Leachate losses from temporary solid livestock manure field heaps

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Abstract
We reviewed existing data on the effects of manure type and storage period on the quality, quantity and pattern of leachate losses from solid manure heaps. Leachates from solid manure heaps frequently contained elevated concentrations of multiple pollutants (e.g. ammonium, nitrate, phosphorus, biochemical oxygen demand and faecal indicator organisms), which could cause detrimental effects if they reached surface water bodies in an undiluted form. Leachate concentrations of most pollutants peaked at the start of the storage period (i.e. within 2 months of leachate generation); however, elevated phosphorus concentrations were measured throughout the whole storage period. Covering poultry manure field heaps (with an impermeable sheet) was shown to be an effective method of decreasing leachate volumes and pollutant losses.

Introduction
An estimated 43 million tonnes of solid manures (straw-based farmyard manure - FYM and poultry manure) are applied to agricultural land in the UK each year [1]. The storage of solid manures enables farmers to spread them when the risks of soil compaction and water pollution are low, and when the nutrients supplied are most likely to be taken up by crops. In the UK, an estimated 69% of cattle/pig FYM and 50% of poultry manures are temporarily stored before land spreading, with the majority (>80%) stored in field heaps [2]. Leachate from solid manure field heaps presents a risk of water pollution, as it typically contains high concentrations of nutrients (e.g. ammonium nitrogen-N and phosphorus) and has a high biochemical oxygen demand (BOD). Storing solid manures on an impermeable base prevents leachate seepage and the accumulation of nutrients in soil below the field heap, which may subsequently be lost to surface and ground waters. However, the costs of installing impermeable base storage and therefore mandatory effluent collection facilities can be very high, with little financial benefit to the farmer.

The objective of this study was to review existing data on pollutant concentrations (nitrate, ammonium, phosphorus, BOD and faecal indicator organisms) in leachates from solid manure heaps and to identify factors that influence the nature and quantity of leachate produced.

Methodology
Relatively few studies have been undertaken in the UK measuring leachate losses from solid manure heaps; for most studies the main focus of the research was on gaseous emissions (i.e. ammonia and nitrous oxide), with any leachate measurements being an 'add-on' [3]. Most information in the scientific literature was from cattle FYM (or 'deep litter' as it is referred to in many EU Member States). In contrast, the experimental evidence reviewed from UK studies was mainly from pig FYM and poultry manures. All of the studies we reviewed used manure heaps stored on concrete (or other impermeable surfaces) to facilitate leachate collection (i.e. they were *not* field heaps on a soil base). We were able to collate leachate data from pig and cattle FYM and poultry manures stored for a range of time periods, and from contrasting management practices (e.g. covered, turned, extra straw added).

Results
Leachate volumes
There was an inverse relationship ($P<0.01$) between the initial dry matter content of poultry manures/pig FYM and the overall volume of leachate generated over the storage period (expressed as a percentage of rainfall volumes), Figure 1. As the dry matter content of the manures increased, the

volume of leachate produced decreased, which was probably because the drier manure heaps were able to 'absorb' more of the rainfall (which was subsequently evaporated) rather than contributing to leachate volumes.

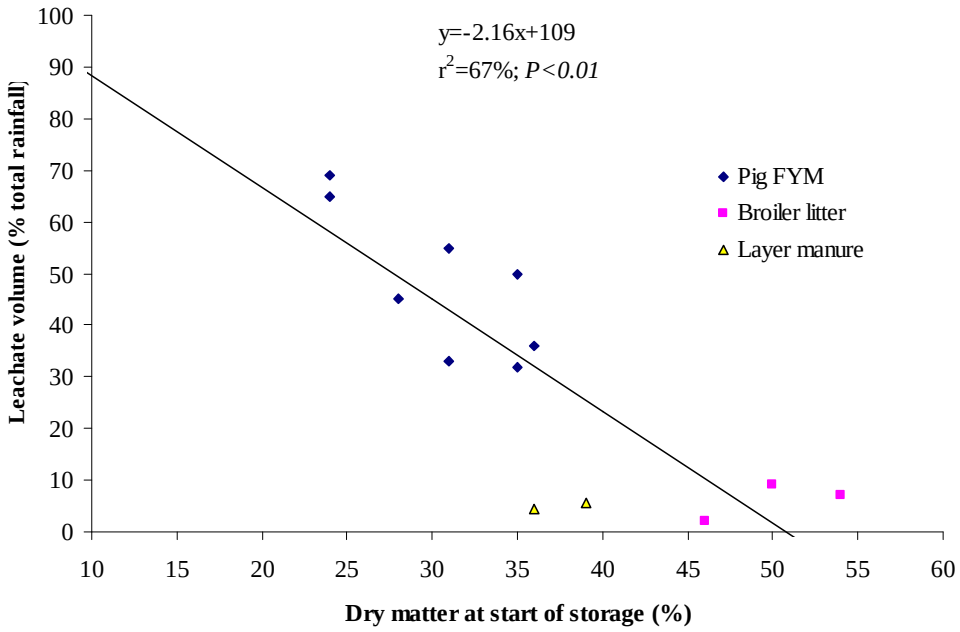

Figure 1. Relationship between the initial dry matter content of uncovered poultry and pig manures and the overall volume of leachate generated during the storage period. Data from [4],[5],[6] and [7]

Lower leachate volumes were measured from covered than uncovered poultry manure heaps (*c*.85%), indicating that covering poultry manure field heaps was an effective method of reducing leachate losses.

Nitrogen concentrations and losses

In general, leachate total N and ammonium-N concentrations (and losses) from both pig FYM and poultry manure heaps were highest at the start of storage (i.e. in the first month of leachate generation) and decreased over the storage period (e.g. Figure 2). Nitrate-N concentrations (and losses) from poultry manure heaps also decreased over the storage period, however, concentrations (and losses) from pig FYM heaps increased over the storage period (Figure 3). Leachate ammonium-N concentrations were consistently higher than the limit value of 0.78 mg/l ammonium-N set in the Freshwater Fish Directive [8], with values >1,000 mg/l commonly measured (Figure 2). Similarly, nitrate-N concentrations often exceeded the Nitrate Directive limit of 11.3 mg/l [9], with concentrations >100 mg/l commonly measured (Figure 3). Total leachate N losses were generally low ranging from 0.8-5.3% of total N into store from uncovered pig FYM heaps and 0.4-8.2% of total N into store from uncovered poultry manure heaps, compared with 0.5-0.8% for cattle FYM [3].

Phosphorus and potassium concentrations and losses

There were no consistent patterns in leachate phosphorus (P) concentrations (and losses) from pig FYM and poultry manure heaps. Total leachate P losses were in the range 3.0–12.5% of total P inputs into store from uncovered pig FYM heaps, and 0.03–0.4% from uncovered poultry manures heaps. Covering poultry manure heaps reduced leachate P losses by around 8-fold.

There were no clear patterns in leachate total potassium (K) concentrations (and losses) from pig FYM and poultry manure heaps. Total K losses from uncovered pig FYM heaps (range 13.4–37.0% of K inputs) were substantially greater than from uncovered poultry manure heaps (1.0–3.0%). Covering poultry manure heaps decreased leachate K losses by around 9-fold. Losses of 26-54% were measured from uncovered cattle FYM heaps, with covering reducing K losses to <10% of initial K content [3].

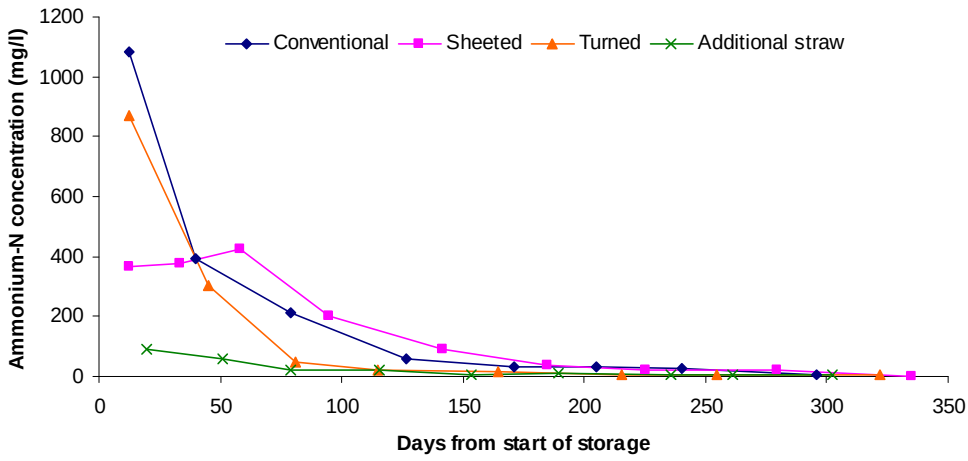

Figure 2. Leachate ammonium-N concentrations from pig FYM stored for *c.*12-months, showing the impact of different management techniques. Unpublished data from [4]

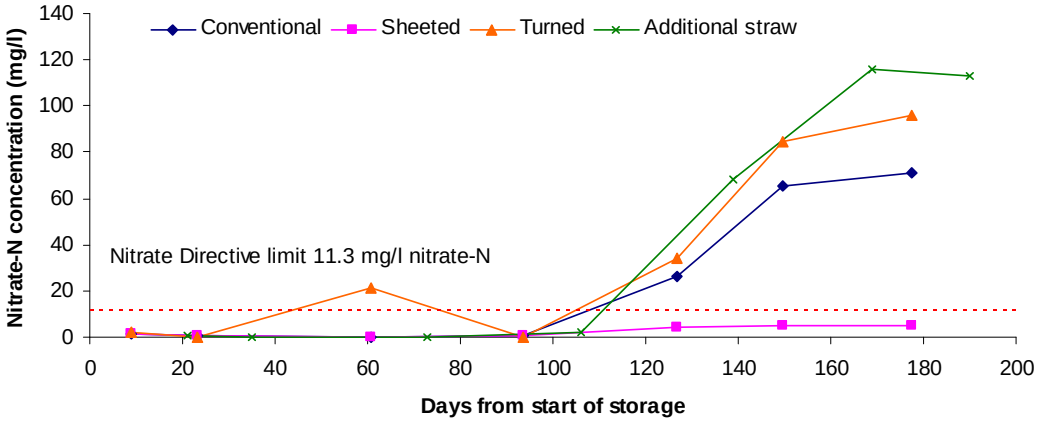

Figure 3. Leachate nitrate-N concentrations from pig FYM stored for *c.*6-months, showing the impact of different management techniques. Unpublished data from [4]

Biochemical oxygen demand (BOD)

In general, BOD concentrations fell over the manure storage period, with peak concentrations in the range 1,000–20,000 mg/l measured within 2 months of leachate generation. The highest BOD concentrations were measured in layer manure heap leachates (mean *c.*14,000 mg/l) compared with broiler litter (mean *c.*4,000 mg/l) and pig FYM (mean *c.*1,000 mg/l) heap leachates.

Faecal indicator organisms (FIOs)

E.coli concentrations in leachates from pig and cattle FYM heaps were highest at the start of storage and decreased rapidly during the first 2-4 weeks of storage (Figure 4). Leachate *E.coli* concentrations were generally close to or above the Bathing Water Directive threshold (500 colony forming units/100 ml) for good/sufficient quality [10].

Conclusion and perspectives

Leachates from solid manure heaps contained elevated concentrations of multiple pollutants (e.g. ammonium-N, nitrate-N, P, BOD and FIOs), which could cause detrimental effects if they reached surface water bodies in an undiluted form. Leachate concentrations of most pollutants (e.g. ammonium-N, BOD and *E.coli*) peaked at the start of the storage period (i.e. within 2 months of leachate generation); however, elevated P concentrations were measured throughout the whole storage period. In practice, pollutants in leachate infiltrating soil underneath a field heap (and in run-off from -

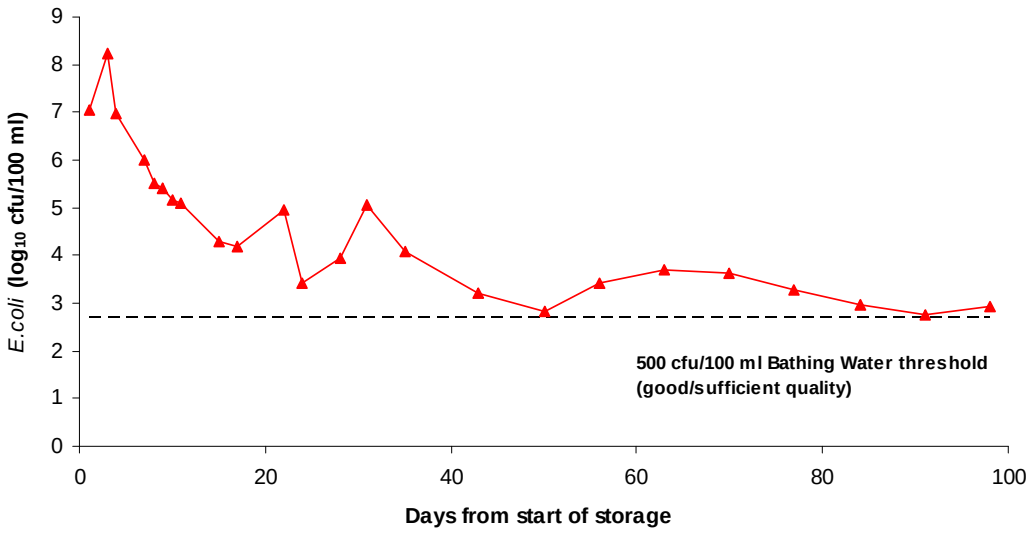

Figure 4. Leachate *E.coli* concentrations from cattle FYM stored for *c.*3 months. Unpublished data from [4]

the heaps) are likely to be either retained in the soil or diluted with 'uncontaminated' water from the rest of the field. Thus, pollutant concentrations will be reduced provided that heaps are sited so that connectivity to watercourses is reduced and there are sufficient 'barriers' (e.g. a buffer distance from surface waters, land drains etc.) between the field heap and the receiving water.

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