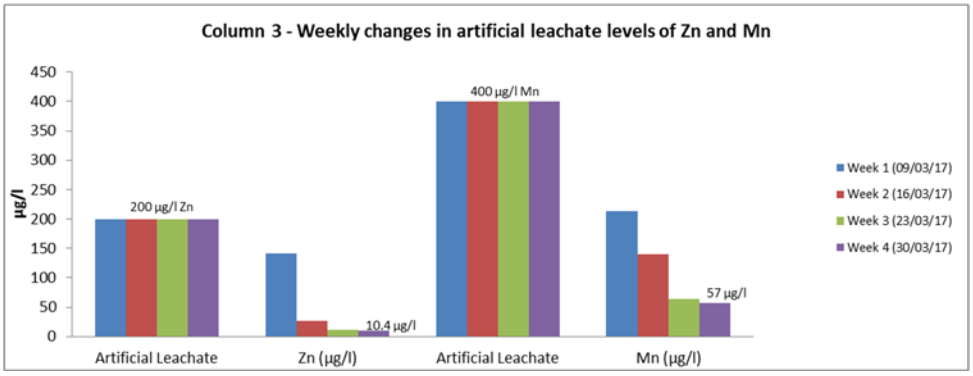
Figure 3 shows the effective reduction of the 6 heavy metal pollutants by the column filtration. Concentration of five elements; Cadmium, lead, chromium, nickel and iron were all reduced within the first week of treatment to below the detection limits of the instrumentation. Copper, zinc and manganese decreased over time (Fig 3 (a & b)). It was suggested that the filter materials would take some weeks to condition and perform well. However, the results clearly indicate that local filter materials have real potential to remove heavy metals. After an initial flush of arsenic from the filter material the concentration levels seem to be gradually decreasing after the second week.

Figure 3. Inorganic pollutants concentration variation with column treatment time

(a) Arsenic, Cadmium, Lead and Copper



(b) Zinc and Manganese



In all period the amount in the column effluent was <1% that of the artificial leachate itself showing that the column 3 is capable of removing all seven contaminants in solution.

These results clearly demonstrate that the columns produced from locally sourced material offer potential for the efficient removal of organic contaminants from leachate.

Results of treatment of landfill leachate with local filter materials

Locally sourced filter materials used in column 2 were tested with landfill leachate in comparison with the standard mix used in column 1. Initially the column test was set up to run for 4 weeks but performance at week 7 showed a dramatic change in the concentration of ammonium-nitrogen and that of nitrite/nitrate-nitrogen and improved biological toxicity test results, therefore the running time of the columns was extended in order to examine this effect further

Table 10 shows the pH, conductivity and ammonium nitrogen and nitrite/nitrate nitrogen concentrations from week 2 to week 13. Between week 4 and week 7, treated leachate from column 2 filled with the local ash and peat mixture showed decreasing ammonium-nitrogen concentration while the nitrite/nitrate nitrogen concentration was increasing. This same phenomena was continuing at week 13. This suggests that the filter mixture is now behaving similarly to the column with the standard mixture, effectively nitrifying ammonium nitrogen to nitrite/nitrate nitrogen.

Table 10. Properties of treated leachate: pH, conductivity and concentration of ammonium nitrogen and nitrate / nitrite nitrogen

	Week2			Week4		
	Leachate before column	Column1 Sandard mix	Column 2 Local mix	Leachate before column	Column1 Sandard mix	Column 2 Local mix
pH	7.39	6.74	7.62	7.34	6.82	7.54
conductibity (mS/cm)	2.28	2.21	2.05	1.85	1.80	1.62
N-NH4 (mg/L)	119.79	3.37	57.99	87.61	6.17	85.54
N-NO2&NO3 (mg/L)	0.00	107.97	1.86	2.16	95.77	10.20
	Week7			Week13		
	Leachate before column	Column1 Sandard mix	Column 2 Local mix	Leachate before column	Column1 Sandard mix	Column 2 Local mix
pH	7.08	6.87	7.8	7.83	7.43	7.52
conductibity (mS/cm)	2.03	2.17	1.87	2.70	2.52	2.21
N-NH4 (mg/L)	152.05	6.77	7.25	139.77	2.35	0.24
N-NO2&NO3 (mg/L)	2.10	95.11	100.47	0.00	165.66	172.64

Results from the biological toxicity test are summarised in Table 11 The mobility of the *Artemia salina* was dramatically improved between week 4 and week 7 and this continued through to week13. After week 7, the toxicity was improved even at 95% leachate concentration (400μl leachate and 20μl artificial sea water and 20-30 number of *Artemia salina*). Even 24 hours after addition of the column treated leachate, artemia could still be observed swimming strongly within the cells of the microplate indicating a more favourable, less toxic environment as a result of the column filtration.

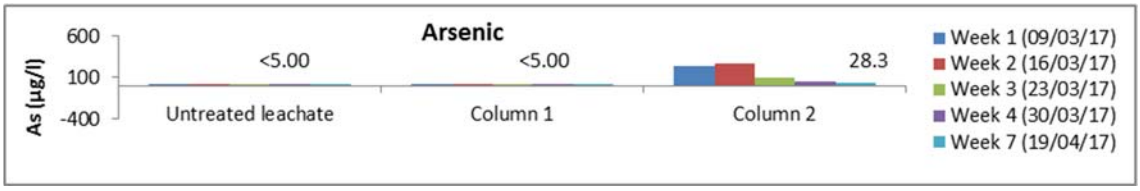
Table 11 Biological toxicity test from week 2 to week13

% Artemia immobility	Week2			Week4		
	Leachate before column	Column1 Sandard mix	Column 2 Local mix	Leachate before column	Column1 Sandard mix	Column 2 Local mix
0% leachate	3	1	5	0	0	3
48% leachate	3	0	2	0	0	2
71% leachate	11	1	0	5	0	4
83% leachate	23	0	2	42	0	26
89% leachate	61	1	21	65	2	73
95% leachate	85	42	71	98	22	93
% Artemia immobility	Week7			Week13		
	Leachate before column	Column1 Sandard mix	Column 2 Local mix	Leachate before column	Column1 Sandard mix	Column 2 Local mix
0% leachate	0	2	1	3	0	2
48% leachate	0	0	0	0	3	1
71% leachate	7	0	3	29	0	0
83% leachate	58	2	3	82	3	2
89% leachate	77	14	2	87	10	3
95% leachate	100	23	8	100	34	4

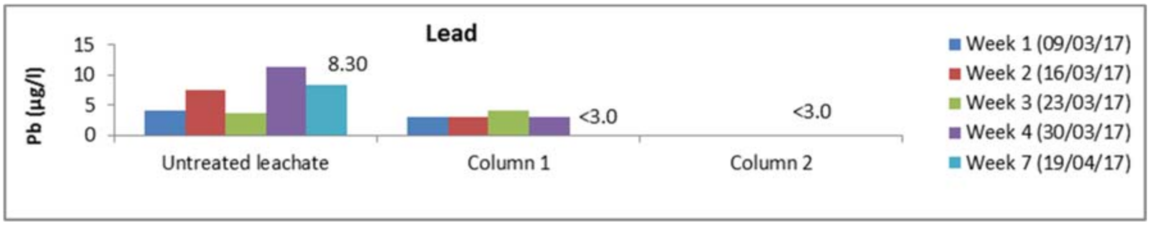
After column treatment, five heavy metals: nickel, iron, lead, chromium and cadmium were effectively removed from the leachate to below detection limits of the instrumentation. Figure 4 shows the results from week1 to week7 for these 5 elements. It was observed that arsenic was released from the column materials with concentrations peaking at week 2 before decreasing gradually with the concentration at week 7 having declined to 28µg/l, similar to the standard mix. Column 2 also reduced manganese (c) and zinc (d) effectively. Filter materials seemed to release copper, too. But it decreased gradually removed from filter materials.

Figure 4. Changes in Inorganic pollutant concentrations

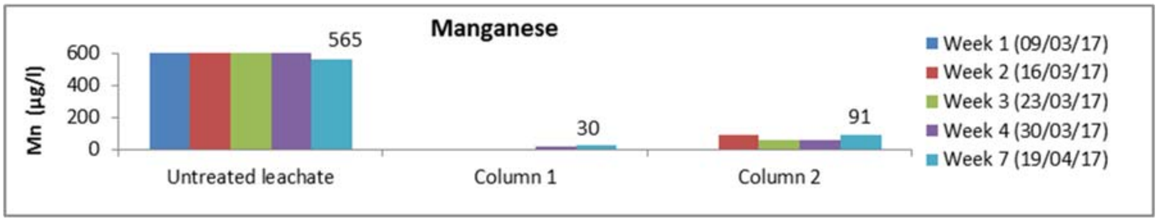
(a) Arsenic



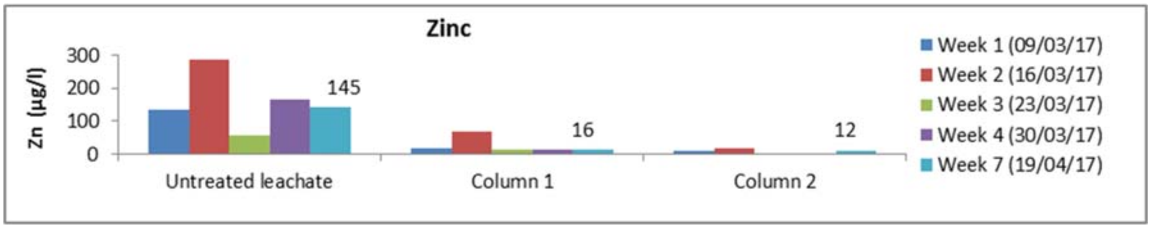
(b) Lead



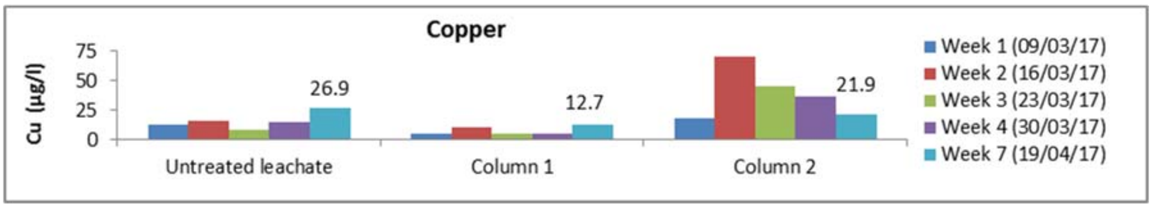
(c) Manganese



(d) Zinc



(e) Copper



All organic pollutants were below the detection limit as standard untreated leachate were analysed for the presence of 21 PAHs and 7 PCBs prior to column filtration.

Conclusion

This study only ran for 6 months in order to try to determine the potential of implementing the Laqua® system for the on-site management of landfill leachate in Northern Ireland. There is strong evidence from 24 hour shaking tests followed by controlled column filtration tests, that locally sourced materials have the potential to function effectively and similarly to the tried and tested standard Laqua® systems filtration media. In order to build on-site landfill leachate treatment filters, a scaled up quantity of filter material will be required and indeed recharged after a number of year's operation hence the importance of the local and sustainable sourcing filter media materials.

It is apparent that some prefiltration filter conditioning is required in order to remove inorganic pollutants (copper and arsenic) as well as to activate the microbiological populations for eg ammonium nitrification. This study has indicated that 4-5 weeks will achieve this.

Only one combination of ash and peat was examined by the column test in this initial study but other combinations showed similar results from the 24 hours shaking experiments. Further column testing will be undertaken to investigate these identified peat/ash mixtures. Additionally, an on-site pilot trial using 1m^3 cipax containers is being implemented in order to test the durability and real-world functionality of a scale up. It is considered that if the column experiment results can be replicated in these, then a full-scale pilot at a landfill site would be a plausible solution for sustainable leachate management.

Acknowledgements

The Authors acknowledge the financial support of Northern Ireland Environmental Agency (NIEA), Government challenges Ideas from business Innovate solutions (SBRI) and InnovateUK and Strategic Investment Board.

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