Geo-Environmental Engineering Research Group

Dr. Mark Healy | Senior Lecturer
Civil Engineering, College of Engineering and Informatics

GENE
Geo-Environmental Engineering Research Group

NUI Galway
OÉ Gaillimh
Ryan Institute
Environmental, Marine and Energy Research

Interreg
North-West Europe
ReNu2Farm

Research Focus

‘To study the impact of engineering and agricultural activities on the soil, environment and atmosphere’

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Surface and Subsurface Flow of Contaminants Ecosystem Services

Filtration Resource Recovery and Reuse of Waste Materials in

Remediation Soil Fertility Greenhouse Gas Emissions

Pollution Swapping Life Cycle Assessment Constructed Wetlands

Natural Wetlands Vadose Zone Modelling Forestry

Emerging Contaminants Drainage Bioreactors

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Reuse of treated sludge in agriculture

Dr. Mark Healy | Senior Lecturer
Civil Engineering, College of Engineering and Informatics, National University of Ireland, Galway

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Report No. 200

epaResearch
Climate - Water - Sustainability
Identifying pressures • Informing policy • Developing solutions

Health and Water Quality Impacts Arising from Land Spreading of Biosolids

Authors: Mark G. Healy, Owen Fenton, Enda Cummins, Rachel Clarke, Dara Peyton, Ger Fleming, David Wall, Liam Morrison and Martin Cormican

Background

Wastewater in

Clean water out

Sludge generated

Background

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Background

- In 2015, more than 4 million tonnes (dry solids) of sewage sludge was produced in the European Union*
- EU legislation has forced those involved in sludge management to find alternative uses for sludge.
- Recycling to land is currently the most economical and beneficial way for sewage sludge management

*Eurostat. 2018. http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00030&language=en

Background

Scientists' Open Letter on the Dangers of Biosolids (2016)

"Contaminant risk from sludge [is] an 'unknown unknown'"

"Governments are playing Russian roulette with sewage sludge"

The land disposal of sewage sludge (aka Biosolids) has resulted in significant controversy, and a resistance movement is rightfully building to this misguided policy. Quite simply, the science doesn't support the disposal of sewage sludge across the landscape. The supposed benefits are m… environmental… the issue with…

An unimag… contaminants… product up to,… investigations… contaminant load. We cannot even say with any degree of confidence what the true range of contaminant risk is from the sludge. Call it an "unknown unknown." Because of potential synergistic interactions between the contaminants in the sludge, the risks are largely unknowable.

Most public discussions of the chemical contaminants in sewage sludge involve well known groups such as heavy metals, flame retardants, and pharmaceuticals, among many others. But these are just the contaminants we have identified. To refer to our current knowledge base as the tip of the iceberg would be grossly overestimating how much we actually do know.

Regulators and others – including elected officials – up and down the policy chain appear to lack a real appreciation for the scope of the problem, and the costs of beginning to understand it. If a city were to test the sludge just once for all possible contaminants in the material, the bill would be well into the hundreds of thousands of dollars. You are not going to find a problem if you don't look for it. Of course, over time, that problem may also come looking for you.

To illustrate the difficulties, take just one group of persistent, bioaccumulative, and toxic compounds known to be in sewage sludge at high concentrations: brominated flame retardants. Perhaps the most well known sub-class of the brominated flame retardants are called polybrominated diphenyl ethers (PBDEs). There are 209 different PBDEs, each of which has a unique toxicology and environmental fate. …ed around the world for several …ve a very poor understanding of the …ease into the environment. …aminant class among many. There are …bers of the PCBs. Similarly, add in …d dioxin "congeners." The total …s in sewage sludge climbs as we begin to consider that effectively all current a… industrial chemicals end up in our sewage, ar… treatment process they move into the sludge… sludge to the land, we have transferred our t… onto the landscape. Then add on all pharmac… personal care products, as well as any other c… use in the home or at work, and all their pote… degradation products. The complexity discuss… touches on the chemical contaminants. Add t… massive numbers of biological contaminants… viruses, prions, etc. The current and future problem is inconceivably large, particularly since the human population is producing sewage sludge at a rapidly growing rate.

Those from the large public and private sector industry that has developed around marketing and selling sewage sludge for land disposal – which we collectively term Big Sludge -- claim the materials are "non-toxic" and a resource to be cherished, not shunned. The state of the science does not agree with this oversimplification.

While there have been some attempts to review the science surrounding sewage sludge, these are generally wanting. Either the reviews are out-of-date and incomplete, failing to account for all that we do know about emerging contaminants and what we don't know about all contaminants, or they are written more as promotional materials for Big Sludge in an attempt to sell the product to an ever more sceptical public.

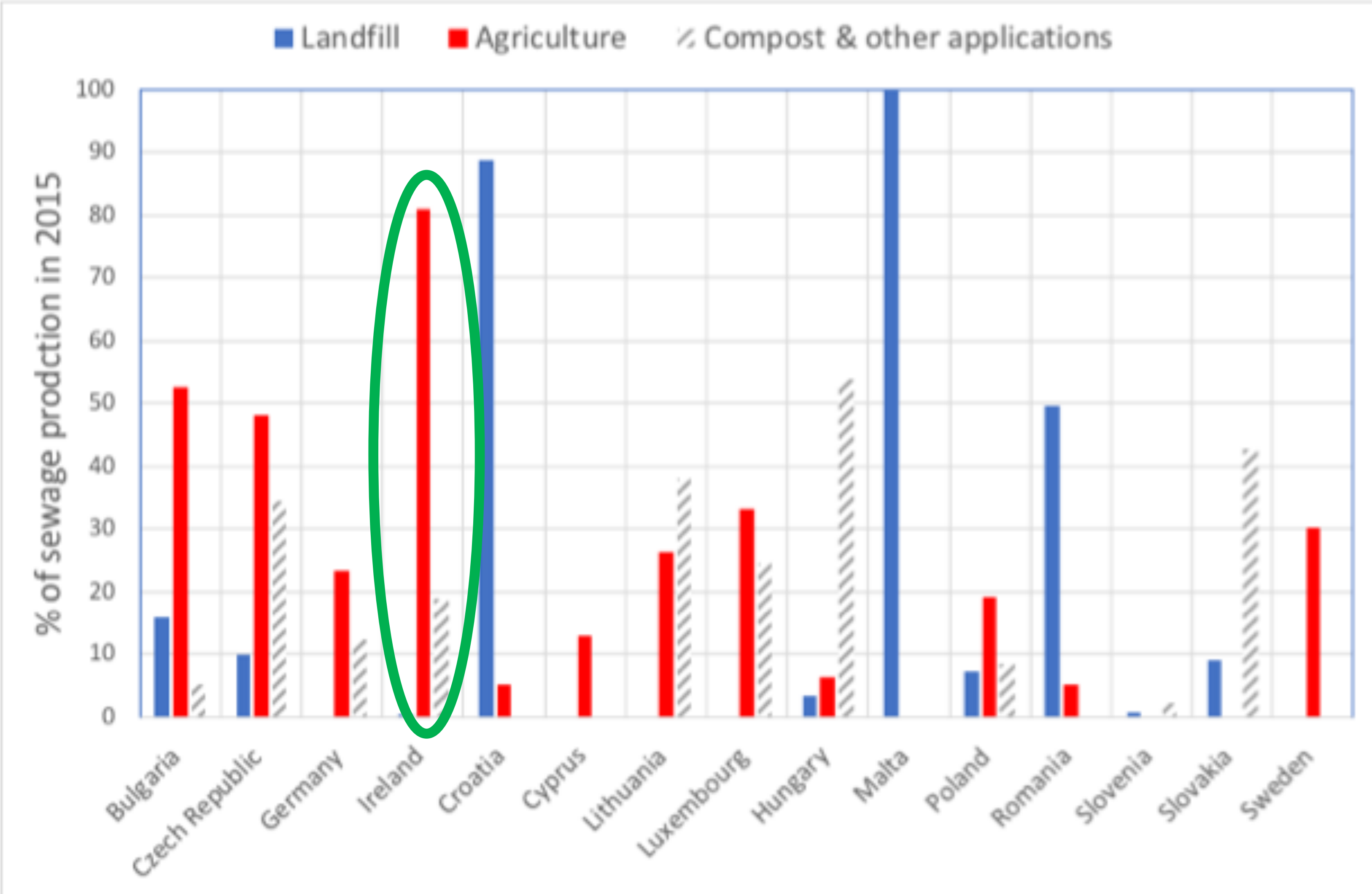
What should we do in response to all these concerns? Immediately halt the land disposal of sewage sludge as a starting point, and begin either stockpiling or landfilling the material in secure locations with full leachate collection systems until a more responsible means of dealing with the problem is implemented. In the meantime, the science must continue in an effort to better understand the risks and to …about …sal, but …nt …wilful …rises …ilities …all Governments are playing Russian roulette with sewage sludge, and over time there is a high probability this game will be lost at the public's expense.

Sierra Rayne, PhD, John Werring, MSc, RPBio
Richard Honour, PhD , Steven R. Vincent, PhD

Sierra Rayne is an independent scientist; John Werring is a senior science and policy advisor for the David Suzuki Foundation; Richard Honour is the executive director for The Precautionary Group; Steven R. Vincent is the Louise Brown Professor of Neuroscience with the Department of Psychiatry at the University of British Columbia.

Background

Percentage of sewage sludge production sent to landfill, reused in agriculture, and compost and other applications.



Eurostat. 2018. http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00030&language=en
Data presented from countries from which data are available

Background

Sewage sludge destination routes in Ireland in 2016*

	Agriculture	Composting	Landfill	Other	Total
Quantity (tonnes dry solids)	45,344 (81%)	9,610 (17%)	102 (0.2%)	962 (2%)	56,018

*EPA. 2017. Urban Waste Water Treatment in 2016. http://www.epa.ie/pubs/reports/water/wastewater/Urban%20waste%20water%20report%20for%202016%20Final%20Version.pdf

Background

Sewage sludge destination routes in Ireland in 2015

	Agriculture	Composting	Landfill	Other	Total
Quantity (tonnes dry solids)	46,697 (80%)	10,946 (18.7%)	94 (0.2%)	650 (1.1%)	58,387

Sewage sludge destination routes in Ireland in 2014

	Agriculture	Composting	Landfill	Other	Total
Quantity (tonnes dry solids)	42,483 (79.3%)	9,266 (17.3%)	361 (0.7%)	1,433 (2.7%)	53,543

Background

Producer Criteria | Page 9 of 23 Sustainable Dairy Assurance Standard - Revision 01, December 2013

3.6 Land Management

Background Information

Producers will be aware of the need to manage the land available to their farming enterprise(s) so as to optimise production from the land while maintaining or improving the environment. Producers will also be aware of the need to comply with the Nitrates Directive (S.I. No. 378 of 2006, European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006 on nitrate fertilisation of the soil.

a) **Raw or treated sewage / sludges are prohibited from being used on Bord Bia certified farms (Critical).**

b) Where stock is out-wintered, the Producer must avoid placing livestock on poorly drained land and steps must be taken to minimise poaching particularly near watercourses. Producers must comply with the regulatory requirements / restrictions relating to areas of special conservation under their control.

Growing the success of Irish food & horticulture

Bord Bia
Irish Food Board

Sustainable Dairy Assurance Scheme

Producer Standard

Revision 01, December 2013

Bord Bia
Irish Food Board

Background

- Benefits of recycling treated sludge ('biosolids') to grassland:
  - May be used as a soil conditioner, improving physical, chemical and biological properties
  - May reduce the possibility of soil erosion
  - A cheap alternative to commercial fertiliser

Background

- Drawbacks of recycling biosolids to grassland:
  - Nutrient, metal and suspended sediment losses may occur
  - Presence of 'emerging contaminants', such as pharmaceuticals, microplastics, etc.
  - Presence of human enteric pathogens, as complete sterilisation is difficult to achieve
  - Metals may accumulate in soils and crops after repeated applications

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Background

- The Code of Good Practice[1] states that untreated wastewater should not be landspread or injected into soil.
- However, for PEs <5000 no treatment is required for sludge to be used in agriculture (SI 148/1998)[2]

- Treatment methods include:
  - Aerobic and anaerobic digestion
  - Thermal drying
  - Lime stabilisation
  - Composting

[1]Fehily Timoney and Company (1999). Codes of good practice for the use of biosolids in agriculture - guidelines for farmers. http://www.environ.ie/en/Publications/Environment/Water/FileDownLoad,17228,en.pdf.

[2]S.I. No. 148/1998- Waste management (Use if sewage sludge in Agriculture) regulations 1998 http://www.irishstatutebook.ie/1998/en/si/0148.html

Background

Anaerobically digested biosolids

Thermally dried biosolids

Lime stabilised biosolids

Composted biosolids

Research aims

- To characterize the metal concentrations and investigate the presence of microplastics in treated municipal sludge in Ireland.
- To measure the surface runoff of nutrients, solids, microbial matter, pharmaceuticals, and metals following land application.
- To measure the uptake of metals by vegetation (ryegrass).
- To measure the impacts on human health arising from land application of biosolids [Not covered in this presentation]

Research aims

- To characterize the metal concentrations and investigate the presence of microplastics in treated municipal sludge in Ireland.

Research aims

THE IRISH TIMES

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NEWS | SPORT | BUSINESS | OPINION | LIFE & STYLE | CUL

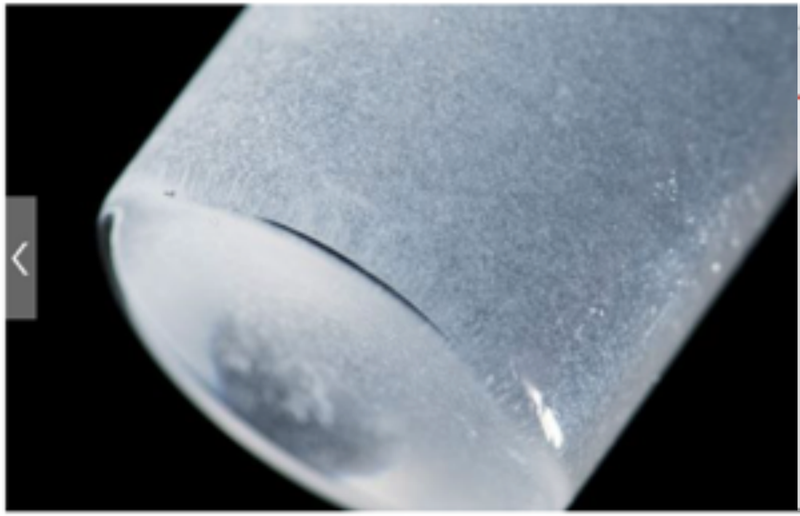
Environment › Heritage & Habitat | Illegal Dumping | Water Charges

Public health at risk from rising use of microbeads, says EPA

Study coincides with UK engineers' discovery of biodegradable alternative to microplastics

Thu, Jun 8, 2017, 15:50

Kevin O'Sullivan



The growth of polluting microplastics in the Irish environment has been confirmed by the Environmental Protection Agency (EPA).

THE IRISH TIMES

Tue, Sep 19, 2017

NEWS | SPORT | BUSINESS | OPINION | LIFE & STYLE | CULTURE

Environment › Heritage & Habitat | Illegal Dumping | Water Charges

Ireland should ban microbeads, says top marine biologist

Government 'could take lead' on issue ahead of European Union-wide prohibition

THE IRISH TIMES

Tue, Sep 19, 2017

NEWS | SPORT | BUSINESS | OPINION | LIFE & STYLE | CULTURE

Environment › Heritage & Habitat | Illegal Dumping | Water Charges

How Ireland's plastic pollution became part of our diet

Plastics are entering the world's oceans at an alarming rate and Irish scientists are finding them everywhere

Wed, Apr 26, 2017, 14:47 | Updated: Wed, Apr 26, 2017, 14:48

Kathleen Harris

Methodology – Metal characterisation

- Treated sludge was collected from 16 wastewater treatment plants (WWTPs) with population equivalents (PE) ranging up to approximately 2.3 million.

- Metals analysed using a handheld X-ray fluorescence (XRF) analyser

- **Metals examined:** Cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), molybdenum (Mo), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), tin (Sn), and zinc (Zn)

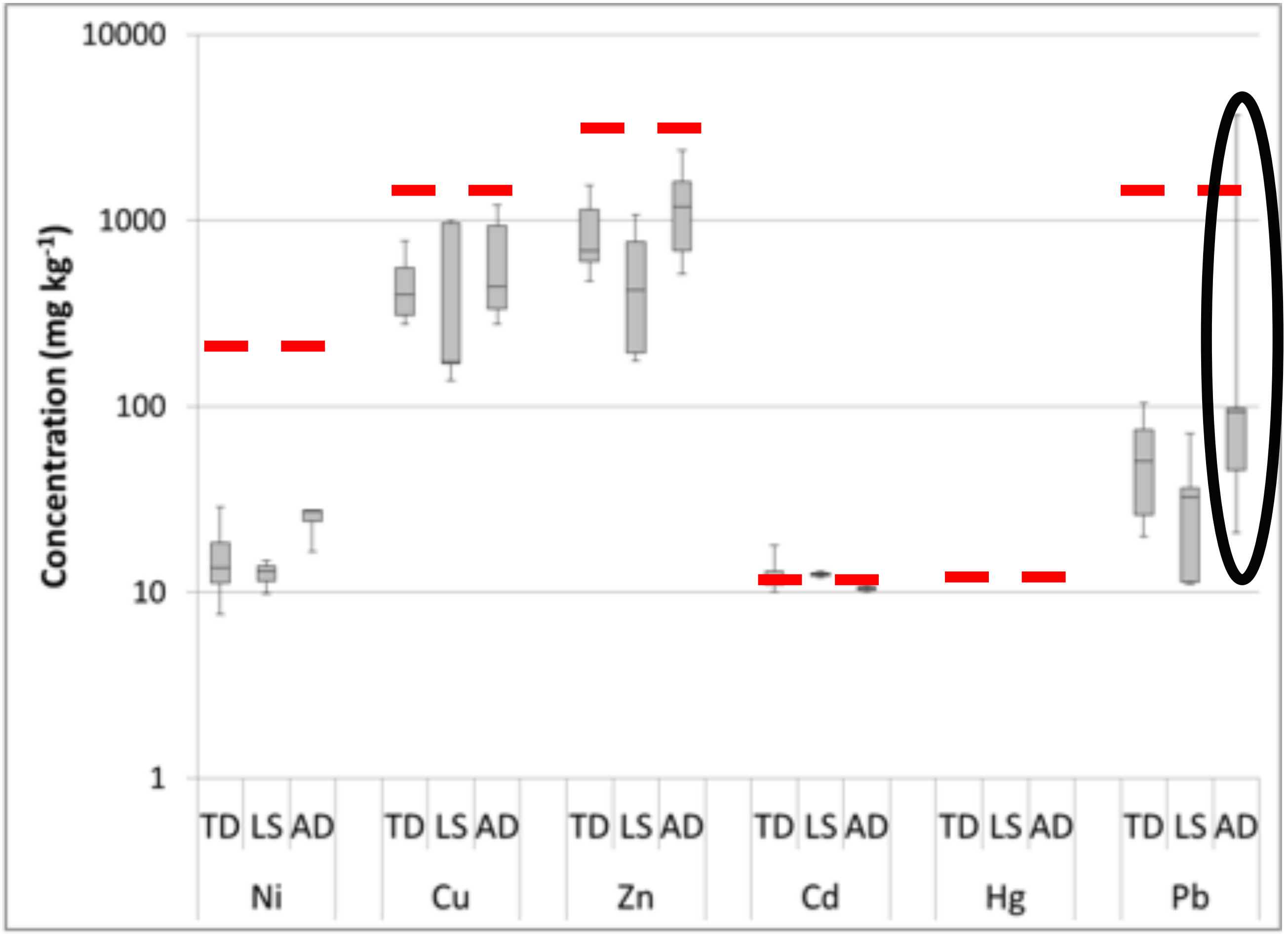
Methodology

- Three types of biosolids, were examined:
  - anaerobically digested (AD)
  - lime stabilized (LS)
  - thermally dried (TD)

Results

Healy, M.G., Fenton, O., Forrestal, P.J., Danaher, M., Brennan, R.B., Morrison, O. 2016. Metal concentrations in lime stabilised, thermally dried and anaerobically digested sewage sludges. Waste Management 48: 404-408.

Characterization of biosolids from 16 WWTPs



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Results

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Characterization of biosolids from 16 WWTPs

Concentrations (mg kg^{-1}) of <u>unlegislated metals</u> (in the EU) in the treated sludge

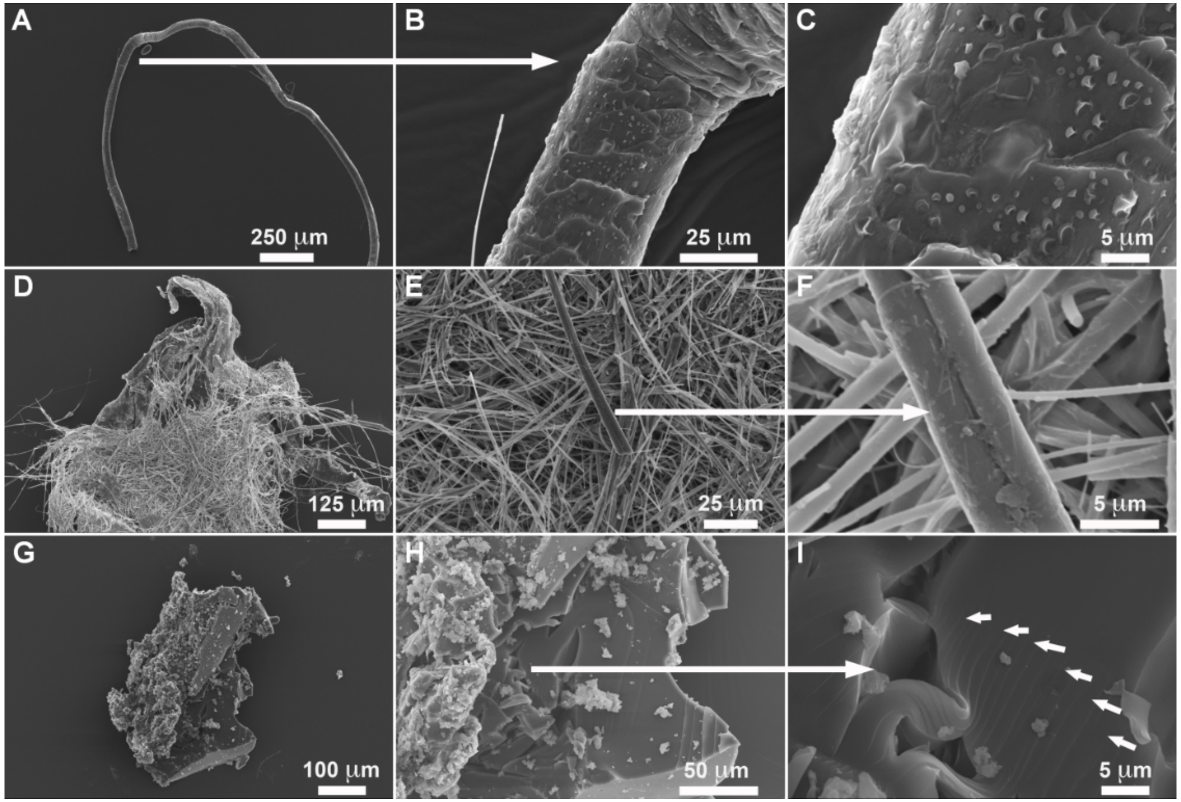
Metal	Anaerobic digestion		Lime stabilisation		Thermal drying	
	Mean	***SD***	***Mean***	***SD***	***Mean***	***SD***
As	<LOD		<LOD		<LOD	
Se	3	2	3	1	2	1
Sr	162	61	183	[illegible]	[illegible]	[illegible]
Mo	5	2	4	[illegible]	[illegible]	[illegible]
Ag	11	2	11	[illegible]	[illegible]	[illegible]
Sn	55	57	23	4	23	5
Sb	20	5	17	3	17	4
Cr	51	43	25	15	16	12

Antimony (Sb) is substantially higher than in non-polluted soils (0.53 mg kg^{-1})

Results

- Small particles of plastic, called ‘microplastics’, have also been found on sludge particles.

- These may carry contaminants that may attach to their surface.



Mahon, A.M., O’Connell, B., Healy, M.G., O’Connor, I., Officer, R., Nash, R., Morrison, L. 2017. Microplastics in sewage sludge: effects of treatment. Environmental Science and Technology 51(2): 810 – 818.

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Research aims

- To characterize the metal concentrations and investigate the presence of microplastics in treated municipal sludge in Ireland.
- To measure the surface runoff of nutrients, solids, microbial matter, pharmaceuticals, and metals following land application.
- To measure the uptake of metals by vegetation (ryegrass).

Research aims

- To measure the surface runoff of nutrients, solids, microbial matter, pharmaceuticals, and metals following land application.

Aims

To quantify losses of:

- nutrients
- metals
- microbes (total and faecal coliforms)
- anti-microbial agents, triclosan and triclocarbon

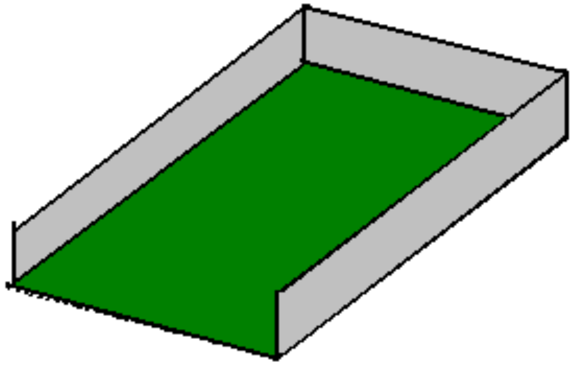
in runoff from micro-plots (n=5) at time intervals of 24, 48 and 360 hr following application of three types of biosolids

- Thermally dried
- Anaerobically digested
- Lime stabilised

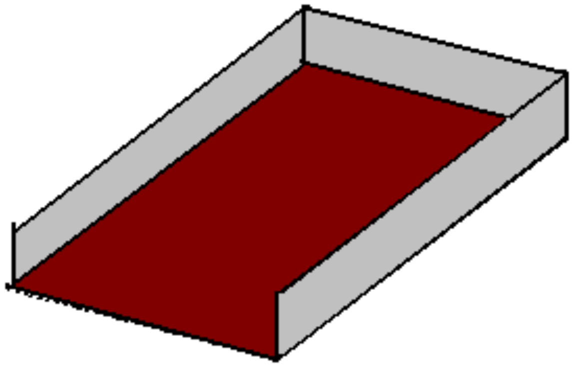
applied at the legal application rate.

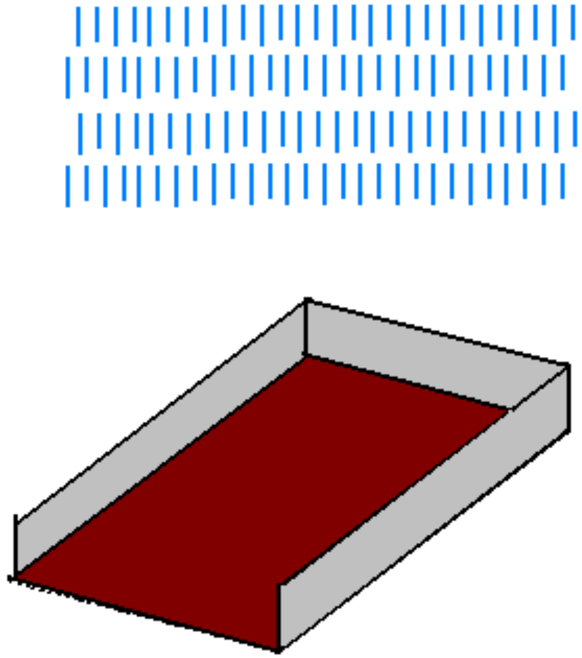
Runoff was also compared to runoff from dairy cattle slurry, applied at the same rate.

Methodology



Plot isolated using PVC sheeting (50 mm below soil surface)





Rainfall simulators used to apply rain 24, 48, 360 hr after application date

Target Intensity 10.5 mm hr^{-1}

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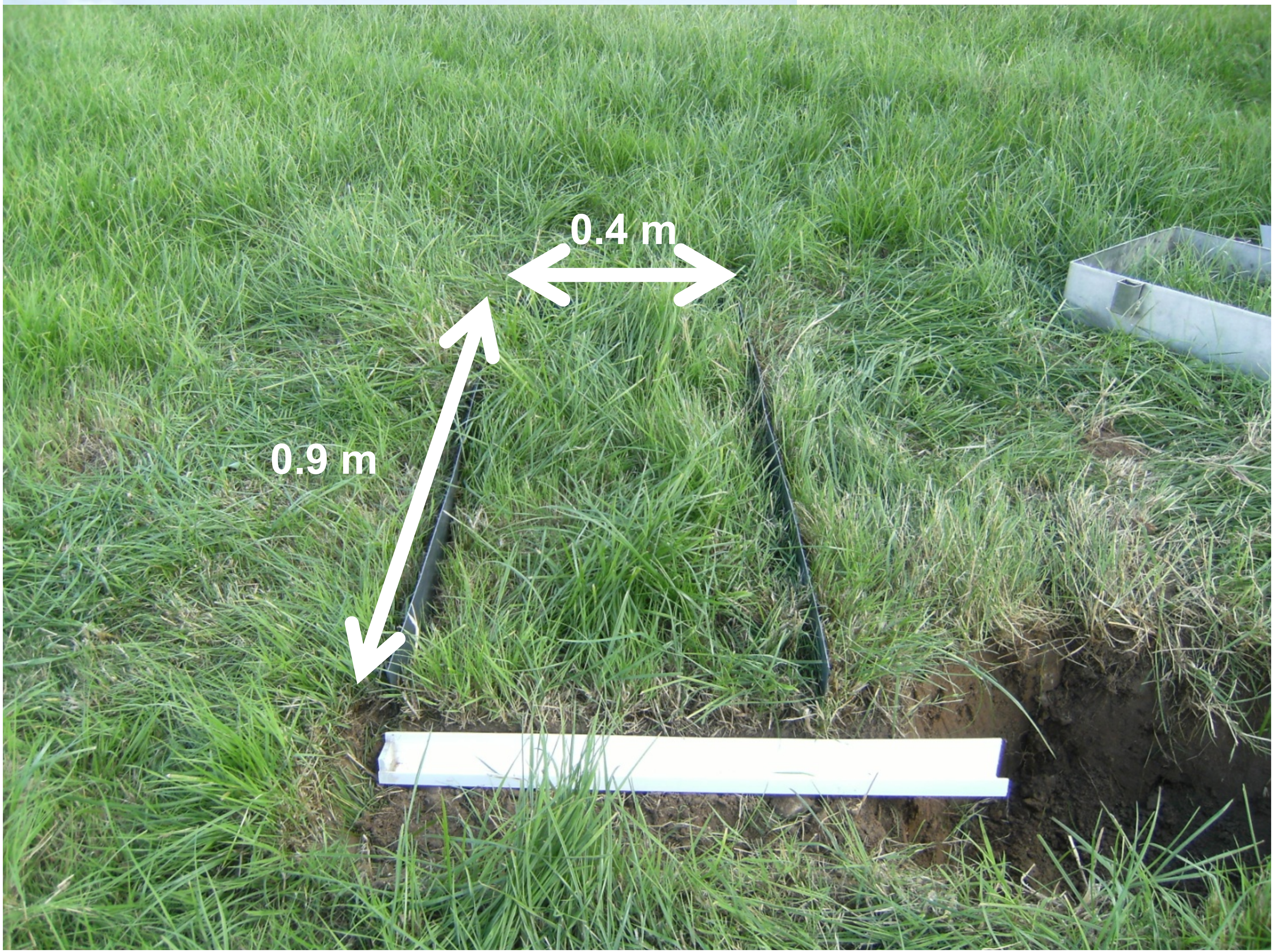

0.4 m
0.9 m

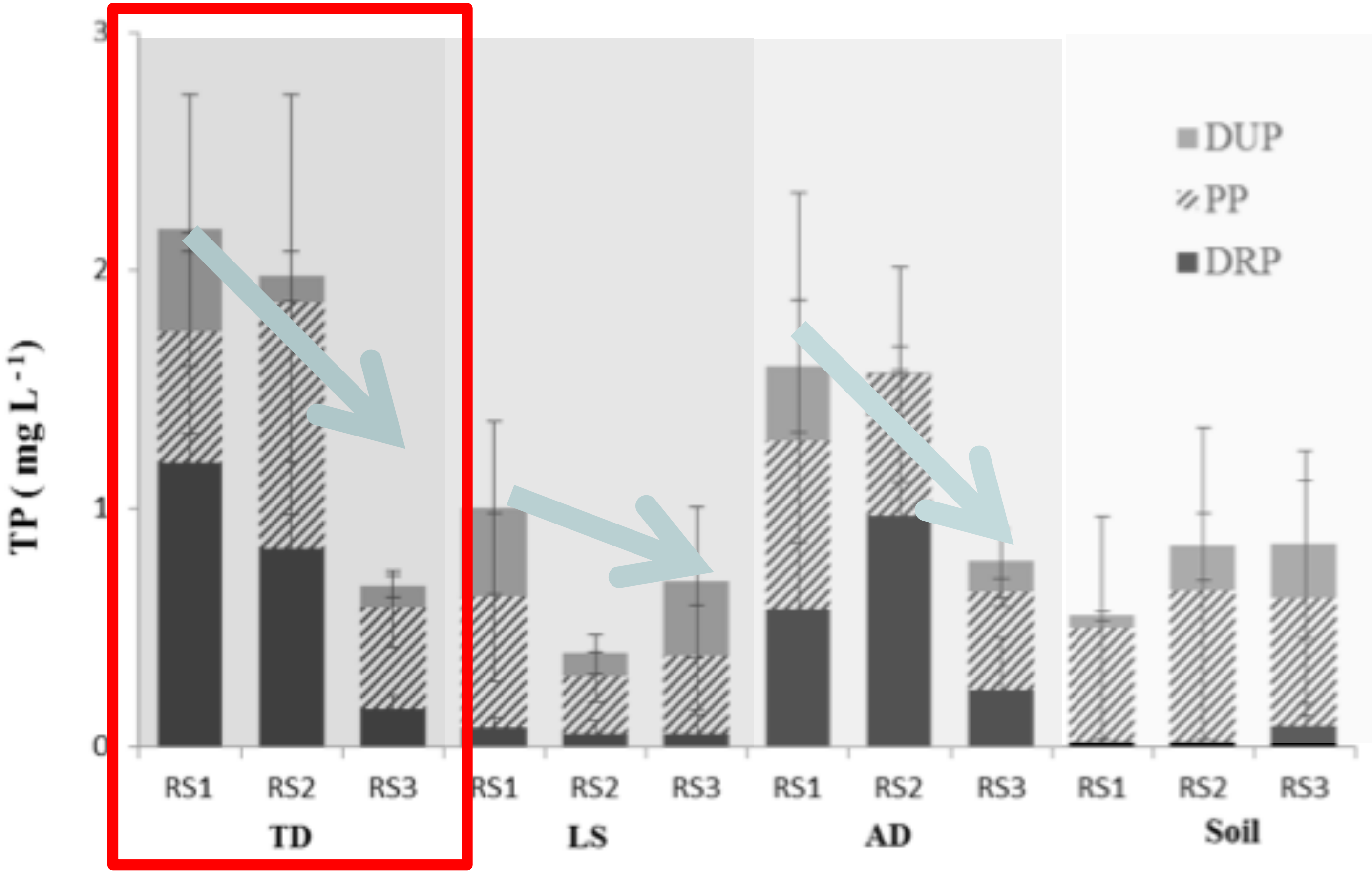
Measurement and modelling of health impacts arising from the landspreading of biosolids

2012-EH-MS-13

Results

Phosphorus loss in runoff

RS1 = 24 hr after application
RS2 = 48 hr after application
RS3 = 360 hr after application

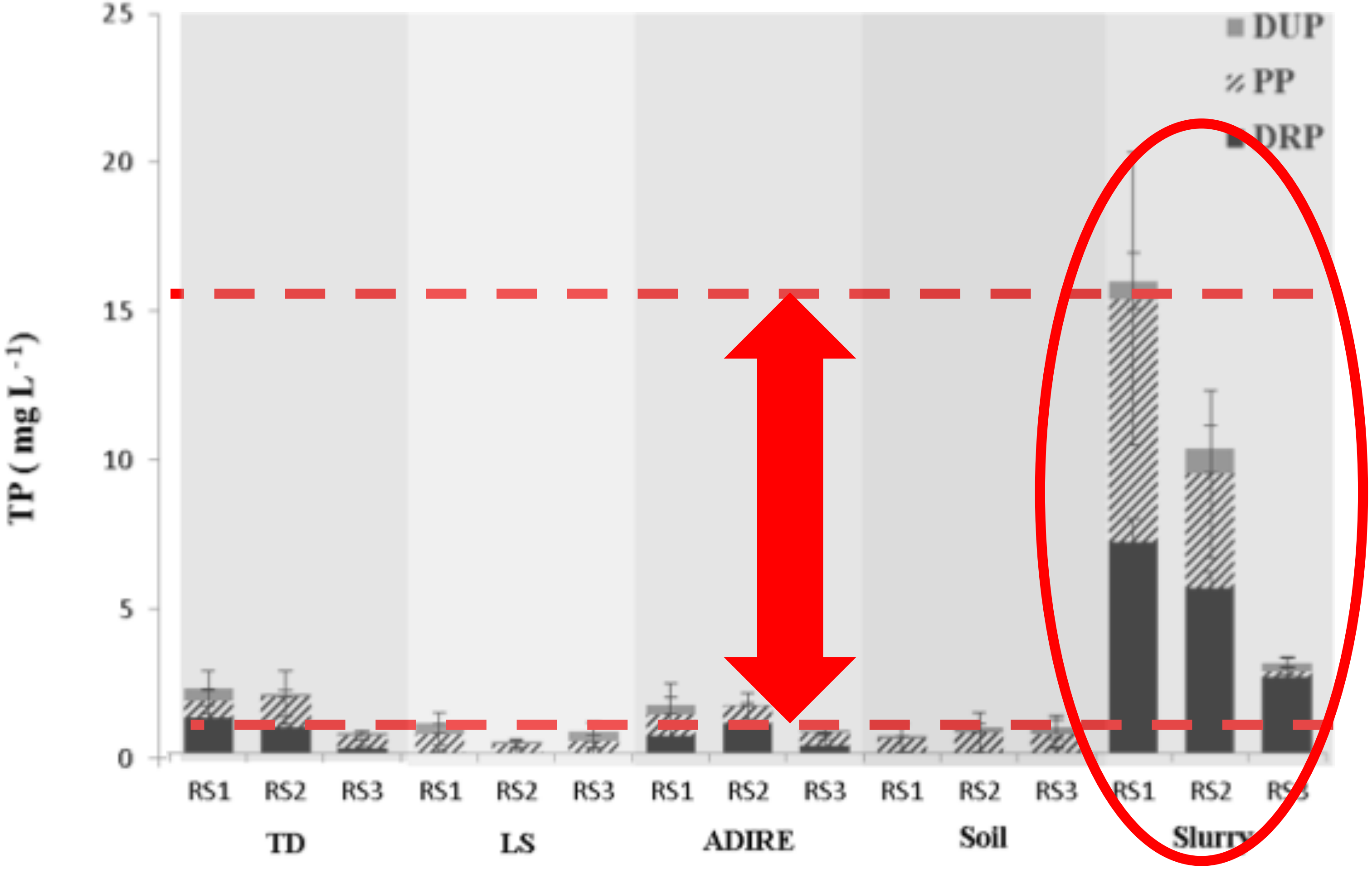


Peyton, D.P., Healy, M.G., Fleming, G.T.A., Grant, J., Wall, D., Morrison, L., Cormican, M., Fenton, O. 2016. Nutrient, metal and microbial loss in surface runoff following treated sludge and dairy cattle slurry application to an Irish grassland soil. Sci. Tot. Environ. 541: 218-229.

Results

Phosphorus loss in runoff

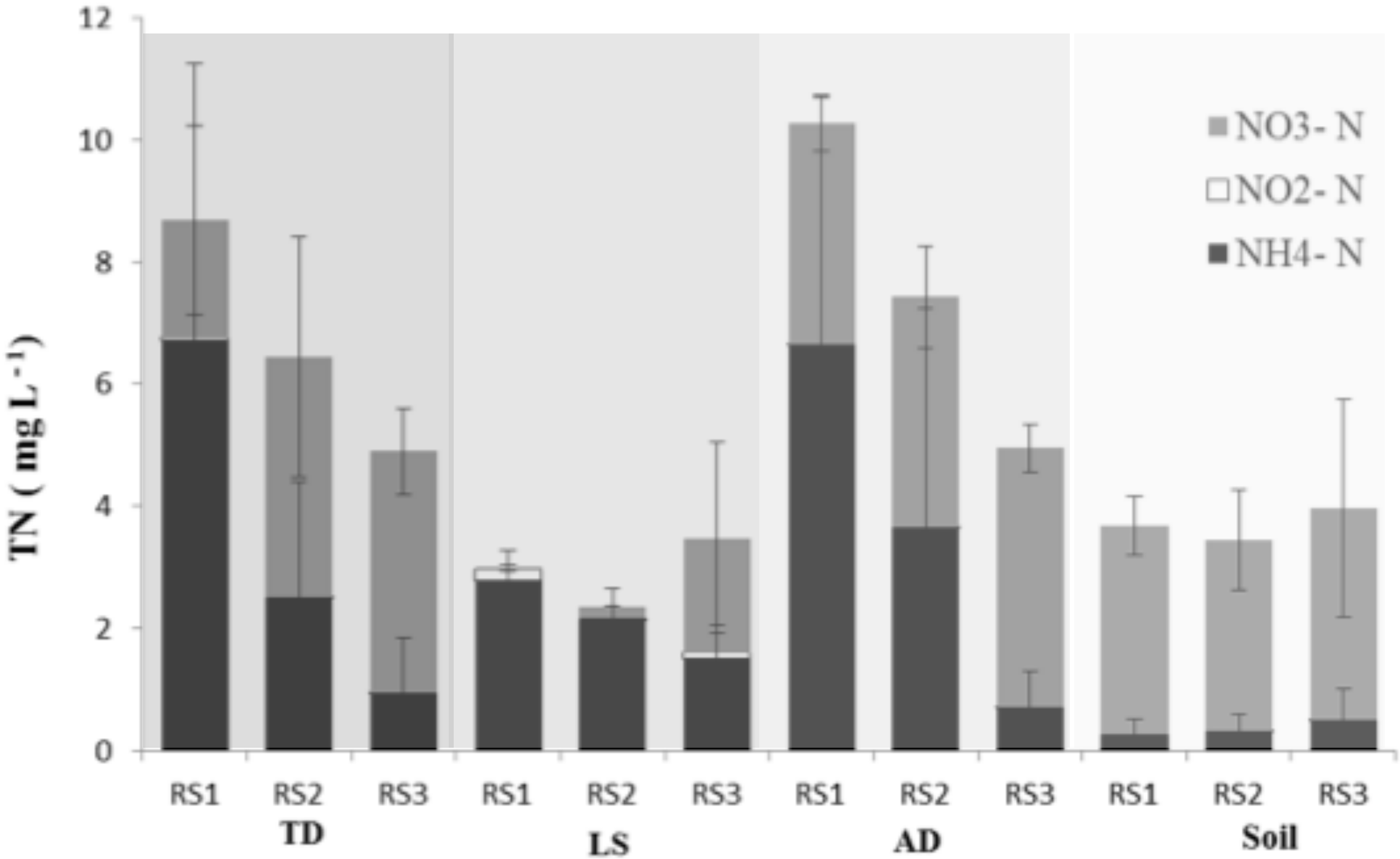
RS1 = 24 hr after application
RS2 = 48 hr after application
RS3 = 360 hr after application



Results

Nitrogen loss in runoff

RS1 = 24 hr after application
RS2 = 48 hr after application
RS3 = 360 hr after application



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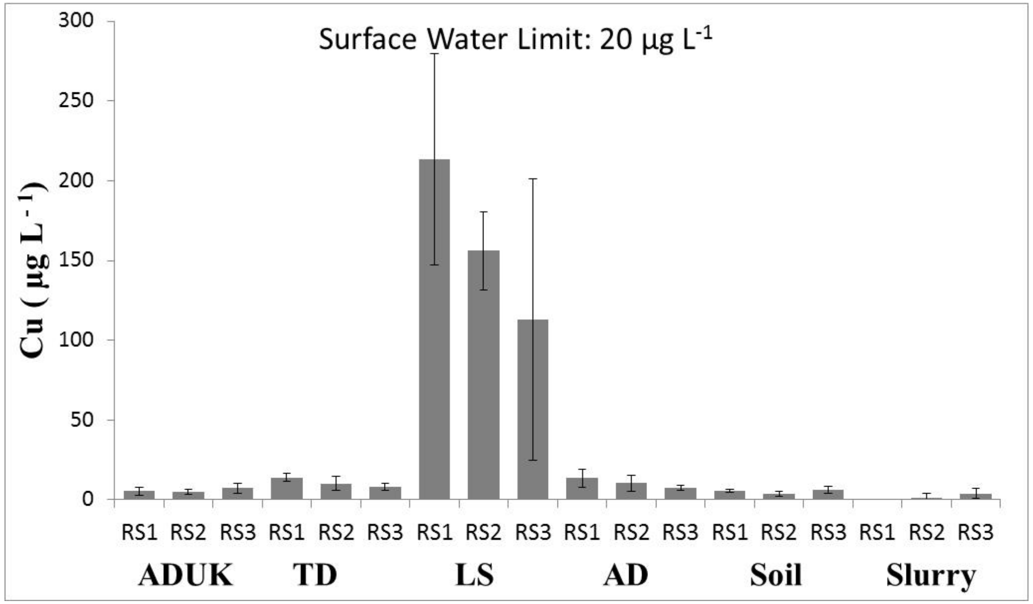
Metal loss in runoff

Regulated parameter	Surface water limit (µg L^{-1})*	Runoff in excess of surface water limit
Nickel (Ni)	None	n/a
Copper (Cu)	20	Yes
Zinc (Zn)	500	No
Cadmium (Cd)	1	No
Lead (Pb)	50	No
Chromium (Cr)	50	No



* S.L. 549.21

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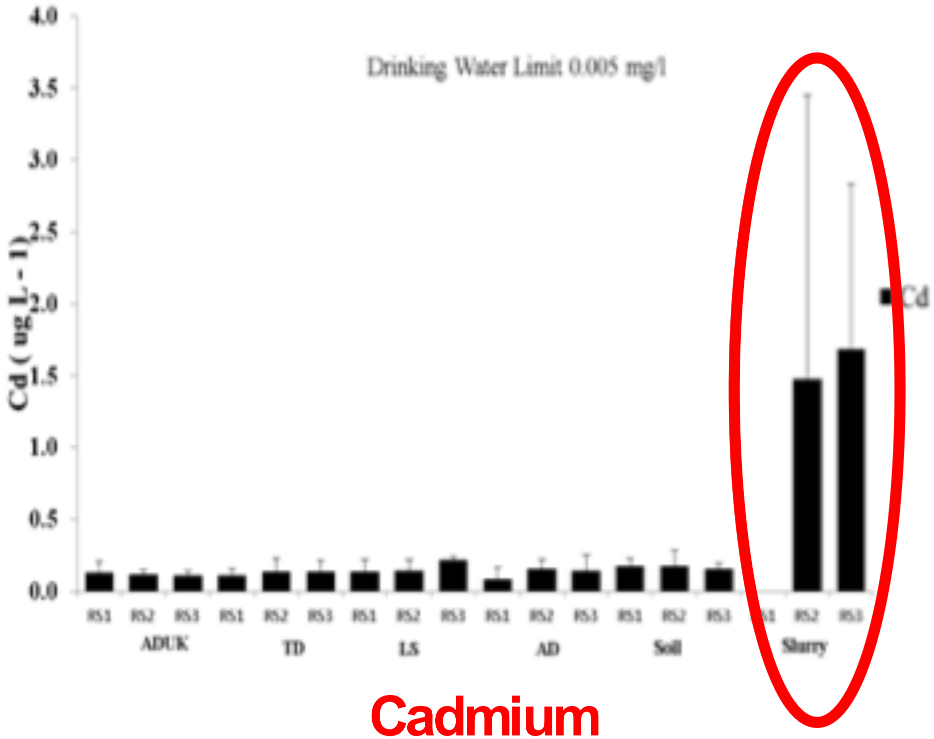
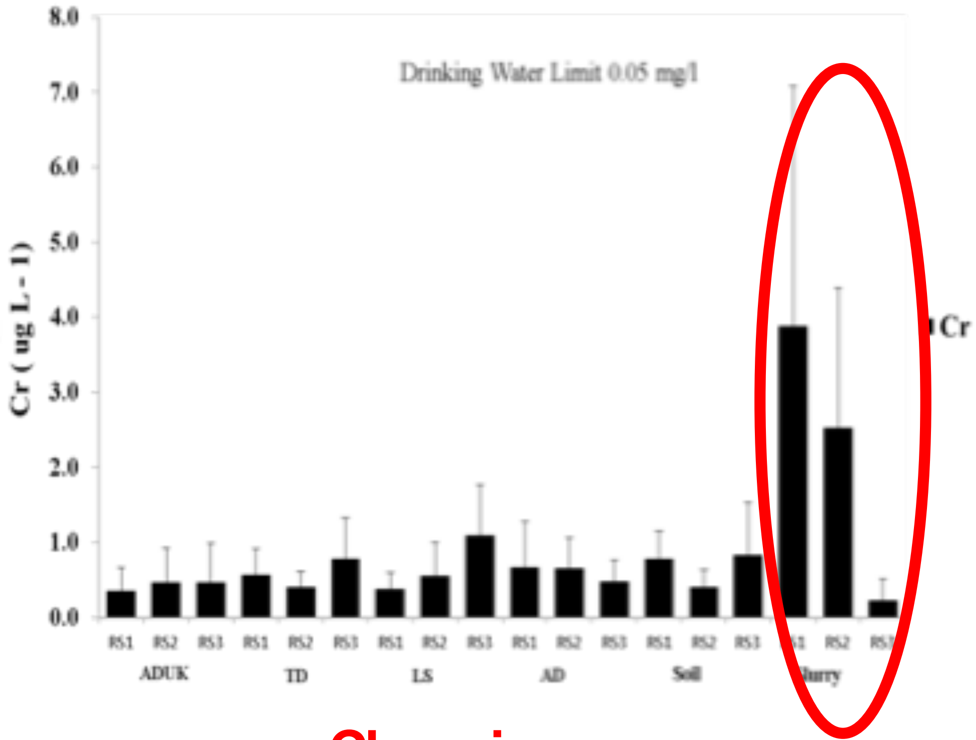
Peyton, D.P., Healy, M.G., Fleming, G.T.A., Grant, J., Wall, D., Morrison, L., Cormican, M., Fenton, O. 2016. Nutrient, metal and microbial loss in surface runoff following treated sludge and dairy cattle slurry application to an Irish grassland soil. Sci. Tot. Environ. 541: 218-229.

Metal loss in runoff



Cadmium



Chromium

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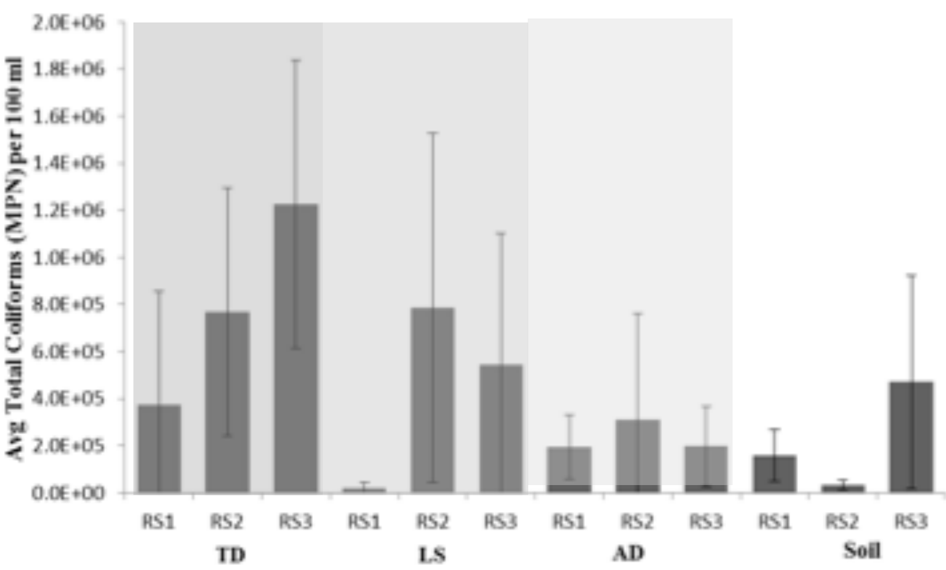
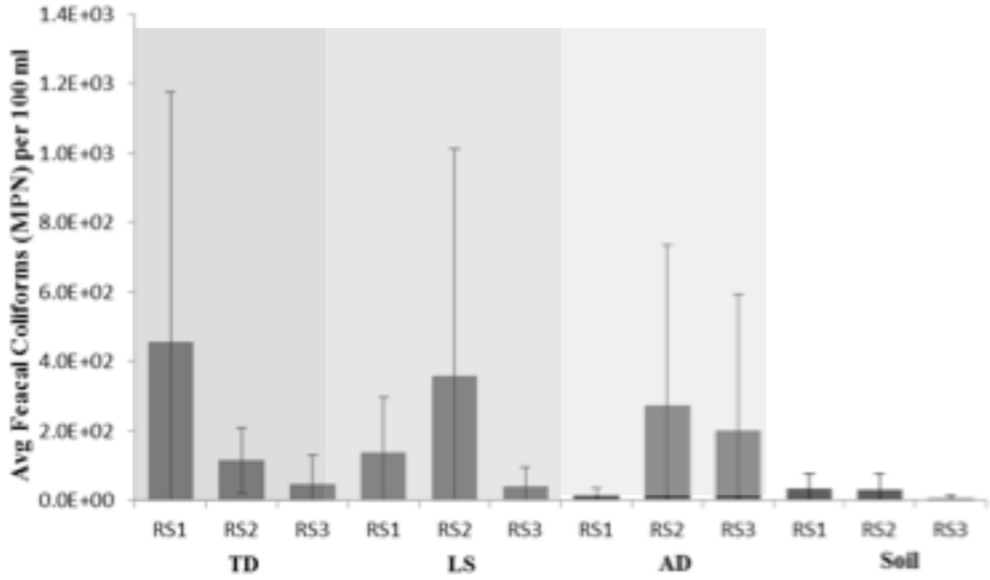
Total and faecal coliform loss in runoff





Results

Triclosan and triclocarban loss in runoff

Type of sludge	Compound in biosolids (ug g^{-1})		Application rate (expressed as dry matter) (t ha^{-1})	Concentration in runoff (ng L^{-1})	
Anaerobically digested	0.27	<2.4	6.7	<90	<6
Thermally dried	4.9	0.05	2.6	<90	<6

Healy, M.G., Fenton, O., Cormican, M., Peyton, D.P., Ordsmith, N., Kimber, K., Morrison, L. 2017. Antimicrobial compounds (triclosan and triclocarban) in sewage sludges, and their presence in runoff following land application. Ecotoxicity and Environmental Safety 142: 448 – 453.

Research aims

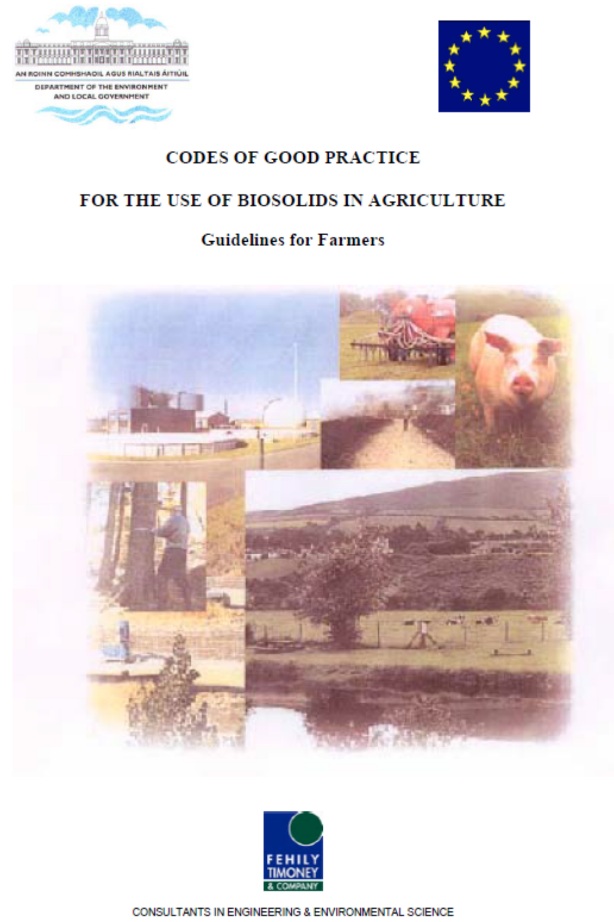
- To characterize the metal concentrations and investigate the presence of microplastics in treated municipal sludge in Ireland.
- To measure the surface runoff of nutrients, solids, microbial matter, pharmaceuticals, and metals following land application.
- To measure the uptake of metals by vegetation (ryegrass).

Research aims

- To measure the uptake of metals by vegetation (ryegrass).

Best landspreading practices

•Guidelines state that 'no animal fodder, including kale, food beet or silage, may be harvested until at least three weeks after application of biosolids, and livestock should not be turned out to pasture which has been fertilised with biosolids until three to six weeks after the date of application'.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DEPARTMENT OF THE ENVIRONMENT AND LOCAL GOVERNMENT

CODES OF GOOD PRACTICE

FOR THE USE OF BIOSOLIDS IN AGRICULTURE

Guidelines for Farmers

FEHILY TIMONEY & COMPANY

CONSULTANTS IN ENGINEERING & ENVIRONMENTAL SCIENCE

... and Company (1999) Codes of good practice for the use of biosolids in agriculture - guidel... for farmers.
http://www.environ.ie/en/Publications/Environment/Water/FileDownLoad,17228,en.pdf

Healy et al. 2016. Eco. Environ. Safety 130: 303-309.

Best landspreading practices

To investigate this regulation, we applied three types of biosolids to grassland (ryegrass) plots and measured the metal uptake over a period of up to 18 weeks.

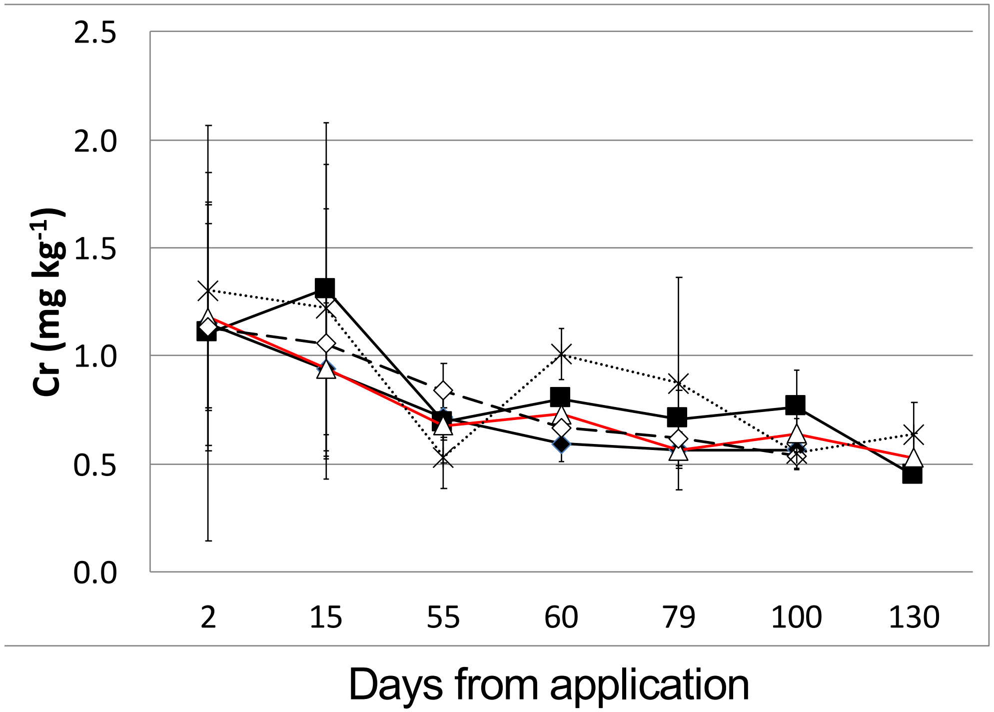
The treatments were:

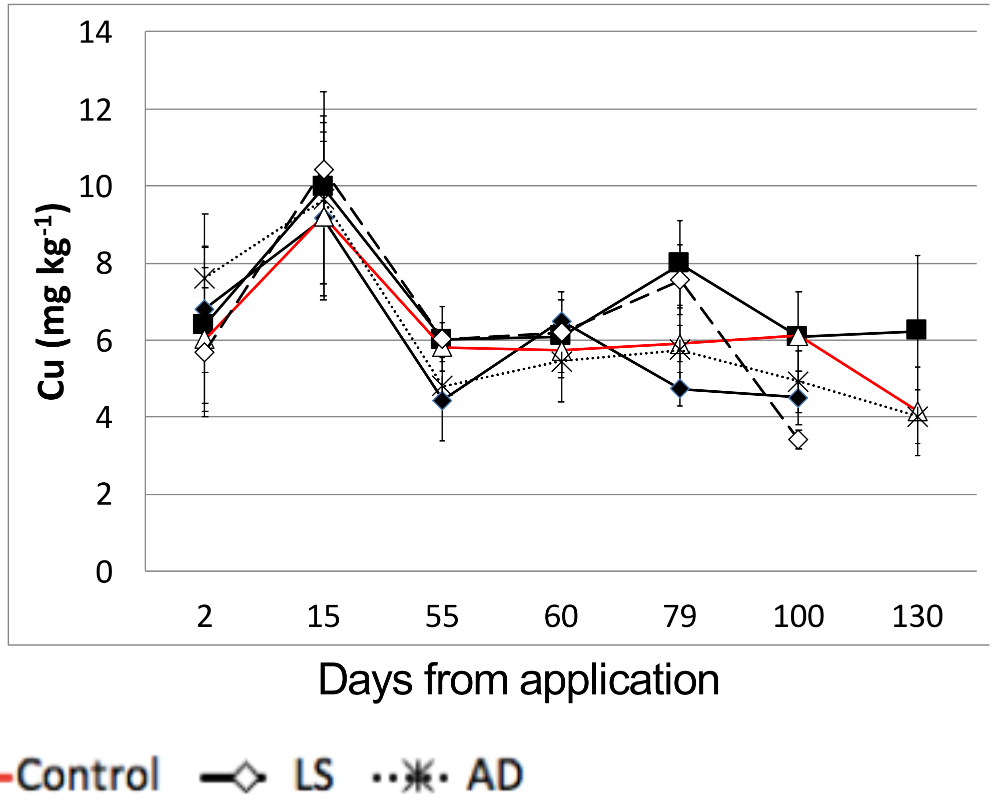
- Anaerobically digested biosolids
- Lime stabilised biosolids
- Thermally dried biosolids
- A study control (grass without biosolids)

Healy et al. 2016. Eco. Environ. Safety 130: 303-309.

Best landspreading practices

All legislated metals (Cr, Cu, Pb, Ni, Zn, Cd) had similar concentrations to study control and reduced in concentration over time.





Healy et al. 2016. Eco. Environ. Safety 130: 303-309.

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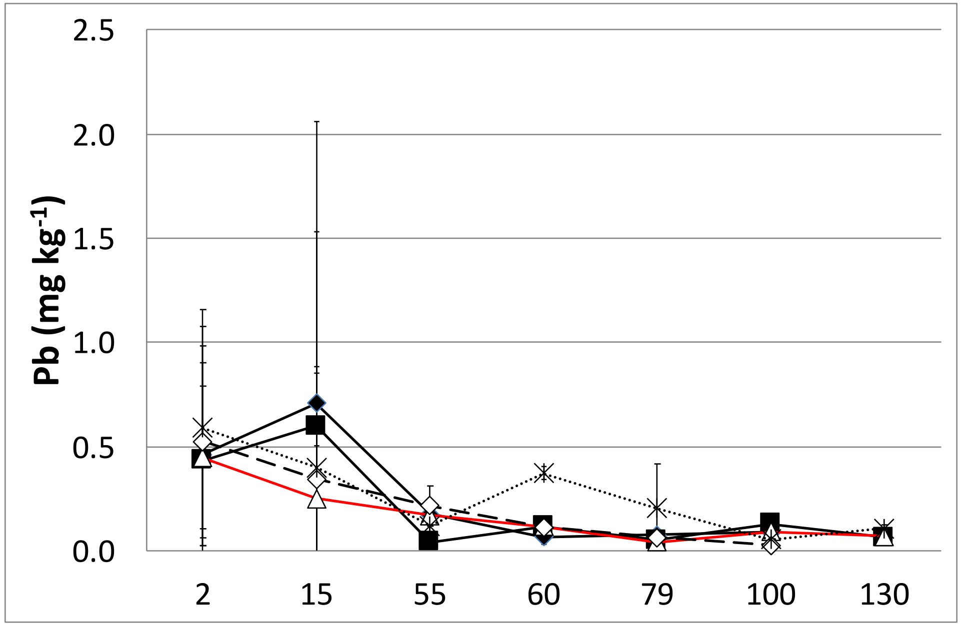
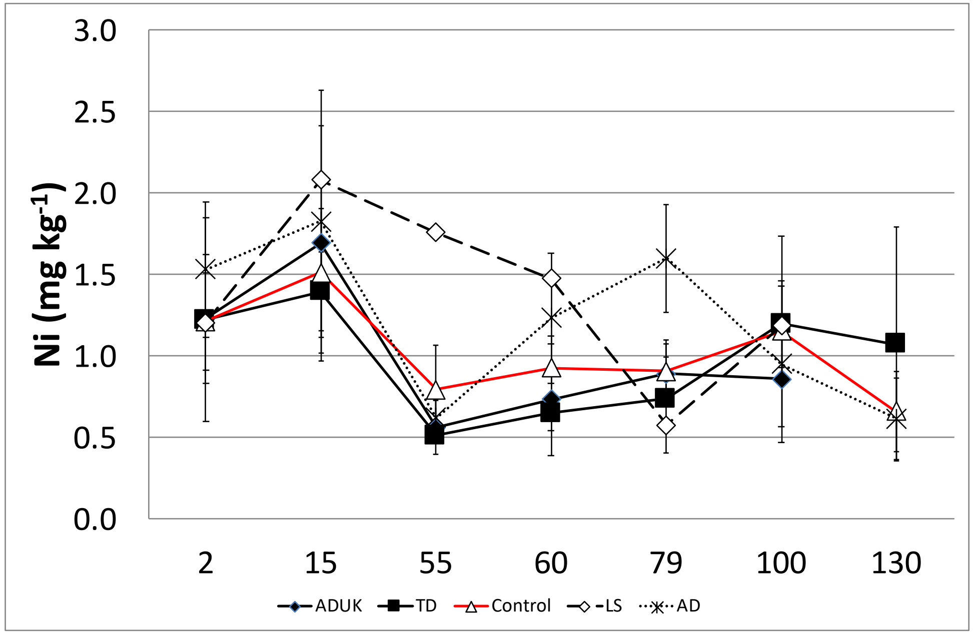


Days from application



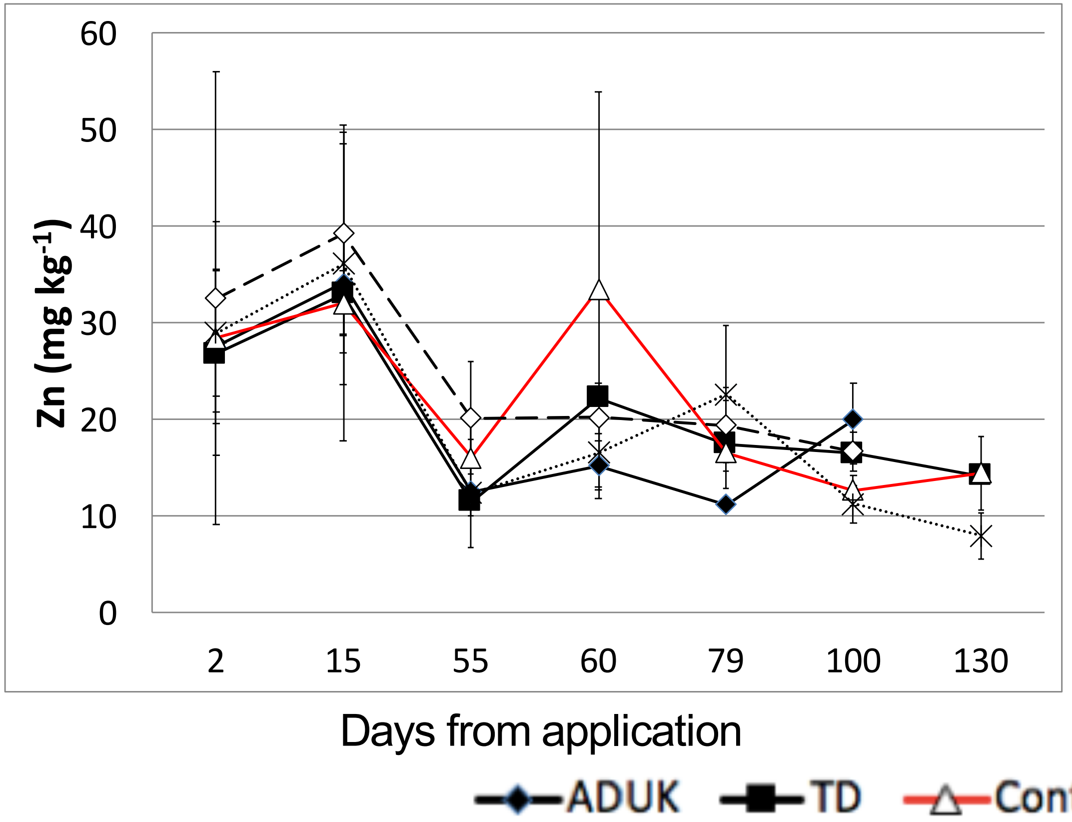
Days from application

ADUK TD Control LS AD

Healy et al. 2016. Eco. Environ. Safety 130: 303-309.

Best landspreading practices

All legislated metals (Cr, Cu, Pb, Ni, Zn, Cd) had similar concentrations to study control and reduced in concentration over time.



(Cd was below the limits of detection).

Conclusions of metal uptake by plant study.

There was no statistically significant difference between shoot metal concentration of ryegrass in biosolids-amended plots and unamended (control plots).

On the basis of the parameters measured, it would appear the guidelines are overly strict.

Overall conclusions

- Land applied biosolids pose no greater threat to water quality than dairy cattle slurry and cattle exclusion times from biosolids-amended fields may be overly strict (within the context of current exclusion criteria).
- Unlegislated metals and PPCPs may be inadvertently applied to land.
- With multiple applications over several years, these may build up in the soil and may enter the food chain, raising concerns over the continued application of biosolids to land in Ireland.

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Further reading

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