Reducing nutrient runoff from horse paddocks by removal of dung

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***Abstract*—Horse paddocks pose a risk of N and especially P leaching into vulnerable water ecosystems. By regular removal of dung, the nutrient load from paddocks can be reduced. In this study, the effect of cleaning intensity on the N and P runoff from horse paddocks was investigated in small-scale demonstrations. In addition, the rate and extent of nutrient loss from horse dung was examined under rain simulation.**

The demonstration paddocks showed that the amount of N and P in the drainage water increased notably with an increase in the dung load. Decreasing dung load from that of a hot spot – area to a half also resulted in 50% decrease in the amount of N acquired in the drainage water. The N leached from the dung was mainly in organic form whereas P was as inorganic PO_4-P. Both N and P were released from the dung at a high rate during rain simulation. Due to the high N and especially P leaching potential of the dung, frequent cleaning of horse paddocks is recommended.

Keywords—paddock, horse dung, runoff, nutrient leaching, rain simulation

I. INTRODUCTION

In Finland, the average paddock size is 1100 m^2 and hosts two horses for around 7 hours per day [1]. In one year, this average paddock may receive more than 5 kg P and 30 kg N in the horse faeces. When dung is left on the ground, these nutrients are susceptible to leaching. Horse paddocks, especially the so called hot spots which are the feeding and excretion areas, have been shown to pose a high risk for extensive N and P losses [2], [3]. Eutrophication of waterways due to agricultural P load is currently a major concern in the Northern Europe [4]. Minimizing the N and P concentrations in the runoff waters is thus an important target. Regular removal of dung provides a simple way of reducing the nutrient loss potential from horse paddocks.

In this study, the effect of cleaning intensity on the amount of N and P leakage from horse paddocks was investigated in small-scale demonstrations. The potential load and availability of nutrients from horse dung was investigated in more detail using rain simulation. Under controlled environment, the rate of nutrient release during a rain event could be assessed.

II. MATERIAL AND METHODS

A. Demonstration paddocks

The demonstration paddocks were constructed in plastic boxes (0.5 m^3) having a surface area of 1 m^2. Official Finnish recommendations for the three-layered structure of paddocks were followed. A 20 cm layer of gravel with a particle size of 18-32 mm was laid at the bottom of the box. Then a 5 cm layer of coarse sand (0-20 mm) was added on top of the gravel layer. The surface was levelled with a 10 cm layer of fine sand (0-2 mm). The demonstration paddocks were equipped with both surface and drainage runoff collection systems and placed outdoors under natural weather conditions.

Different intensities of cleaning were imitated by increasing additions of horse dung. Four dung addition levels were used: 0 (control), 0.2, 2.1 and 4.2 kg fresh manure per 1 m^2 in three-week intervals. The lowest addition level of 0.2 kg corresponded to the average manure load received by a typical Finnish paddock. The higher levels represented hot spots arising due to the natural latrine behaviour of horses. Dung was added to the paddocks 10 times between October 2013 and April 2014. The experiment was conducted in a completely randomized design with three replicates of each of the four treatments.

The drainage water was collected after every event of rain. No surface runoff occurred. The amount of drainage was quantified by weighing, after which a subsample was taken for analysis of NH_4-N, NO_3-N, total N, PO_4-P and total P. The water analyses were carried out with Lachat autoanalyzer.

B. Rain simulation

In the rain simulation, the leakage of N and P from dung collected from four different horses was studied. Dung aliquots of 3-l (corresponding to 0.25 ± 0.02 kg dung dry mass) were subjected to rainfall of 8 mm h^{-1} for 8 h. Percolated water was sampled in every 30 min. After the 8-h rain period, the dung samples were placed in cold storage for a week, after which the rain simulation was continued for 6 h, during which samples of percolated water were collected in every 60 min. The water samples were analysed for NH_4-N, NO_3-N, PO_4-P and total P with a Lachat autoanalyzer. Dung samples collected prior to

the rain simulation were analysed for total N concentration by the Kjeldahl method and for total P by aqua regia digestion.

III. RESULTS

A. Nutrient leaching from demonstration paddocks

The winter 2013-2014 was milder than usual in Finland and especially in December 2013 and February 2014 the temperatures were several degrees (Celsius) over the long-term average. Therefore, the demonstration paddocks were frozen only a short period during January–early February and instead of having a spring runoff peak, drainage water was collected rather steadily over the wintertime. On average 330 ± 20 l of drainage water was acquired from one paddock during the 30-week study period.

The first results on the amounts of N and P leached from the demonstration paddocks show a clear increase in the nutrient runoff with the increase in the amount of dung added (Fig. 1 and Fig. 2). Over the period from mid-October to the end of March, during which eight manure additions were given, the average paddock (receiving the lowest manure addition) produced an N load of nearly 250 mg. That is almost double in comparison to the amount of N leached from the control paddocks with no manure additions. A tenfold increase in the amount of manure added into the paddock led to around fivefold increase in the amount of N in the drainage water. A further twofold increase in the amount of manure lying on the paddock nearly doubled the amount of N leached. The majority (89 ± 4%) of N acquired from the paddocks with high manure inputs was in organic form whereas the N in the leachates from the control paddocks was mainly inorganic NO3-N.

The background P load acquired from the control paddocks between mid-October and mid-March (7 manure additions) was around 25 mg (Fig. 2). During that period, the average paddock with the lowest manure additions produced a P load of 65 mg. In the paddocks with the high manure inputs, the variation in the amounts of P leached was quite high between the replicates the averages being around 1500 mg and 2000 mg. The majority (84 ± 4%) of P acquired from the paddocks with high manure inputs was inorganic PO4-P, whereas the P in the leachates from the control paddocks was mainly in organic form.

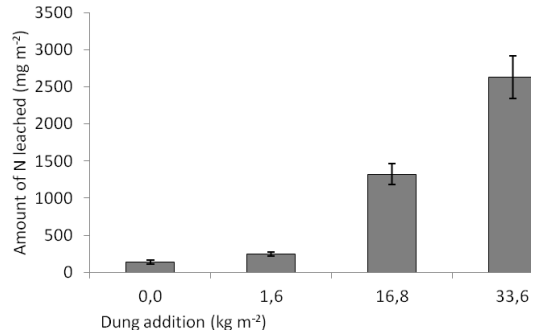

Fig. 1. The amount of N leached (mg m^{-2}) in drainage water collected from demonstration paddocks between mid-October 2013 and end of March 2014. The paddocks received increasing amounts of fresh horse dung. The bars are averages of three replicates ± standard deviation.

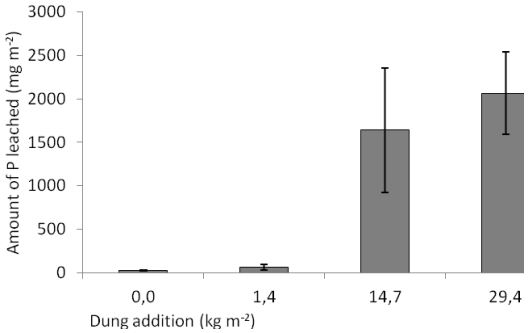

Fig. 2. The amount of P leached (mg m^{-2}) in drainage water collected from demonstration paddocks between mid-October 2013 and mid-March 2014. The paddocks received increasing amounts of fresh horse dung. The bars are averages of three replicates ± standard deviation

B. Nutrient leaching from horse dung under rain simulation

The horse dung subjected to rain simulation contained on average 6.9 ± 0.4 g P kg^{-1} dry weight (dw) and 14 ± 1 g N kg^{-1} dw. During the 8-h and 6-h long events of artificial rainfall, nearly 60% of the total P content of the dung was leached (Fig. 3). For N, the corresponding loss was nearly 20% (Fig. 4). Half of the total amount of P released over the 8-h period of rain was acquired during the first two hours of percolation. Inorganic PO_4-P comprised 81 ± 8% of the total amount of P leached. In contrast, majority of the N leached was in organic form. The proportion of NH_4-N was merely 5 ± 3% and that of NO_3-N 2 ± 1%. Likewise to P, over half of the amount of N leached was acquired during the first hours of percolation.

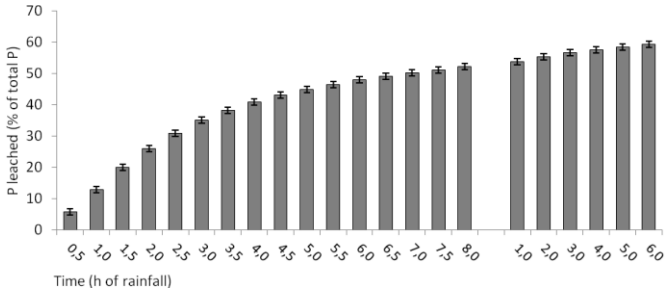

Fig. 3. The cumulative amount of P (% of the total P content) leached from 3-l samples of horse dung under artificial rainfall of 8 mm h^{-1} over subsequent 8-hour and 6-hour periods separated by a one-week dry span. The bars are averages of three replicates ± standard deviation.

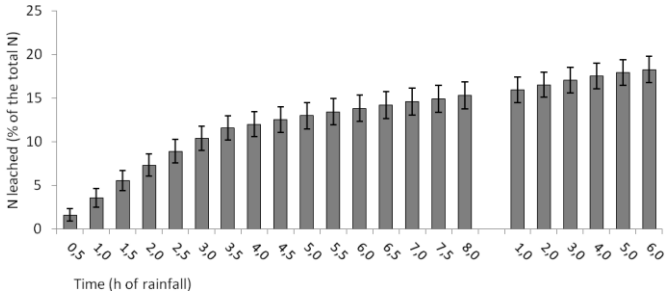

Fig. 4. The cumulative amount of N (% of the total N content) leached from 3-l samples of horse dung under artificial rainfall of 8 mm h-1 over subsequent 8-hour and 6-hour periods separated by a one-week dry span. The bars are averages of three replicates ± standard deviation.

IV. DISCUSSION

The demonstration paddocks showed that the average N and P load in the drainage water increases dramatically with an increase in the amount of dung lying on the paddock. The lowest dung addition level used was chosen to represent the dung load estimated for a typical Finnish paddock having a size of 1100 m^2 and a year around horse density of 5.3 ha^{-1}. However, in practice, horses do not excrete randomly over the paddock but use a small excretion area composing on average 5% of the size of the paddock (Parvage et al. 2013). Therefore, the high dung addition treatments give a more realistic idea on the risks of nutrient leaching from the hot spots of horse paddocks. In addition to the drainage runoff, uncleaned paddocks are susceptible to extensive nutrient losses via surface runoff [5]. In our study, the amount of N lost in the drainage water could be decreased on average by 50% by removing half of the dung loaded on the hot spot area. The corresponding decrease in the amount of P was 20% though the variation in the amounts of P leached was high.

The rain simulation study showed high leaching potential of N and P from horse dung. Even though the results of the intensive leaching treatment cannot be directly applied to field conditions, the results indicate that N and P are released from dung into the percolating water at a high rate. Therefore, horse dung should be removed from the paddocks without delay.

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