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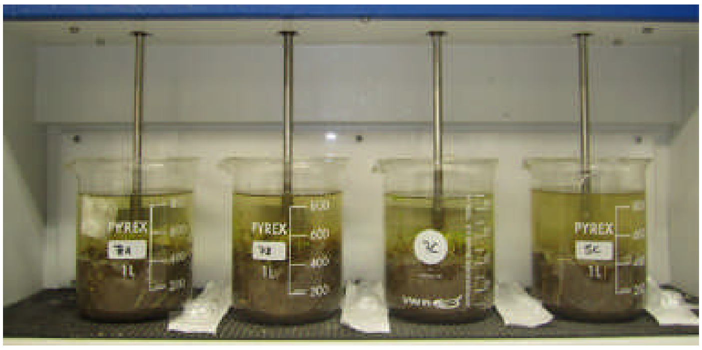
Chemical amendment of slurry to control phosphorus losses in runoff



Key external stakeholders:

International research community and practitioners using chemically amended slurry or considering using it in the future.

Practical implications for stakeholders:

This research provides important data on the effectiveness and feasibility of using chemically amended slurry and dirty water to decrease incidental losses of phosphorus and nitrogen.

- This research highlights that the current management practice for dairy slurry and dirty water application should not include chemical amendment. Their potential use is in identified critical source areas to protect losses during episodic rainfall events.
- In chemical amendment research both effectiveness, feasibility and pollution swapping at field scale must be taken into account.

Main results:

- In laboratory agitator and simulated runoff experiments, chemical amendments were effective at controlling phosphorus losses in runoff. When combined with feasibility criteria (e.g. cost and handling considerations) whole scale application was not advised due to cost restrictions.
- Using chemical amendments also has implications for nitrogen in the runoff phase. Solubility is increased leading to greater runoff volumes and therefore greater loads of nitrate and ammonium are lost.
- Chemical amendments also effect gaseous emissions following slurry application. Ammonia emissions were reduced by Alum, ferric chloride ($FeCl_2$), poly-aluminium chloride (PAC) and biochar, but were increased by lime. Cumulative N_2O emissions were increased when amended with alum and $FeCl_2$ and reduced when amended with lime, PAC and charcoal. The release of CO_2 form soil was not significantly affected by any of the amendments. Methane emissions followed a similar trend for all of the amended slurries applied with an initial increase in losses followed by a rapid decrease and then steady release for the duration of the study. All of the amendments examined reduced the initial peak in CH_4 emissions compared to the slurry only treatment. There was no significant effect of any amendment of slurry on global warming potential (GWP) caused by land application of dairy cattle slurry, with the exception of charcoal.
- After considering pollution swapping in conjunction with amendment effectiveness from best to worst, the amendments recommended for further field study are PAC, alum and lime. This study has also shown that charcoal has potential to reduce GHG losses arising from land application of dairy cattle slurry.

Opportunity/benefit:

Data obtained in this research provides an improved understanding of the effectiveness and feasibility of chemical amendment to dairy slurry and dirty water. It has identified that chemical amendment of slurry may have a place in critical source areas which are connected to a surface waterbody. The laboratory experiments in this study were useful to identify amendments suitable for field scale studies.

Collaborating Institutions:

NUI-Galway –Civil Engineering Department

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Teagasc project team: Dr Owen Fenton (Project Leader/PI)
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External Collaborators: Dept. of Civil Engineering, NUI Galway (Dr. Mark Healy)

1. Project background:

Land application of dairy slurry and dirty water can result in incidental losses of phosphorus (P) and nitrogen (N) to runoff where land application is followed by a heavy rainfall event. The risk of P loss from soil can also be increased as a result of a high buildup in soil test P. Fenton et al. (2008) proposed that preliminary laboratory tests (e.g. beaker agitator and runoff box tests) should be conducted to investigate the effectiveness and feasibility of chemically amended slurry and dirty water to control incidental losses. As part of this process a variety of amendments were chosen in agitator, flume and runoff studies which included ochre, ferric chloride, aluminium chloride, charcoal, alum, lime, poly-aluminium chloride hydroxide (PAC) and alum (aluminium sulphate) water treatment residuals.

2. Questions addressed by the project:

- Is chemical amendment of slurry and dirty water an effective way to control incidental losses of P and N and do other losses (pollution swapping) occur when they are used?
- Is chemical amendment of slurry and dirty water feasible within the current management process?

3. The experimental studies:

- Agitator effectiveness study – involved adding slurry mixed with various amendments (mixed in a beaker using a jar flocculator at 100 rpm), to intact soil samples at field capacity. Slurry was applied with a spatula, submerged with overlying water and then mixed to simulate runoff. Feasibility here was judged on cost and handling. The same experiment was conducted with dirty water.
- The flume study – intact grassed soil samples were placed in lab runoff boxes and simulated rainfall fell on this setup for 30 minutes.
- Gas experiment – incubation experiments with chemically amended dairy slurry and its affects on losses of NH_3, CH_4, N_2O, and CO_2.

4. Main results:

In laboratory agitator and simulated runoff experiments, chemical amendments were effective at controlling P losses in runoff. When combined with feasibility criteria (e.g. cost and handling considerations) whole scale application was not advised due to cost restrictions. As an example alum (aluminium sulphate) would cost €7.4 per m3 of treated slurry or €66.7 per kg of P reduction. A summary of the results is shown in Table 1.

Table 1. Summary of results from agitator and column experiments. (Abbreviations: a-pig slurry, b-dairy dirty water, c-dairy slurry, d-pig slurry column, NL-no leaching losses found, AFWMC-average flow weighted mean concentration decrease, TDP-total dissolved P, DRP-dissolved reactive P, SS-suspended sediment, TP-total P).

	Agitator/Column	
Amendment	P	N
Alum	DRP (86%)[a], DRP down 83%[c], minor decrease[d]	NL[d]
PAC	DRP (73%)[a], minor decrease[d]	NL[d]
Ferric Chloride	DRP (71%)[a], DRP down 88%[c], minor decrease[d]	NL[d]
Fly-ash	DRP (58%)[a], DRP down 72%[c],	
Biochar		
Lime	DRP (54%)[a], DRP down 81%[c]	NL[d]
Flue gas by-product	DRP (74%)[a], DRP down 72%[c],	

Using chemical amendments also has implications for nitrogen in the runoff phase. Solubility is increased leading to greater runoff volumes and therefore greater loads of nitrate and ammonium are lost. A summary of results form the run-off experiment is shown in Table 2.

Table 2. Summary of results from run-off experiments. (Abbreviations: a-pig slurry, b-dairy dirty water, c-dairy slurry, d-pig slurry column, NL-no leaching losses found, AFWMC-average flow weighted mean concentration decrease, TDP-total dissolved P, DRP-dissolved reactive P, SS-suspended sediment, TP-total

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P).

	Runoff
Amendment	P
	AFWMC of TP to 1.08 mg/L (56% PP)[a], SS down[a], P+SS down[b], SS down 88%[c]
Alum	TP down 94%[c], PP down 95%[c], TDP down 81%[c], DRP down 88%[c]
PAC	AFWMC of TP to 0.64 mg/L (42% PP)[a], SS down[a], DRP down 86%[c]
Ferric Chloride	AFWMC of TP to 0.91 mg/L (52% PP)[a], SS down[a], P+SS down[b],
Fly-ash	
Biochar	
Lime	P down SS up[b]

Chemical amendments also effect gaseous emissions following slurry application. Alum, ferric chloride ($FeCl_2$), poly-aluminium chloride (PAC) and biochar reduced ammonia (NH_3) emissions by 92, 54, 65 and 77%, respectively, compared to the slurry control. Lime increased emissions by 114%. Cumulative N_2O emissions of dairy cattle slurry increased when amended with alum and $FeCl_2$ by 202 and 154 % compared to the slurry only treatment. Lime, PAC and charcoal resulted in a reduction of 44, 29 and 63%, respectively, in cumulative N_2O loss compared to the slurry only treatment. Addition of amendments to slurry did not significantly affect soil CO_2 release during the study while CH_4 emissions followed a similar trend for all of the amended slurries applied with an initial increase in losses followed by a rapid decrease and then steady release for the duration of the study. All of the amendments examined reduced the initial peak in CH_4 emissions compared to the slurry only treatment. There was no significant effect of any amendment of slurry on global warming potential (GWP) caused by land application of dairy cattle slurry, with the exception of charcoal. After considering pollution swapping in conjunction with amendment effectiveness from best to worst, the amendments recommended for further field study are PAC, alum and lime. This study has also shown that charcoal has potential to reduce GHG losses arising from land application of dairy cattle slurry. The summary of the results form gaseous emissions experiments are shown in Table 3.

Table 3. Summary of results from gaseous emissions experiments. (Abbreviations: a-pig slurry, b-dairy dirty water, c-dairy slurry, d-pig slurry column, NL-no leaching losses found, AFWMC-average flow weighted mean concentration decrease, TDP-total dissolved P, DRP-dissolved reactive P, SS-suspended sediment, TP-total P).

Amendment		Gas		
Alum	NH_3	Cumulative N_2O	soil CO_2	CH_4
PAC	Down 92%[c]	Up by 202%[c]	No effect	No difference from slurry
Ferric Chloride	Down 54%[c]	Down 29%[c]	No effect	No difference from slurry
Fly-ash	Down65%[c]	Up by 154%[c]	No effect	No difference from slurry
Biochar				
Lime	Down 77%[c]	Down 63%[c]	No effect	No difference from slurry
Flue gas by-product	Up 114%[c]	Down 44%[c]	No effect	No difference from slurry

5. Opportunity/Benefit:

Use of chemical amendments needs to be tested at field scale in a holistic way e.g. runoff, leaching and gaseous losses for N&P needed to be considered.

6. Dissemination:

Main publications:

Brennan, R.B., Fenton, O., Rodgers, M., Healy, M.G. 2011. Evaluation of chemical amendments to control phosphorus losses from dairy slurry. Soil Use & Management, 27, 238-246

Brennan, R.B., Fenton, O., Grant, J., M., Healy, M.G. 2011. Impact of chemical amendment of dairy cattle slurry on phosphorus, suspended sediment and metal loss to runoff from a grassland soil. Science of the Total Environment, 409: 5111-5118.

Fenton, O., Serrenho, A., Healy, M.G. 2011. Evaluation of amendments to control phosphorus in runoff from dairy soiled water. Water Air and Soil Pollution, 222, 185-194.

O' Flynn, C.J., Fenton, O., Wilson, P., Healy, M.G. 2012. Impact of pig slurry amendments on phosphorus, suspended sediment and metal losses in laboratory runoff boxes under simulated rainfall. Journal of Environmental Management. In press.

O' Flynn, C.J., Fenton, O., Healy, M.G. 2012. Evaluation of amendments to control phosphorus losses in runoff from pig slurry applications to land. CLEAN - Soil, Air and Water 40: 164-170.

Popular publication:

Fenton, O., Healy, M.G., Brennan, R.B., Serrenho, A.J., Lalor, S.T.J., OhÚallacháin, D., Richards, K.G. 2011. Agricultural Wastewaters. Waste Water Edited by Fernando S. Garcia. Intech Publishers.

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