Influence of animal slurry pre-treatment and soil application technique on leachates composition: a soil column experiment

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Abstract
The main objective of this work was to assess the influence of different combinations of slurry pre-treatments and/or soil application techniques on leachates composition.
A disturbed soil columns experiment was performed using dairy slurry, to compare the behaviour of 6 different treatments/application techniques in 3 different soil types. Different combinations of slurry acidification and or separation as pre-treatments, and surface application or injection as application technique were tested. No significant differences were observed in the leachate pH of the different treatments considered. There was greater leaching of salts in soils amended with acidified fractions. Treating slurry by separation or acidification may lead to an increase in NO_3 leaching relative to whole slurry (WS) surface application but the differences relative to WS injection were not significant.

Introduction
Soil application of animal slurry by injection is the recommended method in many European countries since it is the most efficient solution to avoid ammonia emissions [1]. However, slurry injection implies high investments in machinery and it may not be practicable in some areas due to soil characteristics neither in permanent grassland. Band application of pre-treated slurry is an alternative to slurry injection in order to minimize NH_3 emissions. Indeed, it was shown that slurry acidification strongly decrease ammonia emissions [2, 3] and application of the liquid fraction (LF) obtained by solid-liquid separation should also be efficient since LF should infiltrate into the soil faster than raw slurry. However, recent studies have showed that efficient solutions to decrease one form of pollution may induce an increase of other losses, leading to the so-called pollution swapping [4,5]. Indeed, on one hand, slurry injection leads to interactions of slurry with soil layers different from soil surface in terms of organic matter as well as aerobic/anaerobic conditions. On the other hand, slurry treatment by separation or acidification affects the N, C and P dynamics after soil application [6, 7]. Nevertheless, few or no information is available relating to the impact of such pre-treatments and application technique on leachate composition from amended soils.
The aim of the present work was to compare the influence of animal slurry pre-treatment and soil application technique on leachate composition following simulated rainfall events over a 24 day experiment under controlled conditions.

Material and Methods
The cattle slurry (WS) used here was obtained from a commercial dairy farm and then subject to several treatments: mechanical separation to obtain a liquid fraction (LF) and acidification to pH 5.5 of both raw slurry (AWS) and the liquid fraction (ALF) by addition of sulphuric acid. The main characteristics of the slurries used are described in Table 1.
A laboratory experiment was performed with disturbed soil columns using PVC pipes,30 cm high and 6.3 cm diameter. Three soil types were considered: a sandy soil (SS), a sandy loam soil (SLS) and a clay soil (CS). The soils were obtained from agricultural fields from the 0-30 cm layers, then air dried and sieved at 5 mm. After packing, the columns were immersed in deionised water until the soil reached saturation. The soil was then allowed to drain the excess of water until it reached field capacity. An amount of slurry equivalent to 240 kg N ha^{-1} was applied in all treatments. The treatments considered were: injection of the whole slurry (WSi), surface application of the whole slurry (WSs) followed by soil incorporation, surface application of the acidified whole slurry (AWSs), surface application of the liquid fraction (LFs), surface application of the acidified liquid fraction (ALFs) and a control treatment without slurry application (CTR). Four replicates for each treatment and each type of soil were made giving a total of 72 soil columns.

Table 1: Main characteristics of the slurries used – mean values of 3 replicates.

Treatments	Organic Matter ($g\ kg^{-1}$)	Kjeldhal N ($g\ kg^{-1}$)	NH_4^+- N ($g\ kg^{-1}$)	pH	Conductivity ($mS\ cm^{-1}$)
WS	30.4	2.8	1.3	7.4	15.9
AWS	32.7	2.8	1.3	5.5	17.8
LF	13.3	2.0	1.1	7.3	17.0
ALF	13.6	1.9	1.2	5.5	17.2

The first leaching event was performed 72 hours after treatments application and then leaching events were performed weekly for a total of 4 leaching events. For this, 300 ml of deionised water were applied to the top of the columns in each event. The volume of water was calculated to be greater than 3 times the total soil pore volume for every type of soil. The total volume of leachate was measured for each treatment at each leaching event and the leachate composition was analyzed in terms of mineral nitrogen, electrical conductivity and pH.

Results

pH

Application to soil of treated or untreated slurry led to an increase in leachate pH (data not shown). Such an increase has been reported in previous studies by Kay et al (2005) [8]. Nevertheless, the leachate pH in treatments receiving acidified slurry or liquid fractions was not significantly different to that for treatments receiving non acidified slurry, indicating that treatment by acidification had no effect on the leachate pH.

Nitrate

The nitrate concentration in leachate did not follow a similar trend over time for all treatments or soil types (Table 2). Indeed, in SS soil, NO_3 concentration decreased with time in most treatments even if a peak was observed on day 17 for Wsi, WSs and ALFs. In the SLS soil, NO_3 concentration in leachates tended to increase with time and a maximum value was observed in many treatments at day 17. However, no systematic trend was identified for the CS soil. This variation mainly reflects the initial nitrate concentration in soil (high values in SS and CS against low values in SLS) as well as the mineralization and nitrification rates in the different soils considered, with the highest values observed in the CS soil in agreement with previous studies [9].

Table 1. Nitrate concentration ($mg\ N\ l^{-1}$) in leachates obtained from amended SLS, SS and CS soils (N=4)

Days after application	WSi	WSs	AWSs	LFs	ALFs	CTR
			SLS soil			
3	*1,001 ^{a}	0,205 ^{a}	0,170 ^{a}	0,219 ^{a}	0,094 ^{a}	0,170 ^{a}
10	12,790 ^{ab}	2,325 ^{a}	8,990 ^{b}	13,034 ^{ab}	7,678 ^{ab}	1,595 ^{a}
17	14,134 ^{a}	8,044 ^{a}	17,787 ^{ab}	26,333 ^{a}	48,818 ^{a}	2,694 ^{b}
24	15,003 ^{a}	12,031 ^{a}	13,226 ^{a}	25,821 ^{a}	29,467 ^{a}	3,768 ^{a}
			SS soil			
3	54,554 ^{b}	66,502 ^{ab}	60,019 ^{ab}	51,746 ^{b}	52,647 ^{b}	70,734 ^{a}
10	30,302 ^{b}	40,973 ^{ab}	43,418 ^{abc}	57,133 ^{a}	46,812 ^{a}	14,468 ^{c}
17	52,948 ^{b}	50,256 ^{bc}	39,322 ^{bcd}	39,713 ^{c}	76,303 ^{a}	9,023 ^{d}
24	12,919 ^{a}	12,828 ^{a}	20,547 ^{a}	11,655 ^{a}	16,022 ^{a}	5,153 ^{b}
			CS soil			
3	47,759 ^{d}	67,978 ^{ab}	62,954 ^{b}	73,324 ^{ac}	46,235 ^{d}	64,707 ^{bc}
10	69,66 ^{a}	17,695 ^{bc}	28,435 ^{c}	61,47 ^{a}	53,734 ^{ac}	9,627 ^{b}
17	60,19 ^{b}	32,691 ^{c}	52,768 ^{b}	131,302 ^{a}	126,832 ^{a}	10,588 ^{d}
24	30,626 ^{b}	31,005 ^{b}	53,986 ^{a}	52,661 ^{a}	42,864 ^{abc}	4,777 ^{c}

*Values followed by same letters are not statistically different at P<0.05

The higher nitrate concentrations were observed in treatments with surface application of liquid fraction (both acidified and not acidified) in the 3 soils types. Nevertheless, such differences were statistically different only in the CS and SS soils. Significant differences in NO_3 concentration in leachates were observed between WSi and WSs only in CS soil. Similarly, the effect of slurry separation as well as acidification on NO_3 leaching was significant only in CS even if on average, higher values of NO_3 were found in treatments receiving acidified or separated slurry.
The total amount of NO_3 leached was greater in the clay soil in all treatments except WSs and CTR and smaller in the sandy loam soil for all treatments. The higher values of total nitrate leached from WSs and CTR treatments were observed in the SS soil. The total amount of NO_3^- -N leached in the WSi and the AWSs treatments was similar inn all the soil types tested.
Similar amounts of NO_3 leached from WSs and WSi were observed in the SS, but in the SLS and CS soils, higher amounts of NO_3 were lost in the WSi. It indicates that slurry injection may increase the potential nitrate leaching in the soil types studied in agreement with results reported in previous studies [4].
Relative to slurry separation, equivalent values of NO_3 leached were observed between WSs and LFs in SS and SLS but LFs led to higher values in the CS. However, no differences were observed between AWSs and ALFs in all soils.

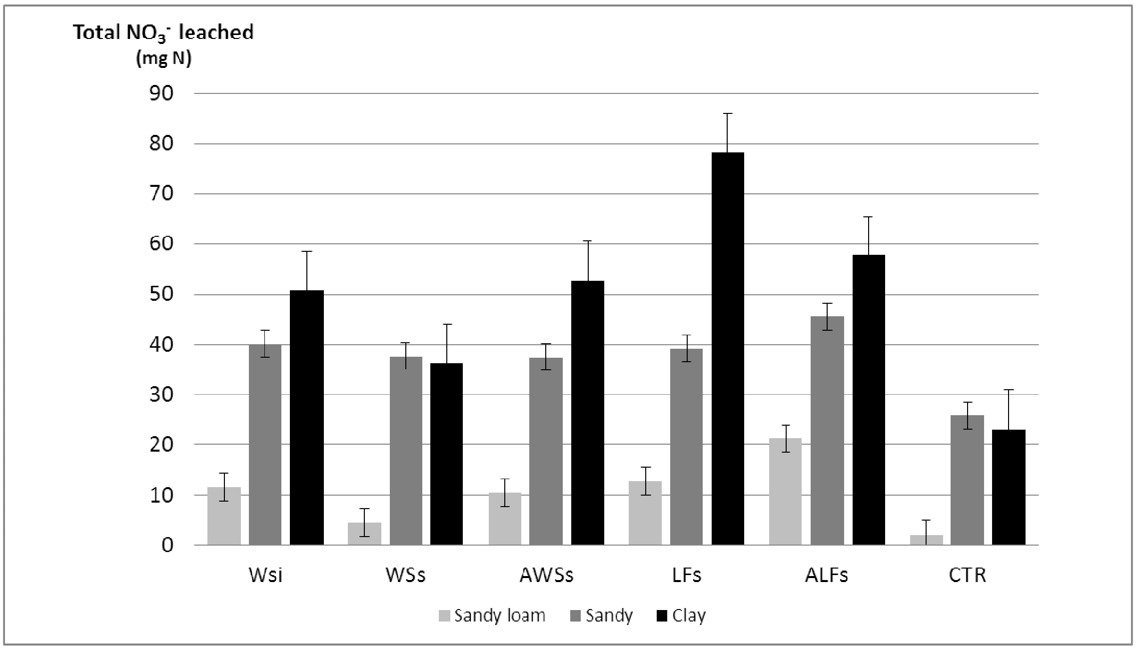

Figure 1. Total nitrate leached (mg N) from treated soils – mean value and standard error of 4 replicates

Electrical Conductivity

Different patterns were observed for the evolution of EC from leachates in the treatments and soils considered. The leachates from the columns amended with acidified fractions presented higher EC values in all soil types indicating that slurry acidification may increase salts leaching following soil application.
In SLS soil, EC values from AWSs decreased in every leaching event reaching the same values than CTR in the final leaching. EC values from WSi and WSs decreased until the 3rd leaching event and then slightly increased in the final leaching. However, EC values from ALFs decreased on the 2nd leaching event but increased along the last two leaching events. In SS soil, EC values from all treatments decreased in the 2nd leaching event, increased in the 3rd and decreased again in the last leaching, except CTR and AWSs that decreased in all the leaching events. In CS soil, AWSs and LFs EC values decreased in all leaching events.

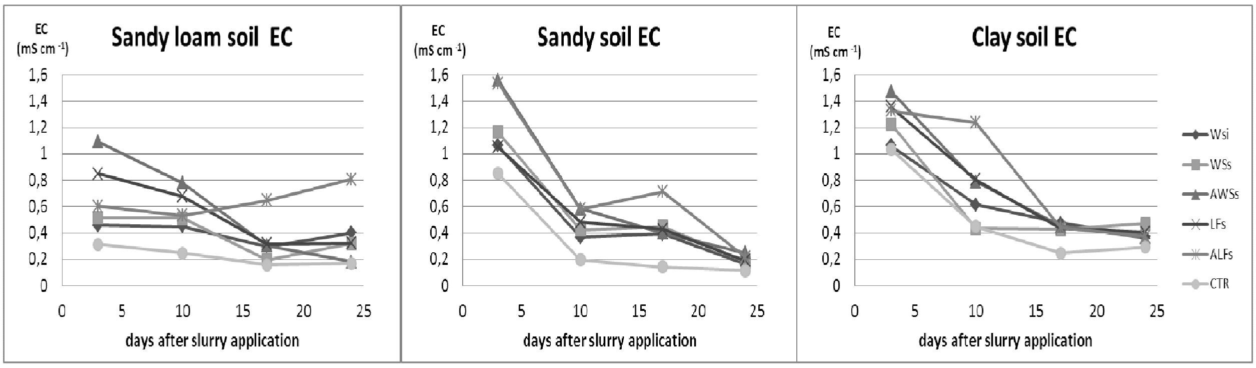

Figure 2. Electrical Conductivity of the leachates in each type of soil

Conclusions

- There is no evidence that the slurry acidification caused changes in the leachates pH comparing with non acidified slurry, but leachates from slurry amended soils present a higher pH than non amended soil leachates.
- Slurry acidification may increase salts leaching.
- Our results showed that application of treated slurry by separation or acidification may lead to an increase of NO_3 leaching relative to WS application but the differences relative to WS injection were not so significant.

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