

# Woodchip pads for out-wintering cattle - technical review of environmental aspects.

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## Executive Summary

Woodchip pads have been used as a generic term to describe both unlined, woodchip corrals and sealed/lined out-wintering pads (OWPs), known also as “stand-off” pads. As originally conceived, the woodchip corral comprised a shallow basin, excavated on permeable, free-draining subsoils, on the premise that sufficient treatment of effluent occurred within the woodchip matrix, before dispersion within the underlying subsoil. Stand-off pads include a compacted clay base or impermeable rubber or plastic lining, filled with a variable depth of woodchip and an effluent collection system of 80–100 mm Ø plastic drainage pipe. Woodchip pads have gained popularity over the last ten years across Scotland, England and Wales, having been already well established in New Zealand and Ireland. In those countries, woodchip pads are considered to offer an economic means of wintering animals, reducing or avoiding the need for conventional housing, reducing labour inputs for feeding and providing improvements in animal performance via increased daily live-weight gain, better feed conversion and decreased fat deposition. The use of woodchip also avoids the high cost and sometimes low availability of straw for bedding. Other claimed advantages are benefits to animal welfare, potential to minimise damage to pasture from stock out-wintered on poorly drained soils and possible reduction in gaseous emissions of ammonia and nitrous oxide.

It has been estimated that more than 600 woodchip pads have been installed on farms in the UK (most in Scotland). However, regulatory controls on woodchip pad construction which preclude the installation of unlined and un-drained facilities, and some catastrophic pad failures, have seen a decline in interest. In view of the concerns about the potentially adverse effects of woodchip pads on surface and groundwater quality, the main focus of this technical review was on environmental impacts and on pad performance.

In contrast to other proven biological treatment systems, for example in aerobic composting, high-rate filter systems for effluent/water treatment, or in bio-filter air scrubbers, conditions within the below-ground woodchip bed, during the winter months, would appear to be far from ideal (in terms of moisture content, temperature, C:N ratio of woodchip and of effluent substrate) for bacterial growth and effective effluent treatment. It is therefore no surprise that controlled studies on effluent quality from corrals or OWPs have shown no evidence of effective treatment, failing to demonstrate significant reduction in “pollutant load” potential (e.g. BOD<sub>5</sub>, COD, SS, total N or NH<sub>4</sub>-N). Results, however, do suggest some physical filtration/retention of slurry solids within the woodchip matrix, the extent of which appears to be related to woodchip size and the depth of the woodchip bed. Moreover, average effluent quality has generally been similar to the analysis of typical “dirty water”, rather than that of cattle slurry. This evidence is, therefore, at variance with the current NVZ Action Programme rules for England and Wales (Anon, 2009), in which effluent from woodchip pads is classified as ‘slurry’.

The few studies that have attempted to quantify nutrient balance within OWPs or corrals, suggest that a relatively small proportion of the total input load from cattle drains from the pad in the effluent, e.g. 5% - 12% of N; 6% - 15% of P (CREH; 2005). There is some evidence that stocking density, depth and type of woodchip (and potential alternatives) will affect the concentration and volume of effluent produced. One study in New Zealand calculated that >60% of the estimated N input from dairy cows was retained within the woodchip matrix (Luo *et al.*, 2006). Low estimates of N and P export in effluent drainage (7% N and 2% P) were also made by Smith *et al* (2005) and (10% N and 5% P) by French and Hickey (2003). Similarly, it was suggested that 90-99% of faecal indicator organisms (FIOs) were retained within the woodchip, rather than in the effluent drainage; however, it seems likely that this observation may have been heavily influenced by the viability of these bacterial cells which is a function of time between the voiding of excreta and drainage from the pad, with other factors such as temperature, UV and desiccation determining the rate of die-off and, hence, the relatively low number of FIOs found in the drainage.

The management of the pad with regard to accumulation of slurry solids and drainage flow is of key importance to the efficient performance of the pad and the comfort and hygiene of the stock. Feeding is a major management input into the pad. In most cases, the feeding area is outside of the main woodchip pad; however, feed may also be supplied within the pad area. Diet is likely to have an impact because of the effect on dry matter content of the dung and, also, on the volume and N content of the urine produced. There is much anecdotal information on pad failure because of a rapid accumulation of slurry; however, few controlled monitoring data are available. It is generally recognised that, in freezing weather, use of the pad must be discontinued as the drainage and movement of dung and urine through the woodchip is impeded. The removal of “exhausted” (i.e. dirty, degraded) woodchip may sometimes be necessary.

To date, there are few data on the nutrient value of either of the woodchip pad by-products, spent timber residue (STR) and OWP effluent. Augustenborg (2007) found the effluent a very effective source of N for grassland production, with a high efficiency (74 to 90%) relative to inorganic nitrogen fertilizer, reflecting the high  $\text{NH}_4\text{-N}$  content and low solids content of the effluent. It is clear from the variable nature of the effluent that analysis data is necessary to give confidence in its N contribution.

Spent timber residues have been shown to contain significant nutrient content, not dissimilar to the levels in FYM and can be recycled back to land to utilise these nutrients. However, more information is needed on the nutrient value of the STR and on optimum application rates and timings; in particular, in relation to application to grassland, where large chips may persist in the sward, causing shading and smothering, with potential impacts on grass response and silage quality.

Very few data are available on the impact of woodchip pads or other out-wintering systems on gaseous emissions. It seems that research data are also lacking regarding the wider environmental impact of overwintering cattle by different methods; e.g. to compare conventional housing (straw yards, cubicles, slats) with out-wintering on woodchip pads and on suitable free-draining land. Further work should include gaseous emissions (nitrous oxide, methane and ammonia) and the potential for nitrate leaching at the whole farm system level.

Though few data of this type were included within this review, many studies have shown that out-wintering of animals on woodchip pads does not appear to compromise animal performance, or animal health and welfare, assuming good management. Detailed information on the costs of construction and management were also lacking in this review, but would be an essential component of any guidelines provided for farmers on the construction and management of woodchip pads.

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# 1. Introduction

The requirement to minimise pasture damage due to animal treading has increased the demand for cheap winter housing systems for cattle and sheep particularly with reference to Cross Compliance requirements for the Single (Farm) Payment Scheme. A solution, which is gaining popularity across the British Isles, and already well established in New Zealand and Ireland, is to use open enclosures with a free-draining woodchip base, otherwise known also as stand-off pads or woodchip corrals. Similar facilities in New Zealand also involve a concrete or crushed limestone floor construction, which increases the costs without the advantages for the welfare and the health of the animals provided by the soft and well-drained surface.

The following definitions now appear to be generally accepted:

- (i) a “stand-off” pad or out-wintering pad (OWP) is a woodchip pad overlying an impermeable subsoil or lining, with drainage pipes delivering effluent to a tank or store;
- (ii) a “corral” is a woodchip pad overlying freely draining soil and with no impermeable lining.

“Woodchip pads” are used as a generic term to embrace both corrals and out-wintering, or stand-off pads.

Conventional housing is expensive and may be prohibitively so, particularly for beef cattle. This has probably been the main driver for the interest in woodchip corrals for out-wintering livestock, although there appear also to be animal health, welfare and production benefits. The Nix Farm Management Pocketbook (2008) quotes covered strawed yard cattle housing (allowing 4m<sup>2</sup> per animal) at £620 per head. The price of a slatted floor building for 120 growing cattle (1.7 m<sup>2</sup> per animal) is quoted at £920 per head. This compares to estimates in Scotland for costs of typical woodchip corrals of £187 per cow (Anon., 2007 - SAC TN595), rising to £215 and £515 per cow, respectively, to add a scraped passage and to provide effluent storage. In a scoping study of farm woodchip pads in England and Wales (Smith *et al.*, 2005), farm estimates of construction costs averaged £106/cow overall, with £131/cow for corrals and £82/cow for the stand-off pads. However, in the latter study, own (i.e. farm labour) costs appear to have been undervalued or even forgotten altogether and pad construction costs ranged up to £300/cow in the case of one 200-cow suckler facility built entirely by contractor.

There are estimated to be upwards of 600 woodchip corrals in the UK (Anon., 2007b) with most in Scotland. Smith *et al.* (2005) identified a total of 75 woodchip pads for wintering beef and dairy cattle in England and Wales, with a concentration in the western areas of Devon, Cornwall and Wales. However, a large number of pads were known not to have been identified within this scoping study and, based on June Census 2005 data, a projected estimate of 170 woodchip pads in England was made, of which c.73% were thought to be used by beef cattle (H Hoult, Defra Farming Statistics, personal communication).

However there is concern across the UK and Ireland that farmers may be overlooking the potential adverse effects of these low-cost structures on water pollution risks, as a result of uncontained runoff or drainage to surface and groundwater. Indeed, SEPA have indicated that surface water pollution from woodchip corrals is now being recorded in

Scotland. The effluent draining from corrals has been shown to be highly polluting (CREH, 2005; Vinten *et al.*, 2006), containing high concentrations of ammonium-N, phosphate and faecal micro-organisms. Together with a high Biochemical Oxygen Demand (BOD), the effluent poses a serious risk to the water environment if not contained and collected. The main concerns are:

- Surface water pollution where effluent is allowed to enter drains or run-off directly to watercourses;
- Leachate draining from the base of an unlined corral percolating into vulnerable groundwater;
- Overstocking of the corral leading to overloading with faeces and urine, resulting in increased risk of overflow of contaminated run-off;
- Inadequate storage capacity, insufficient to contain effluent flow following high rainfall events;
- Blockage/sealing of the corral bed or drainage pipes, resulting in a build-up of slurry within the woodchip matrix;
- Uncertainty concerning the disposal or re-cycling of “spent” woodchips.

There are currently no planning regulations or specific guidance in England and Wales relating to pollution control requirements for woodchip pads. However, there are a number of regulatory controls that might be applied, including parts of the Groundwater Regulations which complete the implementation of the EC Groundwater Directive. In addition, given the appropriate circumstances, a Notice may be served under either the Water Resources Act 1991 (Anti-Pollution Works Notices) or the Groundwater Regulations 1998, to prevent pollution of the water environment.

Gaseous emissions also need to be considered including, in particular, ammonia, nitrous oxide and methane. If woodchip OWPs can be considered at least partly analogous to animals at grass, it seems likely that ammonia emissions from “well managed” woodchip pads (i.e. where design and management minimise the risk of overloading or surface blockage with manure) will be rather less than from the alternative accommodation in buildings or concrete yards, which are known to be major sources of emissions from cattle production systems (Misselbrook *et al.*, 2009).

## **2. Technical background**

### **2.1 Design and management**

Woodchip corrals, within the original concept, are open-air and uncovered enclosures, bedded with large woodchips (B. Lowman, SAC, pers. comm; Edwards *et al.*, 2003). The woodchip bed, typically at least 500mm thick, has been claimed by some to work as a biological treatment unit, reducing the pollutant load from the dung and urine passing through the woodchip and before entry into the underlying, freely draining soil or subsoil on which the corrals were originally constructed. However, it has now been widely demonstrated that the leachate draining from woodchip pads is highly polluting and must be properly collected and stored to avoid pollution of ground and surface waters (section 4.1). Subsequently, ‘stand-off pads’ with a ‘higher’ specification design developed, whereby the soil is excavated and the clay subsoil compacted or a plastic liner installed over more permeable subsoils. Typically, perforated drains are installed at approximately

3.5m spacing, covered with up to 25cm of stones and then a variable depth of woodchips. The leachate is collected and stored, thereby preventing direct contamination of surface and groundwater. Work conducted by Teagasc, in Ireland, showed that the leachate draining from experimental pads at Grange Farm Research Centre (Co. Meath, Ireland) had a BOD of around 3500-9900 mg/l (French and Hickey, 2003).

According to the original concept, many of the chemical and microbial pollutants in the leachate are biodegraded within the woodchip, with nutrients in the leachate claimed to be retained by the woodchips. The high organic carbon content of the woodchip bed might be expected to retard (sorb) organic pollutants and decrease their downward movement. Originally, it was suggested that the woodchip bed works as a "digestion unit" similar to a septic tank. As the dung and urine washed through the woodchips it was claimed that 'digestion' of pollutants by microbes would occur so that relatively clean water would enter the subsoil. Moreover, the proposed breakdown of the dung implied that minimal cleaning of the bed would be required, with a simple top-up of 50-75mm of fresh woodchips, each autumn, possibly all that might be necessary (Thomas, 2001). The New Zealand and Irish systems are known to require periodic removal of exhausted or heavily soiled woodchips, which are composted prior to land spreading.

According to former Scottish guidelines (Anon, 2004b; [www.drenagh.co.uk/indexc.htm](http://www.drenagh.co.uk/indexc.htm)) a rather simpler design could be adopted, in which the topsoil only is removed and about 8 cm of woodchip are spread without any drainage. The frequently reported (farming press) belief was that "...the woodchip corral acts as a filtration unit with processes similar to those occurring within sewage treatment works: the dung & urine are washed through the chips by rainfall, and are broken down....." (paraphrased from Farmers Weekly, "Wood chip corrals are Winter Winner", 1<sup>st</sup> December 2000, p 50).

Calculating the likely average input of dung and urine generated by the number of cows using the pad indicates the weak rationale of these assumptions. In order to limit the excretal load on the woodchip pad, it is also recommended that the feeding area be set outside the pad, on concrete, from where the slurry may be removed by scraping. In fact, a review on the woodchip corral system in Scotland (Edwards *et al.*, 2003) reported that the maintenance of good drainage, which avoids the accumulation of slurry and 'waterlogging', is a primary requirement of the "successful" pad. It is generally regarded that drainage and drainage maintenance are an essential part of good design and management.

## 2.2 Woodchip properties and uses

The rationale for the use of woodchip is based not only the relatively low cost, but also, the soft bedding created by the material compared with the alternatives of stone or concrete floor with straw. Also, wood chips have well-known water absorptive capacity, which helps to keep the surface dry. Woodchip can hold as much as 200 –300 % of its weight in water, depending on the kind of timber used, its moisture content and chip size, the smaller sizes imparting higher specific surface and higher water holding capacity (Aaron, 1964; Haataja *et al.*, 1989). The ideal size and wood source to be used, either in outdoor or indoor bedding is yet to be defined. McLean and Wildig (2000) noted that smaller chip size and uniform grading had a significant impact on costs. The size should take account of the demand for a well-drained, aerobic environment (improving with increased chip size) and the increased absorptive capacity favoured by increased

surface area:volume ratio. The quality of wood should assure the best support and condition for the biological activity and effluent treatment. Efficient breakdown of effluent via any biological activity has yet to be demonstrated.

The idea that woodchip could act as a medium for the “digestion” of organic wastes may, in part, be related to compost technology, where wood chips may be added according to a ratio 2:1; or even 1:1, to raw sludge from a water treatment plant. In this case, the woodchip acts as a bulking agent that helps to maintain porosity and aerobic condition within the composting process. During the composting the woodchip itself degrades partially, together with the sludge. However, this is an active process where high temperature (over 60° C at least) is reached within the compost matrix, sufficient to ensure pathogen destruction and organic matter decomposition (Winter *et al.*, 2003). These conditions are far from those likely within a woodchip corral where it is commonplace that the surface freezes during cold winter conditions.

Woodchip has also been used as an absorbent in rural toilets (La Chapelle and Clark, 2002), but in this situation, further composting occurs and the effluent is treated separately in a septic tank. Where the woodchip is used for animal bedding in indoor systems the soiled bedding is normally composted before spreading (French and Hickey, 2001). However, no “composting” process can be expected if the woodchip is left in place year after year, as is common in many corral systems.

The idea that the woodchip corral could perform as a “digestive” unit relies also on the potential for woodchips to act as a good substrate for bacterial growth. This has potential practical application in bio-filter air scrubbers, which operate at temperatures and moisture status close to those likely to occur within the surface layers of a woodchip pad. Such filter media have been constructed in the past of “brushwood” or inert, corrugated plastic, for the treatment of piggery effluent (ADAS, 1974). Woodchip material has been used in the US as an experimental system for the filtration of drainage water rich in nitrate from agricultural fields (Moorman *et al.*, 2003). However, in contrast to this latter example, the drainage from woodchip pads will not only be rich in nitrate and other nutrients, but also in organic matter and, possibly, pathogens. Hence, only an active process such as composting at elevated temperatures might be expected to provide significant treatment for such a range of contaminants.

Of relevance to the development of woodchip pads is the use of woodchip as livestock bedding in housing systems. Several workers confirm the preference of cattle for woodchip bedding over concrete and even straw (Gregory and Taylor, 2002; Mills *et al.*, 2000). The woodchip is cleaned out and composted in a similar way as is the case for straw. Optimal temperature is not always achieved during the composting process (Airaksinen *et al.*, 2001) and generally the end result was low in “available” nitrogen components (Sommerfeldt and Mackay, 1987; Sommer and Dahl, 1999). In fact, the ideal ratio C/N for composting is 15-30, but the high C content of timber makes this ratio in woodchip compost difficult to achieve. It seems that if composting of woodchip mixes is difficult to achieve under favourable conditions, useful biological activity (digestion) would appear much less likely within the undisturbed, increasingly wet mass of a woodchip corral during the winter months.



### 2.3 Management of livestock

Stocking rates should always be in proportion to the available space and, as a minimum, there should be at least of 3.5 m<sup>2</sup> per cow to allow adequate lying space. However, because of manure loading considerations, it is clear that significantly greater than the minimum requirements will be necessary, dependent also on the daily intensity of pad use (duration on pad) and the length of time the animals will be kept on the pad. At the more intensive level of use, the herd may stay on the pad around 20 hours daily and for up to 5 months per year, in the case of complete overwinter use. It is also generally recognised that, in freezing weather, use of the pad must be discontinued as the drainage and movement of dung and urine through the woodchip is impeded.

*Figure 1. Feeding practices on woodchip pads: (a) dairy cattle on pad with feed passage; (b) self-feed silage on wood chip pad (Teagasc, Moorepark).*

(a)



(b)



Feeding is the major management input into woodchip pads. In most situations, the feeding area is outside of the main woodchip pad area (Figure 1a). However, in specific cases, feeding may sometimes be achieved within the woodchip pad area (Figure 1b). The removal of “exhausted” (i.e. dirty, degraded) woodchip may also sometimes be necessary. Diet is likely to have an impact on the system because of the effect on dry matter content of the dung and, more importantly, on the volume and N content of the urine produced. Another option which has appeared in New Zealand is a temporary or partial cover which will limit the input of rainwater on the pad; or animals may have access to a woodchip pad from within conventional housing.

The management of the pad is likely to greatly impact on the viability and operation of the system and its efficiency, but few controlled monitoring data are available. Much anecdotal information is available on woodchip pads failing because of a rapid accumulation of slurry; Edwards *et al.* (2003) report cases of woodchip corrals waterlogged after 1 year. However, reference has also been made to corrals in operation after 15 years in Scotland (Thomas, 2001).

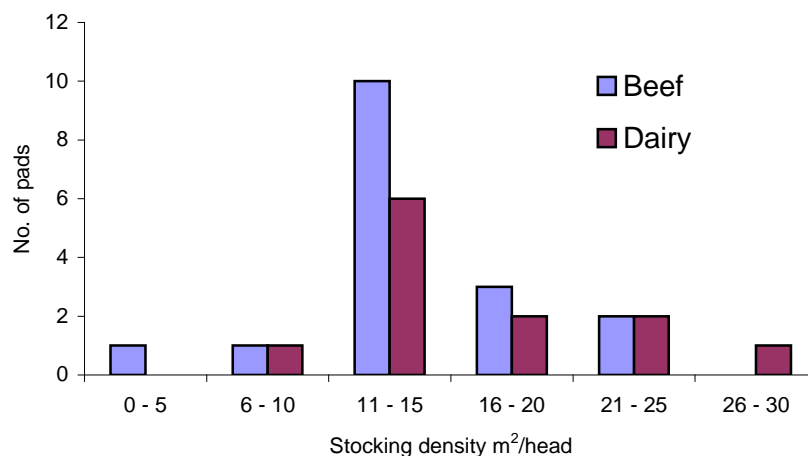
### 3. Woodchip pad performance

#### 3.1 On farm observations

A recent scoping study on woodchip pads in England and Wales found that the average pad area on farms was around 1500 m<sup>2</sup>, overall, with “hotspot” areas (where dung solids are concentrated) noted on about half of these, of typically c.70 m<sup>2</sup> (Smith *et al.*, 2005). Equivalent averages were 1320 m<sup>2</sup> total area and 105 m<sup>2</sup>, for corrals and 1690 m<sup>2</sup> total area and 40 m<sup>2</sup>, for stand-off pads. From farmer comments, these “hotspots” are often related to the presence of trees or other shelter features; or, in other cases, to feed areas with restricted access or with concrete pads without adequate slurry management features. In the latter case, it is important to have a retaining lip or kerbstone to the concrete pad that will allow slurry to be scraped away rather than allowed to drain onto the woodchip bed; in some cases slurry draining from the concrete onto the woodchip has resulted in severe problems with animals sinking in deep slurry accumulation where the capacity of the pad has been exceeded.

Stocking density on pads in the above scoping study varied widely according to the period of accommodation, daily duration on the pad and the feeding arrangements, averaging 16.5m<sup>2</sup>/cow for corrals and 14.4m<sup>2</sup>/cow for stand-off pads. Grouping the pads according to stock type produced no clear trend, with 15.6m<sup>2</sup>/head for beef production and 16.1m<sup>2</sup>/head for dairy units (Figure 2).

Figure 2. Stocking densities recorded on woodchip pads with dairy and beef cattle



The size of the woodchip bedding material appears to be of significance, both in terms of animal welfare and the movement of animal excreta through the bed. Chip size clearly has impact on animal comfort and potential for foot disorders. Smaller size will promote animal comfort, but may result in surface sealing, blockages, dirty animals and, ultimately, in failure of the pad. Anecdotal evidence and specific problems recorded on some of the pads, suggested that woodchip dimensions may be of critical importance. The treading action of animal hooves and the volume and distribution of rainfall are likely to influence the movement of dung solids through the woodchip, although conclusive assessment data are lacking.

### 3.2 Animal health and welfare

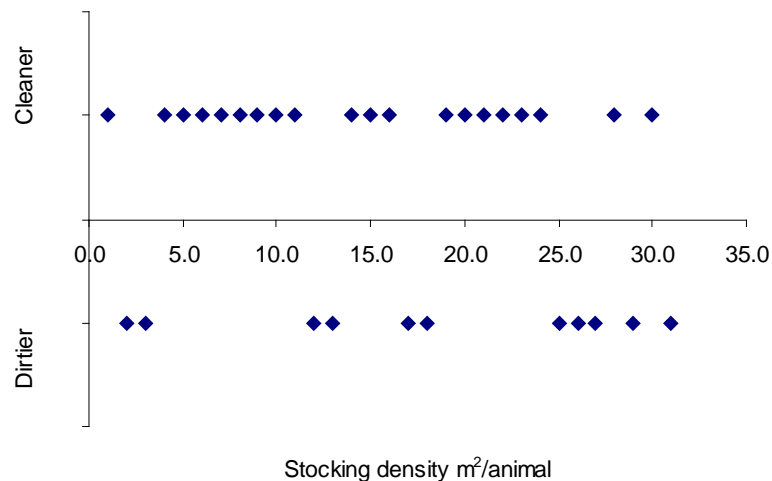
Combined with the economic advantages, the popularity of the woodchip pad is due to the perception of improved health and comfort associated with overwintering animals on a soft, dry wood surface. Information on the extent of these benefits to cattle is readily available in a number of publications, including the scientific literature. The improved conditions on the woodchip encourage cleanliness and comfort and cattle have been shown to spend more time lying down. For example in studies in the Waikato, New Zealand, dairy cows spent longer ( $P < 0.05$ ) lying on woodchips (11.3 hrs) than on concrete (2.4 hrs) or on farm races (4.1hrs) (Stewart *et al.*, 2002). The rapid drainage and cattle treading are thought to keep the surface relatively clean from dung. Therefore foot problems and lameness become rare as, in general, foot disorders are associated with dirty, wet surfaces. However, it has been observed that previously housed cattle, bedded on different material such as straw, do require some time to acclimatise to the woodchip, with the risk of dirtier animals in the initial phase (French and Hickey, 2001; McLean and Wildig, 2000).

Stewart *et al.* (2002) found that, in New Zealand, stand-off pads are often built without the basic welfare provisions of a fresh water supply and shelter to reduce the risk of wind-chill. Whilst a woodchip bed seems to result in a reduction in lameness, on the other hand, mastitis problems may increase due to the increased time spent lying down on sometimes wet, soiled pads. Overall, woodchip pads are accepted as the best option in terms of animal health and welfare among the range of different accommodation, but only when well managed, which means well drained and with periodic renewal of the soiled woodchip surface.

No observations are reported on ewes, however indoor tests on woodchip bedding show that the cleaner surface reduces the risk of infection to new-born lambs, however the sheep were sensitive to feet bruising from irregular sharp chips (McLean and Wildig, 2000).

Anecdotal evidence from farmers also supports woodchip pads as offering a healthier option for overwintering than conventional housing, both for dairy and beef cattle (Anon, 2007b) (Winter Management Options, CSWMO 6.1 and 6.2). The survey carried out by Smith *et al.* (2005) found that the great majority of farms (27 out of 31) reported that cattle, according to the assessment of the stockman, appeared more content on the pads than in alternative accommodation (i.e. generally in buildings with straw yards or cubicles or, possibly, on pasture). Also, in the greater proportion of farms (20 out of 31), cattle were reported to be cleaner on the pads. The incidence of clean/dirty animals might be expected to be, at least partly, related to stocking density on the pads. However, scrutiny of these observations indicated no such trend (Figure 3), suggesting, therefore, that other factors are also likely to be important. Dairy cattle were often noted to be 'dirtier', which would be of concern in relation to the risk of mastitis, but there appeared to be greater interest in the use of the pads for the dry cows only.

Figure 3. Stocking density on woodchip pads and animal cleanliness (Smith *et al*, 2005)



Boyle *et al.* (2005) reported results from a study involving overwintering of 66 spring calving heifers in one of three systems, namely;

- (i) conventional cubicle house;
- (ii) cubicle house with cushioned flooring covering passageway slats (slat mats), and
- (iii) woodchip out-wintering pad.

Behaviour, health and performance indicators were measured on all animals while pregnant, from housing in November 2003 until calving in January 2004. Additionally, data were collected on the first 15 animals to calve in each treatment for the first four weeks of lactation in the spring. They reported that both groups indoors differed greatly from the outdoor heifers in several respects. The outdoor cows had healthier feet and were less affected by injuries to the limbs. They also showed more diverse behaviour and slipped and tripped less. However, their welfare was adversely affected by inclement weather conditions, with indications of immuno-suppression, combined with a reduction in average daily liveweight gain being recorded. Furthermore, they were dirtier and spent less time lying down. None of these factors influenced milk yield, quality or composition in early lactation. The authors considered that the welfare problems associated with the pad were weather and management dependent. Hence, the problems could be addressed by more frequent cleaning of the pad and/or an increase in space allowance, combined with the provision of shelter. Hence, the potential for good welfare in dairy heifers was considered higher on the pad than indoors in a cubicle system.

O'Driscoll *et al.* (2007) compared locomotion, hoof health, and lameness of dairy cows confined in either indoor housing with cubicles or 1 of 3 out-wintering pad (OWP) designs. Treatments were as follows:

- (i) housing with cubicles bedded with rubber mats;
- (ii) out-wintering on uncovered OWP with a concrete feed apron;
- (iii) out-wintering on covered OWP with a concrete feed apron;

(iv) out-wintering on uncovered OWP with access to self-feed silage.

Cows were assigned to a treatment at drying off and remained on treatment until calving, when they were turned out to pasture. Sole lesions, heel erosion, dermatitis and claw hardness on both hind feet were scored according to severity at assignment to treatment, at calving, and 9 and 14 weeks postpartum. Locomotion score was recorded weekly after calving for 14 weeks. Incidence of clinical lameness was recorded during the treatment period and in the subsequent lactation. Overall, the results indicated that the use of OWP as a winter confinement system for dairy cows in late pregnancy does not pose a significant threat to hoof health when managed at a stocking density of 12 m<sup>2</sup>/head. The group in the covered OWP had harder hooves, which may be important in reducing the development of sole lesions after calving. However an OWP with a feeding area that cannot be cleaned needs to be carefully managed. This is to ensure that animals are not exposed to excessive amounts of wet manure, which has negative implications for dermatitis and heel erosion.

### 3.3 Livestock production

In addition to the claimed reductions in construction and maintenance costs, woodchip pads appear to bring livestock production benefits. Research in Ireland has shown that accommodation on woodchip pads improves daily liveweight gain and feed conversion in cattle (Table 1) and decreases fat deposition.

*Table 1. Effect of wintering system on finishing cattle performance*

	OWP <sup>1</sup>	OWP + slats <sup>2</sup>	Slats	Straw
Space allowance (m <sup>2</sup> /head)	18.0	17.5	2.5	4.0
Feed intake (kg DM/day)	10.88	10.58	9.50	9.79
Liveweight gain (kg/day)	1.40	1.33	1.01	1.10
Feed conversion (kg DM/kg LW)	7.77	7.95	9.41	8.90

<sup>1</sup> OWP – out-wintering pad;

<sup>2</sup> Slats at 2.5 m<sup>2</sup>/cow with free access to OWP at 15 m<sup>2</sup>/cow;

Source: P. French, TEAGASC, Moorepark Research Centre, Fermoy.

At Teagasc, Moorepark, four winter accommodation systems were compared for spring calving dairy cows over winters 2005 and 2006 (French and Boyle, 2007):

(i) Conventional cubicle housing;

(ii) uncovered OWP with space allowance of 12m<sup>2</sup>/cow and an easi-feed silage system;

(iii) uncovered OWP with a space allowance of 16m<sup>2</sup>/cow and self-feed silage on OWP;

(iv) OWP with space allowance of 6m<sup>2</sup>/cow, with a windbreak and plastic cover overhead.

The cows on the self-feed silage pad had poorer condition score in the first winter, probably due to poorer silage quality. However, there was no negative impact on subsequent milk production. The cows on the outdoor pads had approximately 4% higher milk solid yield in the subsequent lactations in both years, but this was not statistically significant. The cows on the pads had significantly heavier calves than the cows accommodated indoors in both years even though the gestation period was similar,

as was the incidence of calving difficulty. There was no negative impact of wintering cows on pads on cow welfare and some minor improvements in welfare traits, such as hoof and limb condition at calving and behaviour during the dry period, were observed.

Animal performance on woodchip has also been studied in recent research at Trévarex Experimental Farm (Institute de l'Elevage), Brittany, France. In January 2006, Trévarex constructed two out-wintering pads for 30 cows, with advice on pad design provided by Teagasc. Animals on the woodchip pads were compared to a control group housed in stalls or cubicles or on straw. Observations over a three year period included udder health (mastitis), quality of milk, well-being of the animals, performance of the pads, maintenance of litter (spent chip and straw) and manure management (Table 2).

*Table 2. Diary of trials at the out-wintering pads at Trevarez.*

Periods	Start Nov 2006	End Jan 07	Early 2007	Early 2008	End 2008 Early 2009
<b>Type of animal</b>	Dairy cow early lactation	Dairy cow late lactation	Dry cows + Heifers late lactation	Dry cows + Heifers	Heifers
<b>Pads Bedding</b>	60 cm woodchip	50 cm woodchip + layer of straw		20 cm of woodchip + layer of straw	
<b>No. of Animals</b>		25 to 30		15	22
<b>Performance</b>	Bad		Good	Good	?

In the first year, regular additions of woodchip were found to be necessary; initially once per week (12 kg/m<sup>2</sup>/week), then increasing to twice per week. The woodchip appeared to provide comfortable bedding for the animals. However, there was a problem with waterlogging of the woodchip bed in December 2006 – January 2007 following a period of very heavy rainfall. Animal and udder cleanliness was found to be a significant problem during this very wet weather. Further disadvantages of woodchip as a bedding material were noted by researchers at Trévarex, including increased cost compared to straw, and difficulties in applying additional woodchip to the pad with conventional machinery. As it was necessary to drive onto the woodchip pad to apply additional woodchip, the authors of this review, consider it possible that damage to the drainage system may have occurred. It should be noted that such waterlogging of woodchip pads in the UK has not been a problem where an effective drainage system is in place.

Due to the problems associated with the woodchip bedding in the first year, in the second year a 50 cm depth of woodchip was covered with a layer of straw, and in the third year a 20 cm depth of woodchip was covered with a layer of straw, with straw additions typically 3 times per week (5 kg/m<sup>2</sup>/week). The use of straw bedding for the surface of the pad was preferred because by the researchers at Trévarex because;

- (i) straw is a cheaper bedding material than woodchip
- (ii) familiarity in the use of straw bedding
- (iii) straw additions can be easily increased during periods of wet weather, to maintain a clean dry surface for the animals.

## 4. Environmental impact

The out-wintering pad (OWP) system provides both potential environmental hazards and benefits. By retaining stock in a confined area, the OWP helps to reduce the risk of over-grazing and of treading damage on the pasture, thereby reducing the risk of nutrient loss by surface run-off and of soil erosion. However, this also creates a concentrated source of animal manure nutrients, which requires careful management in order to avoid uncontrolled dispersion of pollutants into the soil, ground and surface waters and, also, of gaseous emissions to the atmosphere.

Increased risks of water pollution are to be expected from systems without controlled drainage or subsoil sealing, even if located at what appear to be safe distances from water sources. Pads located close to farm buildings can represent a particularly serious risk, where contaminants may have direct access to drinking water drawn from shallow wells. The effluent from woodchip pads may have high BOD, close to the levels found in effluent from slurry stores (see below); and the concentration of nutrients, especially P makes the leachate a serious concern if allowed to escape to the aquatic environment (Edwards *et al.*, 2001).

### 4.1 Effluent quality

Scientific information is needed on nutrient fluxes within and from the woodchip layer, as well as concerning the likely microbiological processes involved in any activity within the woodchip bed. The addition of animal excreta is a potential source of pathogens and the woodchip may contain chemical pollutants derived from timber treatment, e.g. Pentachlorophenol (PCP) (Buttler *et al.*, 1991), if the woodchip is derived from recycled sources, e.g. building materials. Recent studies have confirmed the high pollutant potential of woodchip pad effluent.

In a field trial to evaluate the polluting potential from woodchip corrals to ground and surface waters, new corrals were constructed on a freely draining loamy sand overlying sand soil near Stranraer, Dumfries and Galloway, Scotland (Vinten *et al.*, 2006). These corrals also included lined drains to collect leachate from the woodchips.

The main trial consisted of two new corrals with a nominal stocking density of one animal per 15 m<sup>2</sup> (maximum normally recommended by SAC). One of these had 20 cm depth of woodchips and the other had 40 cm. Each of these corrals had alternating 9–10 m strips of (i) normal size chips (mainly 7–10 cm diameter, 10–12 cm length, with some smaller material); (ii) normal size chips that had been screened to remove material which passed through a 7.5 cm mesh. A lined drain was installed below each of the strips. The cattle were fed on hardstanding areas to the side of the woodchips and slurry accumulating in these areas was scraped into earth-lined lagoons.

To investigate the potential of including soil inside a lined system to ameliorate leachate water pollution, two lined drainage runs had 30 cm of top or subsoil above the pipe, inside the plastic liner. Another newly built corral had 20 cm depth of screenings (small chips passing through a 7.5 cm mesh). This was expected to filter the excreta more effectively, but also to suffer from clogging and a need for more frequent replacement of chips. It was stocked at lower density (nominal 20 m<sup>2</sup>/animal) to counteract the expected rapid clogging. The 'whole corral' in Table 3 was an existing corral with old chips

replaced by new, normal sized woodchips. These were underlain by unlined herringbone drainage systems installed in autumn 2003. Stocking on the new corrals was from February 2004 with pregnant cows and then stores, until May 2004. The 'whole corrals' were restocked from December 2003, after replacement of spent chips. These had been previously stocked for about 18 months.

There were no statistically significant effects of woodchip size or depth on ammonium-N ( $\text{NH}_4\text{-N}$ ) levels in the leachate. Medium chips gave a lower level but this corral also had a lower stocking intensity. Top or subsoil over the drains also reduced  $\text{NH}_4\text{-N}$  levels, as would be expected. Nitrate-N ( $\text{NO}_3\text{-N}$ ) levels were highest where drainage had passed through top or subsoil. Dissolved organic carbon levels closely followed those for  $\text{NH}_4\text{-N}$ . The lowest electrical conductivity (EC) values were for drainage from pipes overlain by top or subsoil; overall, the drainage EC values suggesting a three to four fold dilution compared to slurry.

*Table 3. Average nutrient, dissolved organic carbon (DOC), suspended solids (SS), electrical conductivity (EC), E. coli and Faecal enterococci levels in drainage from the corrals (Vinten et al 2006).*

Corral	$\text{NH}_4\text{-N}$	$\text{NO}_3\text{-N}$	DOC	SS	EC	E. coli	Faecal Enterococci
	mg/l				d/S	cfu/100ml	
Large chips – 40cm deep	1036	4	871	12800	12.1	1.E+055	1.E+023
Large screened chips – 40cm deep	838	12	726	1200	14.4	1.E+049	1.E+023
Large chips – 20cm deep	926	5	735	9800	13.9	1.E+059	1.E+031
Large screened chips – 20cm deep	1059	3	1088	1200	15.7	1.E+059	1.E+027
Large chips – 30cm deep & 30cm subsoil	132	52	121	3	5.4	1.E+020	1.E+006
Large screened chips – 30cm deep & 30cm topsoil	243	14	97	229	6.8	1.E+035	1.E+002
Medium chips – 20cm deep	441	12	339	6500	9.6	1.E+057	1.E+024
Whole corral	485	11	483	370	8.4	1.E+059	1.E+024

The suspended solids (SS) content in water draining from screened chips was lower than from unscreened chips. The screened chips received much less faecal deposition, because the animals did not like to stand on these chips. Once a layer of dung had developed on the chips, this dislike faded. The SS concentrations in the drains overlain by 30 cm top or subsoil were much lower than those draining the woodchips directly, showing effective filtration by the soil. The SS content in effluent from the whole corral was also lower. The SS concentration from the medium-sized woodchips was less than from the unscreened woodchips. The stocking intensity was lower on the medium-sized woodchips at 20 m<sup>2</sup>/animal, compared to 5 m<sup>2</sup>/animal for the large chips. E. coli and



faecal enterococci counts were lower for water draining through 30 cm of underlying top or subsoil rather than directly from the woodchips.

Nitrate leaching from the corrals was estimated from deep soil core data. Sampling depth varied from 210 to 300 cm depending on corral. Nitrate leached (kg/ha  $\text{NO}_3\text{-N}$ ) over the 39–55 day period prior to sampling was calculated. The highest  $\text{NO}_3\text{-N}$  leaching losses were from the whole corral sampled on 5 May ( $566 \pm 216$  kg/ha  $\text{NO}_3\text{-N}$ ; mean  $\text{NO}_3\text{-N}$  content of core soil samples  $404 \pm 54$  mg/l). The other corral samples showed smaller mean losses (159–392 kg /ha  $\text{NO}_3\text{-N}$ , mean  $\text{NO}_3\text{-N}$  content of core soil samples  $114 \pm 52$  to  $174 \pm 44$  mg/l). However, the coefficients of variation were very high (45–134%) and these differences were not statistically significant. The nitrate leaching from “background” observations, reflecting overwintering at pasture at an estimated stocking density of 10–20% of that used on the corrals, was  $190 \pm 48$  kg/ha  $\text{NO}_3$ , with mean soil  $\text{NO}_3\text{-N}$  content  $59 \pm 15$  mg/l. The mean  $\text{NO}_3\text{-N}$  under the permanent feeding area (47 mg/l) was smaller than under the corrals but the  $[\text{NH}_4\text{-N}]$  was greater. It was considered by the authors that these figures suggested that the nitrate leaching per animal from the corrals was lower than from overwintering on grass fields.

In further Scottish studies carried out between autumn 2003 and September 2004, four woodchip corrals of varying characteristics were instrumented to capture, quantify and model the drainage at the base of the corral, where pollutant fluxes may move either vertically to the groundwater environment, or laterally to an adjacent water course (CREH, 2005). To partially capture geographical diversity, paired sites were located in NE and SW Scotland. Some corral details are given in Table 4; the corrals represented both established sites and new build and ranged in stocking density from 8.7 to 23.3  $\text{m}^2/\text{animal}$  and, in chip depth, from 0.3 m to 0.9 m. Flow was measured through tipping buckets and loggers designed to accommodate the topography of each corral. Samples were collected for chemical and bacterial analysis. The results for the entire sampling period, representing both the periods when the corrals were stocked and de-stocked, indicated arithmetic means for total N concentration of 337.1 mg/l (of which about 56% was  $\text{NH}_4\text{-N}$ ) and for total phosphorus (P) of 94.7 mg/l (of which about 53% phosphate-P) in the drainage water. The levels for stocked and de-stocked periods are shown in Table 5.

Table 4. Site information and mean flow rates, total nitrogen, phosphorus and dissolved organic carbon levels in the liquor and mean hourly outputs

	Units	SW 1	SW 2	NE 1	NE 2
<b>Corral area</b>	m <sup>2</sup>	1282	1300	1846	370
<b>Woodchip depth</b>	m	0.6	0.6	0.9	0.3
<b>Corral age</b>		Established	New build	Established	Re-build
<b>Cattle type</b>		Beef suckler cows	Beef suckler cows	Beef suckler cows	< 1 year old
<b>Stocking density</b>	Head/1000m <sup>2</sup>	115	115	65	43
<b>Cattle on corral</b>		Nov 03 – Apr 04	Nov 03 – Apr 04	Nov 03 – Apr 04	Dec 03 – May 04
<b>Rainfall</b>	mm	732.6	733.4	565.8	587.0
<b>Flow rate</b>					
Cattle on	l/hr/m <sup>2</sup>	0.20	0.20	0.21	0.05
Cattle off	l/hr/m <sup>2</sup>	0.15	0.13	0.05	0.04
<b>Nutrient concentrations:</b>					
<b>Nitrogen - total</b>					
Cattle on	mg/l	584.7	532.5	213.6	589.1
Cattle off	mg/l	263.3	177.5	38.42	99.2
<b>Phosphorus - total</b>					
Cattle on	mg/l	246.9	89.1	37.9	76.3
Cattle off	mg/l	62.4	85.3	90.2	80.9
<b>Dissolved organic carbon</b>					
Cattle on	g/l	4.31	3.82	1.58	2.56
Cattle off	g/l	1.99	1.76	0.88	1.31
<b>Nutrient losses:</b>					
<b>Whole corral</b>					
<b>N-total</b>					
Cattle on	g/hr	147.0	128.3	47.5	3.93
Cattle off	g/hr	25.4	15.3	5.34	0.65
<b>P-total</b>					
Cattle on	g/hr	26.0	24.4	6.89	0.84
Cattle off	g/hr	14.1	7.15	6.40	1.05
<b>DOC</b>					
Cattle on	g/hr	1207.1	1088.7	330.7	34.9
Cattle off	g/hr	212.0	219.5	85.7	12.2
<b>Per m<sup>2</sup> of corral</b>					
<b>N-total</b>					
Cattle on	mg/hr/m <sup>2</sup>	114.7	98.7	25.7	10.6
Cattle off	g/hr/m <sup>2</sup>	19.78	11.75	2.89	1.76
<b>P-total</b>					
Cattle on	mg/hr/m <sup>2</sup>	20.3	18.7	3.7	2.3
Cattle off	mg/hr/m <sup>2</sup>	10.97	5.50	3.46	2.85
<b>DOC</b>					
Cattle on	mg/hr/m <sup>2</sup>	941.6	837.5	179.2	94.2
Cattle off	mg/hr/m <sup>2</sup>	165.4	168.8	46.4	33.3

*Table 5. Total nitrogen and phosphorus and dissolved organic carbon levels in drainage water for corral stocked and de-stocked periods (mean all corrals)*

Corral	Total nitrogen mg/l		Total phosphorus mg/l		Dissolved organic carbon mg/l	
	Range	Mean	Range	Mean	Range	Mean
<b>Stocked</b>	213.6-589.1	479.0	37.9-246.9	112.5	1578.4-4312.3	3065.5
<b>De-stocked</b>	38.4-263.3	144.6	62.4-90.2	79.7	875.8-1987.0	1477.6

The geometric mean concentrations of total coliform (TC), E. coli (EC) and intestinal enterococci were 95,461, 94,983 and 55,552 cfu/100ml, respectively. Significant flows of liquor (>1 l/hr from the sampled area) occurred at the base of the corrals on most assessment days. Table 4 summarises site information and key results, including, total N, P and dissolved organic carbon (DOC) levels in the liquor and the mean hourly effluent outputs per m<sup>2</sup> and per corral.

Not surprisingly, the total nutrient load arising from the corral base was related to rainfall, corral size and stocking density. However the 'absolute' concentration of nutrients can be higher in the liquor from a lower stocking intensity, depending on other factors. The concentrations were lower from the corral with a stocking density of 65 beef suckler cows per 1000m<sup>2</sup> than from the one with a stocking intensity of 43 <1 year old animals per 1000m<sup>2</sup>. In this case, the depth of woodchip is likely to have been important; 0.9m for the higher stocking density and 0.3m for the lower density.

In Tables 6 and 7 the CREH data and results on effluent flow and nutrient content have been used to estimate percent of N and P input in cattle excreta passing through in the drainage. These figures are dependent upon a number of assumptions about the total N and P content of cattle excreta, the actual number of days "on" and "off" the pads and the liquor flow rates applied; at this stage, they must be seen only as rough estimates for discussion. The estimates assume pad occupancy of 180 days "cattle on" (Nov-Apr) and 150 days off "cattle off" (May-Sept). The percentage losses are largest from the corrals with the highest stocking densities (SW 1 & SW 2); and, comparing the two corrals with the lowest stocking (NE 1 & NE 2) density, higher losses are estimated on the shallow chip depth (0.3m rather than 0.9m). For comparison, the losses of N and P in the liquor from the two highest stocking density (SW 1 & SW 2) corrals are not dissimilar from estimates of N and P draining from weeping wall slurry stores, which were reported at c.20-25% and c.15% of N and P inputs, respectively (Smith, 2005).

Table 6. Estimate of total nitrogen inputs and losses from corrals

	SW 1	SW 2	NE 1	NE 2
<b>Losses kg total N</b>				
<b>Nov 03 – Apr 04*</b>	635.0	554.3	205.2	17.0
<b>May 04 – Sept 04**</b>	91.4	55.1	19.2	1.87
<b>Nov 03 – Sept 04</b>	726.4	609.4	224.4	18.9
<b>Input***</b>				
<b>Nov 03 – Apr 04</b>	6040.5	6126.5	4917.6	270.0
<b>Losses % of input</b>	12.0%	9.9%	4.6%	7.0%

\* For NE 2 Dec 03 – May 04

\*\* For NE 2 June 04 – Sept 04

\*\*\* Based on suckler cows (over 500 kg) excreting 6.83 kg total N per month and cattle under <12 months (3-12 months) excreting 2.83 kg total N per month.

Table 7. Estimate of total phosphorus inputs and losses from corrals

	SW 1	SW 2	NE 1	NE 2
<b>Losses kg total P</b>				
<b>Nov 03 – Apr 04*</b>	112.3	105.2	29.8	3.6
<b>May 04 – Sept 04**</b>	50.6	25.7	23.0	3.0
<b>Nov 03 – Sept 04</b>	162.9	130.9	52.8	6.6
<b>Input***</b>				
<b>Nov 03 – Apr 04</b>	1057.1	1072.1	860.6	47.3
<b>Losses % of input</b>	15.4%	12.2%	6.1%	14.0%

\* For NE 2 Dec 03 – May 04

\*\* For NE 2 June 04 – Sept 04

\*\*\* Based on suckler cows (over 500 kg) excreting 1.20 kg total P per month and cattle under <12 months (3-12 months) excreting 0.50 kg total P per month.

The CREH study also investigated the effects of stocking density and corral woodchip depth on the potential for effluent discharge through a modelling approach. The model was populated with drying and moisture capacity data from laboratory experimentation and with rainfall data from the NE2 site over a 100 day period from the 1st January 2004. A range of corral woodchip depths from 0.3 m to 1.2 m and stocking densities from 43 to 115 head/1000m<sup>2</sup> were run and the total modelled outflow and days of outflow are presented in Tables 8 and 9. The model was run with the assumption that there was maximum moisture capacity at the initial state of each run and an excretal output for cattle of 30 l/day onto the woodchip area. The ranges investigated for stocking density and for corral woodchip depth are within the range typical for Scottish corrals.

Table 8. Effluent outflow (m<sup>3</sup> effluent) for a 1000 m<sup>2</sup> corral for a range of corral depth and stocking densities using 100-day rain data from 1 Jan 2004.

Corral Depth (m)	Stocking density (animals/1000 m <sup>2</sup> )			
	43	65	90	115
<b>0.3</b>	187.9	250.8	325.8	400.8
<b>0.6</b>	71.3	136.8	211.8	286.8
<b>0.9</b>	0.0	25.7	100.0	174.9
<b>1.2</b>	0.0	0.0	0.0	63.4

Table 9. Days of outflow for a 1000 m<sup>2</sup> corral for a range of corral depth and stocking densities using 100 day-rain data from 1 Jan 2004.

Corral Depth (m)	Stocking density (animals/1000 m <sup>2</sup> )			
	43	65	90	115
0.3	94	96	98	98
0.6	24	55	93	93
0.9	0	9	36	89
1.2	0	0	0	26

Luo *et al.* (2006) undertook laboratory experiments using 300mm diameter x 300mm high polythene columns to test the potential of various natural materials for increased retention of N in stand-off pads and, also, for reduction of ammonia (NH<sub>3</sub>) emission. The materials tested were soil, pine bark, woodchips and zeolite. The pine bark, woodchips and zeolite had a particle size range of 4-10mm. Cattle excreta (1:1 ratio of urine and faeces) were applied to the columns every day for 5 weeks at the equivalent of 3.5 l/m<sup>2</sup>. This would be equivalent to the estimated amount excreted by dairy cows over 20 hours at the recommended stocking rate for dairy cows on stand-off pads in New Zealand. During the 5 weeks 403 g N/m<sup>2</sup> were applied. Over 10 weeks each column also received 330mm de-ionized water (about 16.5mm per application). This amount of water was equivalent to the 75th percentile from local records for winter rainfall over the past 10 years.

The effects of the different natural materials in reducing gaseous NH<sub>3</sub> emissions and drainage N losses are also presented in Table 10. For columns containing soil, bark and zeolite, most of the losses occurred when excreta were applied during the initial 5 weeks. Most of the N in drainage from zeolite, pine bark and wood chips was in the NH<sub>4</sub>-N form. Lower (P<0.05) amounts of N were found in the drainage from soil columns. After 10 weeks, cumulative total N drainage losses from the columns were in the following order: soil < zeolite ≤ bark < wood chips. These losses were about 1%, 8%, 9% and 14% of total excreta N applied to the columns containing soil, zeolite, bark and wood chips, respectively. The N losses from the woodchip columns were close to those estimated from the CREH studies on corrals. Chemical analyses of the materials suggested that significant amounts of N, ranging between 66% and 76% of applied excretal N, had accumulated in zeolite, bark and soil. About 35% of applied excretal N accumulated in the wood chips. Most of the N was retained in the top layers (0-75 mm) of all the materials. Luo *et al.* (2006) considered that the retention of N could be attributed to enhanced microbial N immobilisation and/or direct adsorption of ammonium ions (Bolan *et al.* 2004; Luo & Lindsey 2006). Bolan *et al.* (2004) have also demonstrated that treatment of farm effluent with pine bark achieves a considerable reduction in the N concentration, which they attributed to immobilisation of N by the C- rich bark material (C:N ratio = 265:1). Crushed pine bark and zeolite both have large total surface areas and cation exchange capacities (CEC). Ammonium ions in cattle excreta can adsorb onto these surfaces, thereby decreasing the concentration of NH<sub>4</sub> ions in solution and, hence, the quantity of NH<sub>3</sub> at risk of volatilisation. As wood chips generally have a smaller surface area than crushed bark they will have a lower capacity for retention of NH<sub>4</sub> and organic N compounds. Sawdust has similar properties to wood chips, but has a higher surface area. Therefore, sawdust could be another useful material for stand-off pads to reduce N losses. Soils generally have relatively low porosities and are prone to consolidation over time, therefore are less likely to be suitable for use on woodchip pads.

Table 10. Cumulative N losses in  $\text{NH}_3$  emissions, drainage and retained in pad materials ( $\text{g N/m}^2$ ) after total application of  $403 \text{ g excreta N/m}^2$  in the column study (Luo *et al.*, 2006)

	Zeolite	Bark	Soil	Wood chips	LSD <sub>0.05</sub>
<b><math>\text{NH}_3</math>-N emissions</b>	53 (13)	101 (25)	121 (30)	157 (39)	43
<b>Organic N in drainage</b>	6.2 (1.5)	7.9 (2.0)	2.6 (0.6)	11 (2.7)	3.5
<b><math>\text{NH}_4</math>-N in drainage</b>	24 (6.0)	26 (6.5)	1.1 (0.3)	43 (11)	4.6
<b><math>\text{NO}_3</math>-N in drainage</b>	ud <sup>1</sup>	ud	0.3	ud	
<b>Cumulative N in materials</b>	267 (66)	270 (67)	305 (76)	139 (34)	41
<b>Unaccounted for N<sup>2</sup></b>	53 (13)	-1.9 (0)	-27 (-7)	53 (13)	

<sup>1</sup> ud - under detection limits.

<sup>2</sup> Unaccounted for N due to errors of sample collection and analysis; also emissions as  $\text{N}_2$  and  $\text{N}_2\text{O}$ .

( ) numbers in brackets are % of N in applied excreta N.

A field scale study was also carried out with two stand-off pads constructed in May 2005 (Luo *et al.*, 2006). These were each 20m long, 7m wide and 0.9m deep, each with its own drainage system. The pads contained either crushed pine bark (particle size 3-12mm) or sawdust. Each pad was overlain with about 0.1 m depth of coarse bark (particle size 12-25 mm). Pads were used for holding 21 cows for about 18 hours/day during the winter period (31 May to early August) in 2005. Monitoring of pad performance was carried out regularly to determine N retention and N and faecal bacteria export in drainage water.

The results from the field study showed that both bark and sawdust retained a considerable amount of N (Table 11). During the 2005 winter it was estimated that about 170 kg of excreta N was deposited by the cows on each stand-off pad. However, only about 4% (6-6.6 kg N) of the deposited excretal N was collected in the drainage from the pads. Most of the N in the drainage was in the  $\text{NH}_4$ -N form (data not reported in paper). Analyses of both fresh and used materials showed that both sawdust and bark retained about 60% of the deposited excreta N, most of which was recovered from the top layers. Mass balance calculation indicated that about 35% of the deposited excretal N was not accounted for in the pad materials and drainage. Analyses also indicated that both sawdust and bark retained significant amounts of deposited excretal P, K and S (data not reported in paper). In February 2006, 8 months after commencing use of the pads, there was no indication of any breakdown of the sawdust and bark materials within the pads. Thus the results of the field study confirmed the findings from the column study, suggesting that the C-rich materials (bark and sawdust) can be used in stand-off pads for increased retention of N and other nutrients.

Table 11. Nitrogen balance after 21 cows had been held on stand-off pads in the winter (31 May - early Aug 2005) (Luo et al, 2006)

	Amount (kg N)		Recovery (%)	
	Sawdust	Bark	Sawdust	Bark
Deposited excretal N	170	170		
Drainage N	6.0	6.6	4	4
N retained in pad materials	102	103	60	61
Unaccounted for N <sup>1</sup>	62	60	36	35

<sup>1</sup> Unaccounted N was due to gaseous N losses and/or errors of sample collection and analysis.

Drainage from the stand-off pads was tested on a weekly basis for *Escherichia coli* (*E. coli*) and *Campylobacter* levels. More *E. coli* were consistently recovered in the bark pad (total recovered  $3.1 \times 10^{11}$  *E. coli*) drainage than in the sawdust pad (total recovered  $7.5 \times 10^9$  *E. coli*) drainage with the difference statistically significant ( $P < 0.05$ ). For *Campylobacter* the total yield was  $1.1 \times 10^7$  in the bark drainage and  $5.5 \times 10^6$  *Campylobacter* in the sawdust drainage, though the difference was not statistically significant. After the cows were removed from the stand-off pads in August, drainage was collected approximately monthly until November 2005. The total load of *E. coli* in drainage collected after the cows had moved off the pad was  $2.1 \times 10^9$  *E. coli* from the sawdust pad and  $2.9 \times 10^9$  *E. coli* from the bark pad, however, no *Campylobacter* were recovered in the drainage from either pad during this period. It was concluded that stand-off pads efficiently capture a large proportion of faecal bacteria shed by cows, estimated at 99.7% in the sawdust pad and 90.2% in the bark pad. Whilst the pad materials retained large numbers of faecal bacteria, the continued recovery of *E. coli* in drainage liquor demonstrated that these bacteria remained viable for the two and a half month monitoring period after the cows had been removed.

Preliminary leachate analysis data from the Trévarez pads in Brittany, France (out-wintering dairy cattle) indicated very low nutrient concentrations which was, at least partly, a consequence of the very high rainfall during the initial experimental period, diluting the effluent. Leachate from the pad was lower in nutrient concentrations than farm effluent following primary treatment<sup>1</sup>, indicating significant retention of effluent solids and nutrients within the woodchip matrix (Table 12; Sèité and Ménard, 2008). The effluent from the pad was considered a 'low concentrated effluent' which could be treated before being discharged to surface waters.

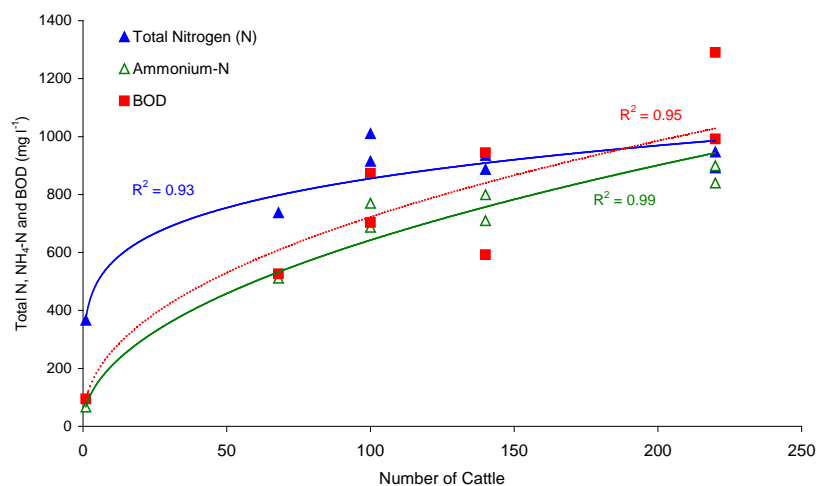
<sup>1</sup> Refers to primary treatment of farm effluent in a 3 stage farm wetland effluent treatment system, after which water is discharged to surface waters.

Table 12. – Results of pad leachate analysis compared to that of livestock manure collected in the lagoon (results all in mg/l).

Parameter	Leachate from pad	Reference values for 'low load effluents' after primary treatment
Suspended Solids	282	933
COD	1489	265
Total Nitrogen	49	254
Ammonium-N	17	170
Phosphorus	35	35
Potassium	50	35

Smith *et al* (2005) monitored effluent nutrient concentrations from a large stand-off pad in Staffordshire holding dry adult dairy cows and young stock, over the January – March 2005 period. A total of 8 weekly samples were collected, starting on 10<sup>th</sup> January and finishing on 11<sup>th</sup> March with the results summarised in Table 13. The winter period was unusually dry, with a total of only 116 mm between 1<sup>st</sup> December and early March. It did not prove possible for any of the samples to be collected during, or soon after, anything more than very light rainfall, but there was always a gentle flow from the drainage outfall to the slurry lagoon. In this study, there was no obvious relation between rainfall and effluent concentration, which was probably a reflection of the dry conditions of the study period and the restricted drainage. During the monitoring period, dry cows were progressively removed from the woodchip pad as animals calved (Table 13 and Figure 4). As a consequence of the reduction in excretal load, effluent nutrient concentrations declined with reducing animal numbers on the pad (i.e. stocking density), this being particularly apparent with BOD, total N and NH<sub>4</sub>-N concentrations, but this was not the case with effluent P. A power or logarithmic function best described the shape of the curve, indicating a likely upper limit on stocking density, beyond which the capacity of the woodchip matrix for nutrient retention might be impaired, or performance of the woodchip pad to decline or fail.

Figure 4. Impact of cow numbers on nutrient concentrations (mg.l<sup>-1</sup>) in the drainage from a stand-off pad (Smith *et al.*, 2005).





Effluent nutrient concentrations are compared with the typical analysis of (undiluted) slurry (Anon, 2000) and, also, of dirty water (Cumby, *et al.*, 1999) in Table 13. It might be suggested that the effluent is similar in analysis to dilute slurry, or dirty water, at least in terms of COD, total N and NH<sub>4</sub>-N. However, the ratio between effluent and slurry, average N content (total and NH<sub>4</sub>-N) and COD, at 0.23-0.4 is rather different than equivalent ratios for P content and BOD<sub>5</sub> (at 0.04 for both). This suggests that there may be some retention of manure P within the woodchip material, possibly associated with solids held back by the matrix of the woodchip material, or possibly P adsorption on the woodchip or bark material. The relatively low BOD<sub>5</sub> may be the result of some 'treatment' (microbial oxidation) during passage through the woodchip or simply due to solids retention. Nitrogen, by comparison, appears to be much less impacted by the relatively short retention within the woodchip. The determination of COD is based on a strong chemical oxidation procedure in the laboratory and this parameter, too, would thus be expected to be less affected by passage through the woodchip bed.

On the final sampling visit, a slurry sample was also collected from the lagoon for analysis. On this farm the lagoon received drainage directly from concrete feeding yards, the collecting yards and dairy, as well as the drainage from the stand-off pad. The lagoon contained very dilute slurry (0.6% solids content), with total N content in line with the anticipated dilution factor and rather less than the N content of the effluent from the woodchip pad. It is interesting to note, however, that the lagoon slurry P content was marginally higher than that of the woodchip effluent. These limited data seem to support the hypothesis of a limited 'treatment' or retention of P and BOD within the woodchip matrix.

*Table 13. Concentration of nutrients (mg.l<sup>-1</sup>) in the drainage collected from a large stand-off pad stocked with dairy cattle. Also comparison with typical analysis of undiluted cattle slurry (Anon., 2000) and dirty water (Cumby *et al.*, 1999)<sup>1</sup>*

Sample date	(Cow numbers)	COD	Total N	Total P	NH <sub>4</sub> -N	BOD <sub>5</sub>
10-Jan	(220)	8630	892	47.8	899	1290
18-Jan	(220)	8400	947	44.3	840	992
25-Jan	(140)	9360	935	42.8	799	944
01-Feb	(140)	9050	887	18.9	710	592
10-Feb	(100)	9450	1010	35.7	770	873
21-Feb	(100)	9680	915	45.8	687	703
28-Feb	(68)	9950	737	18.5	511	526
11-Mar	(0)	5140	366	42.2	66	95
Average <sup>2</sup>		9217	903	36.3	745	846
Slurry lagoon 11-Mar		-	309	50.9	203	-
Typical dirty water <sup>1</sup>		13500	850	410	460	6500
Typical Slurry		40000	4000	870	2000	20000
Ratio <sup>3</sup>		0.23	0.23	0.04	0.37	0.04

<sup>2</sup> Note – average effluent analysis excluding final sampling date where no cattle on the pad

<sup>3</sup> – ratio of average effluent analysis/typical slurry nutrient content

<sup>2</sup> BOD<sub>5</sub> – Biological oxygen demand relates to the amount of dissolved oxygen consumed by biological activity when a sample is incubated in a laboratory at 20°C, for 5 days.

Drainage volumes were estimated (using a water balance method based on rainfall received and estimated evaporative losses) along with excretal load and using effluent concentrations measured, a simple estimate of nutrient export draining from the woodchip pad was made. Over the period 12<sup>th</sup> January – 28<sup>th</sup> February, nutrients draining from the pad were estimated at c.75 kg N, 65 kg BOD and 2.9 kg P. Taking account of cow numbers and their typical occupancy of the pad (supplied by the farmer), total nutrient loadings are estimated at c.1030 kg N, 180 kg P and 4100 kg BOD. Nutrient “export” in the drainage therefore represents only around 7% of the excretal N, 1.6% of the P and 1.6% of the BOD estimated input, respectively. Although the reported data of French and Hickey (2003) do not include a full nutrient balance, N and P “losses” in pad effluent drainage, were estimated at 1.64 kg N per beef steer and 0.17 kg P/steer. These latter losses represented c.10% and 5%, respectively, of N and P of total excretal ‘inputs’ and are similar both to those estimated by Smith *et al.*, (2005) and also the estimated N and P losses in drainage from the CREH (2005) studies on corrals. All of these data suggest significant retention of effluent solids and nutrients within the woodchip matrix, which was confirmed by the column studies of Luo *et al.*, (2006), reported earlier (Table 11).

#### *Nutrient value of effluent*

To date, only Augustenborg (2007) has carried out any evaluation of the nutrient value of the woodchip pad by-products, spent timber residue (STR) and OWP effluent. Field experiments evaluated these products as a nitrogen source for first cut silage, at Teagasc Johnstown Castle, Moorepark and Grange Research centres in Ireland, in 2004 and 2005. The effluent used in the 2004 trials contained 458 mg/l of total N and in 2005 343 mg/l of total N, in both cases with c.60% in the plant-available, inorganic N form (Table 14). The nutrient content from effluent samples from six other OWPs throughout Ireland is also shown in Table 14. The total N in these samples ranged from 97 to 810 mg/l, with 25 to 95% plant-available, inorganic N; not surprisingly showing significant variability in analysis between sites.

First cut silage DM yield was found to be increased by effluent application. Effluent total N at the highest application rate (supplying 28 kg/ha total N) proved 74 to 90% as efficient as inorganic nitrogen fertilizer and was, thus, a very effective source of N for grassland production. It is clear however from the variable nature of the effluent that analysis data is necessary to give confidence in its N contribution.

Table 14. Nutrient analysis of out-wintered pad (OWP) effluent used in 2004 and 2005 experiments and of six other effluent samples taken from OWPs throughout Ireland

Sample	Total P	Total N	NH <sub>4</sub> -N	NO <sub>2</sub> -N	NO <sub>3</sub> -N
All results as mg/l					
<b>2004 trials</b>	101	458	270	0.01	<0.00
<b>2005 trials</b>	44.9	343	215	<0.00	<0.00
<b>Effluent samples from six OWPs in Ireland</b>					
<b>1</b>	27.4	687	518	0.021	-
<b>2</b>	18.8	97.3	24.3	1.71	-
<b>3</b>	39.9	212	93.1	<0.00	-
<b>4</b>	35.1	151	143	<0.00	-
<b>5</b>	63.5	810	424	<0.00	-
<b>6</b>	29.9	157	102	<0.00	-

## 4.2 Gaseous emissions

The dairy and beef sectors represent a major source of ammonia (NH<sub>3</sub>) emissions in the UK at c. 148kt/year (Misselbrook *et al.*, 2006), 56% of the total for UK agriculture, with a substantial component (66kt/year, or 45% of the total for cattle) associated with emissions from buildings and yards. Ammonia emission from manures is dominated largely by surface processes, with rapid hydrolysis of urea from thin layers of urine/slurry on concrete surfaces in the presence of the enzyme urease. Emissions may also be rapid from solid manure beds, where composting and elevated temperatures increase the rate of N transformation. Where exposure of manures and air exchange is reduced, e.g. by covering manure stores, slurry crusting, or by soil incorporation, NH<sub>3</sub> losses are greatly reduced (Smith *et al.*, 2007). It seems likely, therefore, that the rapid drainage of effluent from the surface of the woodchip matrix on well managed pads would reduce the scope for rapid urea hydrolysis and subsequent NH<sub>3</sub> diffusion into the air. Emissions from animals on pasture are considerably less than from emissions from housing or hard standings; if the impact of woodchip pads is in any way analogous to with animals at grass, a considerable reduction in emissions seems possible.

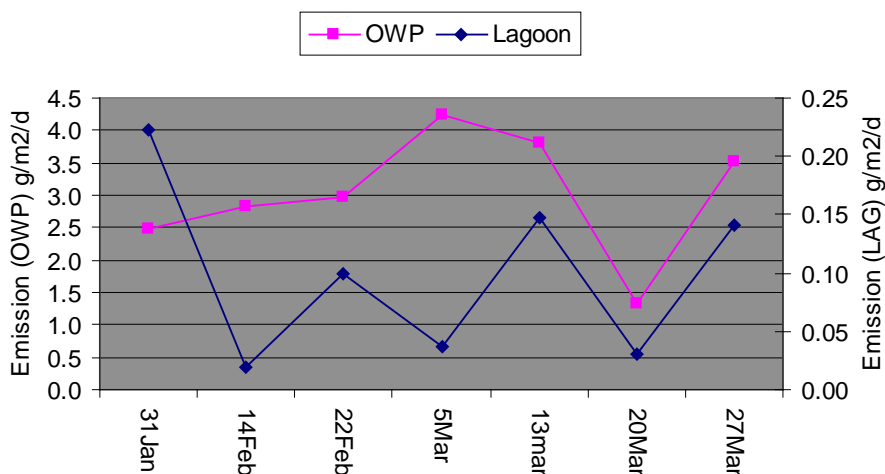
Vinten *et al.* (2006) included short duration measurements of gaseous emissions on one of the corrals (stocked at 15m<sup>2</sup>/cow), using manually closed chamber techniques for nitrous oxide (N<sub>2</sub>O), methane (CH<sub>4</sub>) and carbon dioxide (CO<sub>2</sub>). Ammonia emissions were also measured using a partially closed dynamic chamber technique, based on the field sampler method of Kissel *et al.* (1977). In early May, fluxes of N<sub>2</sub>O were 5–110 g N ha/day (typical range for Scottish soils is 0–30 g N ha/day; Lilly *et al.*, 2003). Fluxes of CO<sub>2</sub> were 3–23 kg C ha/day (typical range for soils of 1–50 kg C/ha/day; Bouwman, 1992). Fluxes of CH<sub>4</sub> were 5–340 g C/ha/day (up to 1000 g C/ha/day can be released from freshly manured soil; Bouwman, 1992). The losses of NH<sub>3</sub>-N from the woodchip pad were reported to be equivalent to 200–970 g N/ha/day. The authors considered these to be within the range between grazing and housing losses, assuming that a young beef animal emits 4 g NH<sub>3</sub>-N/day, two-thirds of the value suggested by Pain *et al.* (1998) and that 5% is emitted during grazing (0.2 g N/day) and 28% during housing (1.12 g N/day). At the stocking rate of one animal per 15 m<sup>2</sup>, this corresponds to 133 and 746 g

N/ha/day for grazing and housing, respectively, although it is not clear from the paper how any of these emissions were calculated.

In the column studies of Luo *et al.* (2006), NH<sub>3</sub> emissions were also measured using an enclosure method and acid traps, with H<sub>2</sub>SO<sub>4</sub>. Results were presented already in Table 10. In this case, interest was in the relative emissions, with different materials used in the columns. The cumulative NH<sub>3</sub> volatilisation losses from the columns were in the following order: zeolite < bark ≤ soil ≤ wood chips. These NH<sub>3</sub> losses amounted to about 13%, 25%, 30% and 39% of the applied excretal N from columns containing zeolite, bark, soil and woodchips, respectively. As discussed earlier, NH<sub>4</sub> ions in effluent can adsorb onto the large surface area provided by these materials, thereby decreasing the quantity of NH<sub>3</sub> available for volatilisation.

Until recently, no robust measurements of NH<sub>3</sub> flux from woodchip pads had been undertaken or assessments of the factors likely to impact on ammonia emissions made. Whilst the small chamber and column measurements of NH<sub>3</sub> emissions of Vinten *et al.* (2006) and Luo *et al.* (2006) are of interest, particularly where relative values are available for different materials or treatments, the absolute values must be regarded with some caution. The first NH<sub>3</sub> emissions data from woodchip pads using larger scale methodology (Hill *et al.*, 2006) were collected from the research pads at Grange Research Station (Figure 5).

Figure 5. Measurement of NH<sub>3</sub>-N emissions from outwintering pads and effluent lagoon at Grange Research Station – preliminary results (Jan – March, 2007)



Emission rates from the pads varied from c.1.5 up to 4.2 g/m<sup>2</sup>/day NH<sub>3</sub>-N, at least an order of magnitude greater than emissions from the effluent storage lagoon, of c. 0.02 up to 0.2 g/m<sup>2</sup>/day NH<sub>3</sub>-N. The values for the pads are similar to the emission factors for slurry stores in the current UK ammonia inventory (Misselbrook *et al.*, 2007). Overall, emissions from the OWP, averaged over a period of 60 days were estimated at 55g/500kg LW/day, compared to 73g/500kg LW/day from the slatted beef housing, over 40 days, a reduction of 25% from the woodchip pads.

Farmers can use woodchip pads to reduce pasture damage in wetter months – for example dry cows and young stock may be kept on the pads, with access to grazing for up to 6 hours per day. Work in New Zealand has confirmed that time spent by cattle on

woodchip pads can reduce N<sub>2</sub>O emissions compared to those from cattle stocked at the same rate on conventional grass paddocks (Table 15) (Luo *et al.*, 2008). This strategy reduces urine deposition to pasture in the winter months and, hence, can reduce both nitrate leaching and N<sub>2</sub>O emissions. Whilst such N<sub>2</sub>O losses are small and of no significance agronomically, they are of great importance environmentally, since nitrous oxide is a very powerful greenhouse gas with global warming potential estimated at 310 times that of carbon dioxide.

*Table 15. Calculated nitrous oxide emissions from grazed pastures.*

Assessment period	kg N <sub>2</sub> O-N/ha	
	Control pasture	OWP + pasture
May – August 2004*	2.99	1.33
May – August 2005*	1.22	0.28

\* late autumn/winter;  
(Source: J Luo *et al.* 2008)

### 4.3 Recycling of spent woodchip

The wider development of woodchip pads imposes the need for additional information regarding the recycling, utilisation and, if necessary, the treatment of any 'spent timber residue' (STR). Some information is already available on composting (McLean and Wildig, 2000) of woodchips. Here the high C/N ratio of exhausted woodchip hampered the composting process. However these data were from woodchip used as bedding within housing systems and, it is likely that there would be a much higher N content in exhausted woodchip from outdoor pads, especially after several months in use. It can be expected that efficiency of the composting process will vary greatly according to the wood source, chip size, the excretal loading, moisture content and temperature. Controlled trials are needed to identify best practices to be adopted in association with the management of woodchip pads.

The experiments of Augustenborg (2007) on residues as N sources for first cut silage included STR as well as OWP effluent. The analysis of the STR is given in Table 16. At the STR application rates of 10, 30 and 50 t/ha tested, total N applied was 40, 121 and 202 kg/ha N, respectively, in 2004 and 42, 126 and 210 kg/ha N, in 2005. The effect of dry timber residue (without manure) was also investigated. The experiments found that there was no significant silage yield or crop N response from the STR. This lack of response in either first or subsequent cut silages indicated that the N content present in spent timber was not available for crop uptake within the four month growing period. The STR provided little N value to the grass crop in the first growing season following its application.

*Table 16. Average dry matter, total nitrogen (N), phosphorus (P), potassium (K) and magnesium content of STR used in 2004 and 2005 trials at the Johnstown, Moorepark and Grange sites.*

<b>Trial year</b>	<b>2004</b>	<b>2005</b>
Dry matter (%)	22.9	23.2
	<b>g/kg (fresh weight)</b>	
Total N	4.0	4.2
Total P	1.1	1.2
Total K	5.4	6.6
Magnesium	0.56	0.71

A significant negative response was observed in silage DM yield following increasing application of dry timber. This suggested that the timber was likely to have a shading effect on the sward which would inhibit grass growth, at least for first cut silage. However, the shading effect of timber reduced as the timber decomposed on the sward surface and was not evident twelve weeks after application.

Fine woodchips are now commonly used, at least in the surface layer, on OWPs in Ireland; for example shredded pallets provide chips which may be several cm in length, but perhaps only a few mm in thickness (Figure 6). The impact of even quite high application rates of STR comprising such fine chip size on sward growth is quite short-lived and grass growth, one month after application, in the example shown in Figure 7 can be seen to be greatest at 40t/ha applied chips (P French, pers. communication).

Other uses of exhausted woodchip from pads, such as a substrate for mushroom production, as biomass for biogas reactors or as a fuel source for power generation have been proposed, though have not yet been subject to further investigation.

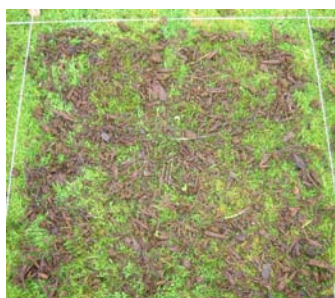
*Figure 6. Shredded pallet fine chip now commonly used as a surface layer on OWPs in Ireland.*



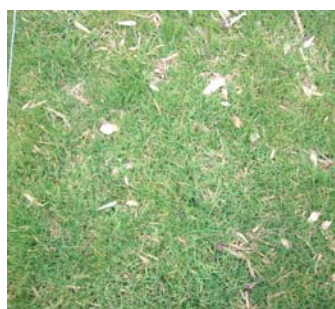
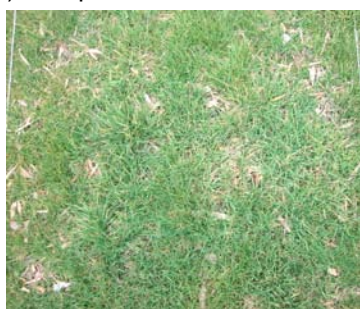


*Figure 7. Images showing appearance of grass sward dates following application of spent woodchips at different rates, on successive dates (10 April, 30 April and 10 May).*

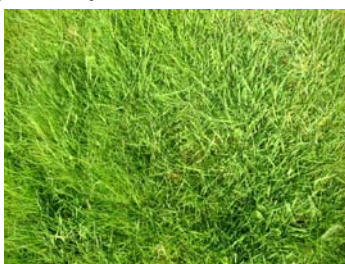
(a) 10 April



(b) 30 April



(c) 10 May



40 t/ha

25 t/ha

10 t/ha

## 5. Discussion and recommendations

The data from all controlled observations show that effluent draining from woodchip pads is highly polluting and it must be contained and managed to prevent serious pollution by percolation to ground waters or discharge into surface waters. Factors such as stocking intensity, woodchip size and depth appear to influence the concentration of pollutants in the drainage water but by no means eliminate its polluting potential. Passage through freely draining soil reduces the concentration of the main potential pollutants,  $\text{NH}_4\text{-N}$ , dissolved organic compounds, suspended solids and faecal micro-organisms, but  $\text{NO}_3\text{-N}$  has been shown to increase. Whether the reduction is sufficient to prevent an unlined site causing pollution seems unlikely and any remote possibility will depend on the local hydrogeology. Any increase in  $\text{NO}_3\text{-N}$  would be of particular relevance if there are local potable water supplies, e.g. springs and boreholes that are within the sphere of influence of an unlined pad.

Justification for the lack of a lining to the base of a pad has sometimes been attempted on the basis of a claimed self-sealing process as sometimes been found in unlined slurry storage (Barrington *et al.*, 1987; Withers *et al.*, 1998). However, should such self-sealing of a corral base occur, this would be quickly followed by a backing up of slurry within the woodchip matrix and, ultimately, by pad failure and the need for removal of animals. Such failures have been known to occur in recent years in the UK. Therefore, the collection and managed removal of effluent from the woodchip pad would appear to be justified not only on environmental grounds, to protect ground and surface waters, but also on technical and logistical grounds, to minimise the risk of pad failure.

The woodchip layer in the past has typically been proposed to a maximum thickness of c.1m. Whilst the few studies of pad performance that include drainage and effluent quality, show some reduction in the N and P load in the effluent draining from the pad (c.5-10% of input N and P), limited data exists of the level of N and P retention within the pad itself (up to 30 – 60% N retention). Such effects seem likely to be the result of a filtration effect, a physical retention of effluent solids within the woodchips, with possibly some sorption of  $\text{NH}_4\text{-N}$  and P on exchange surfaces within the chips and possibly some nutrient retention as a result of microbial activity. Once it is accepted that pads must be lined, with effluent collection and management as part of the design, it follows that any 'treatment' effect and, hence, the depth of the woodchip, is of lesser importance. This is reflected in generally reduced depths of woodchip in newer constructions. Of course overloading of pads and blockage of woodchips with slurry solids is an important consideration, since both may restrict the efficient operation and useful life of a pad. More information on nutrient fluxes within the woodchip matrix and the impact of chip size, pad depth and stocking density seem to be key issues which require further research, because of effects on effluent quality, gaseous emissions and, possibly on stock cleanliness and welfare. The recent work in Scotland concentrated on the potentially adverse effects of woodchip corrals on the environment, particularly from the effluent generated. However, the experimental sites provided little scope for assessing the impacts of factors such as stocking density, chip type and depth.

Further studies on nutrient fluxes should include robust assessments of gaseous emissions; limited observational data to date, suggest some potential for reduction of both ammonia and nitrous oxide for overwintering systems involving woodchip pads.



Published design criteria from New Zealand, Ireland and Scotland for woodchip pads essentially promote similar guidelines. The subsoil is ridged, with drains installed in the base between the ridges. These are overlain with permeable fill onto which the woodchip layer, of variable type and depth is placed. Whether a liner is recommended depends on subsoil texture.

The costs of constructing a pad with 'conventional' woodchip depth, drainage and effluent storage should be compared with those for construction according to a range of design criteria, including different woodchip sizes and depths and alternative drainage systems. Different sources of wood and woodchip should be considered, including cheaper alternatives, such as shredded pallets, or the screenings from green waste composting sites. Small scale column studies would be a good way of investigating the impacts of woodchip depth; for example, a deep pad may require less maintenance and replacement of woodchips.

More experimentation, perhaps augmented by modelling, on the wider environmental impact of overwintering cattle by different methods is required e.g. to compare conventional housing (straw yards, cubicles, slats) with out-wintering on woodchip pads and on suitable free-draining land. This work should concentrate on gaseous emissions (nitrous oxide, methane and ammonia) and the potential for nitrate leaching at the whole farm system level. Stocking density, depth and type of woodchip (and potential alternatives) affect the concentration and volume of effluent produced. It is noted that CREH modelling has suggested that with sufficient depth of woodchip and at certain level of stocking density and rainfall, a woodchip pad may be managed for periods with no effluent drainage (though the authors of this review consider this possible only under a very limited range of conditions).

Out-wintering of animals on woodchip pads does not appear to compromise animal health and welfare, assuming good management. However, from evidence not considered within the current review, provision of adequate shelter, for dairy cattle, would appear to be more important than for beef cattle.

Surface applied spent woodchip residues in limited assessments to date, have not given DM or N responses for silage grass. The effect on grass DM and N response of annual spent woodchip residues application at different rates to long term and permanent pasture needs to be investigated. Moreover, guidance is needed on application rates that will minimise the potential for grass shading and smothering which has been identified in research in Ireland. Concerns about possible negative impacts on grazing and on grass silage quality also need to be considered and investigated.

Spent timber residues have been shown to contain significant nutrient content, not dissimilar to the levels in FYM or slurry. However, more detailed information is required to decide how the STR should be considered (whether similar to FYM or slurry) under the new NVZ regulations – this information would be relevant to rules on storage, application rate and timing.

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## Appendix 1.

### Guidelines on construction and management of woodchip pads

Useful guidance on the construction and management of pads has now been published, not only in New Zealand but also in Ireland and in Scotland, following developments in each of these countries. These guidelines are summarised below.

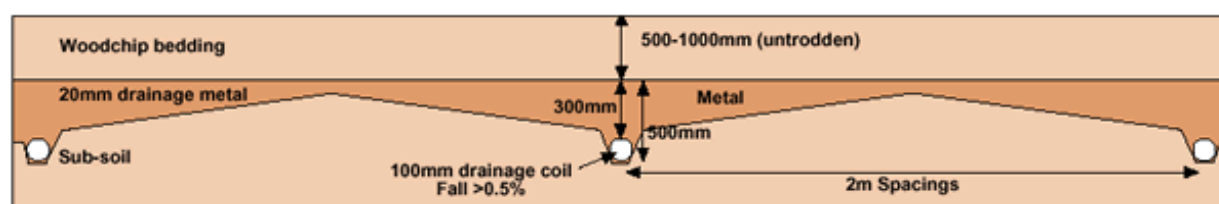
#### New Zealand

In New Zealand, the term “stand-off” pad can apply to “woodchip pads” with drainage installed and also to “metal or lime pads” providing a hard surface from which water runs off ([http://www.dexcel.co.nz/farmfact.cfm?id=3\\_14](http://www.dexcel.co.nz/farmfact.cfm?id=3_14)).

The preferred site is in a well-drained and sunny area, exposed to moderate wind to help the evaporation of liquid excreta, possibly facing south, with a windbreak where appropriate. The size is generally a function of the period of use (see Table A1). Larger dimensions are needed where cows are accommodated over-winter, all day long and for at least 12 weeks. The higher stocking rate is where the pad is used for feeding over a restricted period, perhaps a few hours/day and a few days/year. Sometimes, a canopy is placed over the feeding area. The depth of the woodchip (or bark chip) layer can also vary from 50 to 100 cm, overlying at least 7 cm of sand, which rests over a base of drainage stone. Ridges and furrows in the subsoil, across the corral base, accommodate drainage pipe, at 2 to 5 m spacing. During periods between active use, weeds germinate and grow within and on the edge of the pad. Their growth and spread is controlled through the strategic use of herbicide treatments. In the past, some farmers in New Zealand have spread a further layer of sawdust over the woodchip, which is easier to remove and renovate periodically than the woodchip material itself.

The design of a typical New Zealand “stand-off” pad is summarized in Figure A1.

Figure A1. Cross section of typical New Zealand “stand-off” pad.



Source: Dexcel FarmFact 3-14: Stand Off Pads.

Table A1 shows the area allowances per animal recommended on “stand-off” pads in New Zealand.

Table A1. New Zealand stand-off pads – minimum loafing area (m<sup>2</sup>) per animal

Breed	Short term use <sup>1</sup>		Continuous use
	Woodchip	Metal/lime	
Jersey	5	3	9
Friesian	6	4	10

<sup>1</sup> Short term use is when the cows are on the pad for 1 or 2 days a week/10 days over winter



## Ireland

In Ireland “stand-off” pads are referred to as “out wintering pads” (OWP) with minimum specifications set out in Department of Agriculture and Food Publication S132 Feb 2007. This document can be accessed by the following link:

<http://www.agriculture.gov.ie/areasofi/fds/S132OWPGDfeb2007.pdf>

The document sets out the regulatory procedures (e.g. planning permission, risk assessment) a farmer has to go through before constructing an OWP. A Site Assessment Report from a Local Authority approved site assessor is required. Design of the OWP is essentially very similar to the New Zealand “woodchip pads”. Soil ridge and drain spacing are 3 m. Ridge height is a minimum 150mm, minimum woodchip depth is 200mm and depth of drainage stone layer 150mm over ridge top (300mm over drains), but greater if ridge height is greater. For the drains a fall of at least 2% (1:50) is recommended. Figure A2 shows an example of an OWP during construction.

*Figure A2. Compacted subsoil ridges in a subsoil-lined OWP effluent collection system.*



Source: Department of Agriculture and Food Publication S132 Feb 2007

Table A2 shows recommended space allowances and Table A3 gives a summary the minimum acceptable criteria for the OWP “base” in Ireland, according subsoil criteria.

*Table A2 Minimum space allowances for animals accommodated on an OWP system*

Animal type	Minimum space requirements per animal (m <sup>2</sup> )	
	On pad feeding	Off pad feeding
Dairy cow	18	12
Suckler cow	16	10
Beef cattle (>2 years)	16	10
Cattle (1-2 years)	12	8
Cattle (<1 year)	10	6

Table A3. Minimum acceptable design criteria for the OWP “base”.

Liner type	Minimum acceptable criteria	Subsoil thickness required below OWP underdrainage system
<i>In situ</i> subsoil liner	13% clay or greater*  Low/moderate permeability unsaturated subsoil**, impervious and free of preferential flowpaths	Minimum 1.0m
Compacted subsoil liner	10% clay or greater	Minimum 0.5m compacted** subsoil liner underlain by minimum 0.25m unsaturated subsoil
	Regionally important aquifer present with groundwater vulnerability rating classified as high or extreme or regionally important karstified aquifer present  or  High permeability sand and gravel is encountered in vertical continuity with the main water table	Minimum 0.75m compacted** subsoil liner underlain by minimum 0.25m unsaturated subsoil
Geo-membrane	The geo-membrane shall be overlain by subsoil with a minimum thickness of 0.2m of low to moderate permeability and plastered with remoulded soil.	Minimum 0.15m unsaturated subsoil, the upper 0.05m of which may be a protective fine sand layer.

\* Surface of excavated portion plastered with re-moulded soil

\*\* Permeability no more than  $1 \times 10^{-8} \text{m.s}^{-1}$

There should be a minimum depth of 200mm of woodchip bedding placed on all OWP's. The woodchip used shall be less than 50mm thick and may be produced from sawmill by-product, chipped logs or recycled timber. In all situations the woodchip bedding shall not contain any material that is not derived from wood.

### **Typical characteristics of effluent**

It has been noted that the volumes of effluent generated can be very variable. This may be ascribed to variable weather conditions and livestock slurry generation. Similarly the chemical characteristics can also be variable. The effluent will typically have high levels of microbial pathogens. Based on observations on a number of OWPs, characteristics of effluent are:

- N:  $300 \sim 1000 \text{ g/m}^3$  (mg/l)
- P:  $20 \sim 35 \text{ g/m}^3$  (mg/l)
- Typical BOD effluent values:  $1500 \sim 10,000 \text{ mg/l}$ .



The main determinants of nutrient concentrations are the woodchip depth and woodchip particle size (Tables A4 and A5).

*Table A4. Average effluent nutrient concentrations of pads with three different woodchip depths*

<b>Woodchip Depth</b>	<b>P</b>	<b>NH<sub>4</sub>-N</b>	<b>BOD</b>	<b>Suspended Solids</b>
<b>cm</b>	<b>mg/l</b>			
10	23	118	3511	1033
20	20	60	2517	860
30	14	47	1844	488

*Table A5. Average effluent nutrient concentrations at woodchip depth of 20 cm for varying woodchip types*

<b>Woodchip Type</b>	<b>P</b>	<b>NH<sub>4</sub>-N</b>	<b>BOD</b>	<b>Suspended Solids</b>
	<b>mg/l</b>			
Post peelings	21	50	2294	581
90 mm chips	21	104	3183	1098
30 mm chips	16	70	2394	702

### **Typical characteristics of spent woodchips**

Typical nutrient concentrations of spent woodchips are:

- N: 100 ~ 150 g/kg
- P: 25 ~ 40 g/kg
- K: 150 ~ 200 g/kg

*(Note: above values as presented in guidance doc, but appear unrealistically high. Need to be checked)*

The factors influencing nutrient concentration of woodchip are the animal stocking rate and length of time animals are on the OWP.

## **Scotland**

The SAC Technical Note TN595 "Woodchip Corrals" (Merrilees and Donnelly, 2007) gives guidance on the siting, site preparation and construction of pads. This document can be downloaded via the following links:

<http://www.sac.ac.uk/consultancy/livestock/pubs/beeftechnotes/>

Some information from this note is reproduced below.

### Siting

Given the significant polluting potential of woodchip corrals, particularly unlined ones, the advice of SAC and/or SEPA should always be sought before a corral is built and if modifications are being made to the original design. Test pit(s) excavation will be required to determine soil conditions and drainage status. To ensure effective management and to minimise pollution risk, the following site selection factors must be considered when locating a woodchip corral:

1. Proximity to water courses and water supplies

- At least 50m away from a watercourse, or ditch.
- At least 50m away from a drinking water supply, spring, well or borehole.
- Access to drinking water supply for stock.
- Not overlying permeable soil in Groundwater Vulnerable Zone or within a Nitrate Vulnerable Zone (if unsealed corral).

2. Land form

- Gently sloping site with 2-3° gradient to effluent collection drain.
- No upslope water draining to site.
- Easy access for stock and machinery.
- Upslope of effluent store or effluent treatment system to allow gravity drainage and avoid pumping.

3. Aspect

- Open (avoid too much shelter from buildings/trees).
- South-facing, sunny location without shade, but open to light winds to promote surface drying.

4. Soil type

- Free-draining sandy or gravelly soils to provide dry sites for construction and management. These soils will most likely require a liner for effluent collection to protect groundwater from pollution.
- Heavy clay soils, if sealed, will not require a liner but will require under-drainage and a collection system for effluent.
- Avoid poorly drained and peaty soils.
- Avoid very stony and rocky soils which damage liners.

5. Site drainage

- No springs or seepage (surface or groundwater) upslope or beneath the site.
- No under-drainage crossing site. Any field drains must be intercepted above the site and re-routed around the site to avoid contamination with effluent.
- No water-table within 4 m of ground surface.
- No flood risk.

Site Preparation

As labour and fuel costs are likely to continue to increase, corrals are best sited close to existing silage pits and the main steading to reduce time spent feeding and handling or moving stock. Having selected a suitable site, calculate the corral area required, based on stocking density plus feedstance area and access requirements.

Corral Construction

Corral construction should be timetabled for spring or summer, when ground conditions are dry, over-compaction is minimised and risk of sediment pollution from the works is avoided.

- Strip topsoil layer down to form subsoil base.
- Remove topsoil and re-use within farm the soil came from.

- Check carefully for the presence of field drains, intercept and reroute as required.
- Grade subsoil base to create slope or mound to assist effluent collection.
- Clay soils (non-cracking) – puddle and seal with roller to provide an impermeable layer at least 1 m thick with a permeability coefficient of  $<10^{-9} \text{ m.s}^{-1}$ . All other soils – install impermeable liner.
- Install 80 mm Ø drainpipes at 3 m centres, draining to a 100 mm collector drain at outfall.
- Backfill with 200 mm depth of permeable backfill, 20-40 mm Ø. A drainage raft of 400 mm deep stone can be used as an alternative to pipes and backfill.
- Lay coarse geo-textile filter on permeable backfill surface to prevent ingress of solids into the drainage layer.
- Install recommended depth of chips (minimum 40 cm).

### Design Layout

There are four basic design layouts and the pros and cons are indicated:

#### *Feed On (using feedtrailer or ringfeeder, i.e. no scraped passage)*

- No slurry to handle.
- Requires effluent treatment.
- Heavier soiling of woodchips.
- Low labour and machinery requirement.
- Need to replace chips around feeder every year.
- Loss of fertiliser value.

#### *Feed Off (integrated scrape passage)*

- Requires slurry storage.
- The total volume of slurry produced likely to be very similar to that produced on a yard.
- Reduced soiling of woodchips.
- Labour to scrape/spread.
- Slurry has fertiliser value.

#### *Feed Away (use existing concrete)*

- Could use existing slurry system.
- Reduced soiling of woodchips.
- Labour to scrape/spread.
- Slurry has fertiliser value.

#### *Feed Inside (utilise existing shed)*

- Uses existing slurry system.
- Reduced soiling of woodchips.
- Expands use of existing sheds.
- Can improve overall stock performance.
- Utilise existing labour.

### Chip Size

Large woodchips are more effective for both cattle and sheep as it is easier for stock to tramp dung through the top 7-10 cm of woodchips, leaving the surface cleaner to lie on. The target is fist- to palm-sized chips (7-12 cm long and 7 cm wide). Smaller chips can be used which will be more comfortable but will need to be renewed sooner. Expect a corral built using large woodchips to last two winters, but a small chip corral may only last one winter before becoming too dirty on the surface.

### Stocking Density

The majority of problems caused by corrals are due to overstocking. As the winter progresses, having seen how well the cattle are doing on the corrals and with other cattle still outside poaching fields, there is a tendency to put extra stock into the corrals, resulting in muck overload and increased pollution risk. Maintaining the correct stocking density is essential.

*Table A6. Recommended minimum lying area and chip requirements (per animal)*

	<b>Lying area (m<sup>2</sup>)*</b>	<b>Chip vol. (m<sup>3</sup>)</b>	<b>Chip wt (t)</b>
Cows	15	6	3.0
Finishing cattle	12	5	2.5
Store cattle	8	3	1.5
Sheep	3	1	0.5

\* Excludes feed stance area

### Depth of Chips

Recommended minimum 40 cm depth, but recent SEERAD funded trial demonstrated that chip depth could be decreased to 30 cm if constructed on a drainage layer.

### Choice of Timber

Scots Pine produces the best chips followed by Spruce with Larch the least effective. To avoid the chips “flaking” into smaller sections the wood should be reasonably green. The larger chippers will handle up to 20 cm diameter in 3-4 metre lengths. One tonne of timber will produce approximately 2 m<sup>3</sup> of woodchips dependent on timber dry matter. When the chipper is on site, a stockpile of 0.5 t/animal is recommend as a reserve for maintaining the corral over the next 2 years.

### Other Design Features

Square corrals work best with the chipped lying area in a shallow dome (upturned soup plate). Most use ordinary fencing to contain stock and keep costs down. Alternatively three rows of crash barrier can be used which can be reduced to two rows by threading the barrier through tyres to fill up the space. This is also more animal friendly. Water troughs should be placed outside the chipped lying area and protected against frost. A kick bar (railway sleeper) positioned where stock move on to/off the bedded area helps keep the chips cleaner.