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Literature Review: Equine Facility Runoff

I. Introduction

Stormwater runoff management is an increasing problem in many areas of the country. Development of natural lands into agricultural and urban areas disrupts the water cycle, with increased impervious surfaces associated with development accounting for many of the alterations to hydrology. Development converts natural habitats to land uses with impervious surfaces (such as asphalt and concrete) that reduce or prevent soil infiltration of precipitation. Impervious surfaces create surface runoff with greater velocities, larger volumes, and shorter times to flow concentration (Brun and Band 2000). Water quality problems associated with urban stormwater runoff have been well-documented (Clark et al. 2007).

In addition to highly-developed urban areas, agricultural areas have many of the same water quality problems (Wauchope 1978; Hart et al. 2004). Excess nutrients and bacteria are major concerns in agricultural runoff. There are, however, water quality issues associated with agricultural runoff that are unique (pesticides, manure) and not found in urban areas. While the body of literature has extensively looked at agriculture from the perspective of crop production (Wauchhope 1978; Hart et al. 2004), only one peer-reviewed paper was found that reviewed water quality concerns from livestock operations (Hooda et al. 2000). However, the livestock operations reviewed were primarily for cattle, swine, sheep, and poultry. There is limited information available on equine operations and their impact on water quality and human health (Hooda et al. 2000). Studies focused on the effects horse paddocks have on water quality have been rare (Airaksinen et al. 2007). While there is some information available, there have been significantly more experiments and analyses done regarding cattle and their effects on the environment.

In this literature review, data on horses will be compared to cattle data when available and applicable. There are many areas where no information on equine operations is currently available. In these cases, data on cattle operations will be examined to give an idea of the impact equine operations may have on our water. For comparisons sake, the mass of a horse is approximately 454.6 kg (Davis and Swinker 1996). For every 1,000 kg of horse mass, 51 kg of manure and 10 kg of urine enter the environment each day (ASAE 2003). Beef cattle excrete 58 kg of manure and 18 kg of urine per 1,000 kg of mass each day (ASAE 2003). For the state of New Jersey, this could lead to a potentially large source of polluted runoff as 118 equine facilities are currently in operation (New Jersey Equine Advisory Board 2009).

II. Nutrients

Because of certain compounds in manure, nutrient enrichment in nearby streams and rivers in the watershed is likely during a storm event. Most studies are concerned about nitrogen and phosphorus, because these elements in other forms can be very harmful, even carcinogenic (Hubbard et al. 2004). Additionally, these nutrients can also induce eutrophication and algal growth (Hubbard et al. 2004). Each day, there are 0.3 kg of total Kjeldahl nitrogen (TKN) and 0.071 kg of total phosphorus (TP) per 1,000 kg of live horse mass found in horse manure. For cows, there are 0.34 kg of TKN and 0.092 kg of TP present (ASAE 2003). Watersheds with concentrated livestock populations have been shown to discharge as much as 5 to 10 times more nutrients than watersheds in cropland or forestry (Hubbard et al. 2004). Water quality can be worsened if inorganic fertilizers are applied to produce crops on the same or nearby farms (Hubbard et al. 2004).

Airaksinen et al. (2007) studied the effects of horse paddock hygiene on surface water. They compared the runoff of cleaned versus uncleaned paddock areas. They found that TP and phosphate (PO4) in the feeding area of the unclean paddock was 50 times greater than the cleaned area during spring. The TP in surface runoff from other area of the uncleaned paddock was only ten times greater (Airaksinen et al. 2007). These differences were consistent throughout the study. Feeding areas were shown to also contain higher levels of TP, TKN, ammonia (NH4) and PO4, especially when the paddock was not cleaned properly.

Similar results were found in studies involving manure and runoff from cattle farms. Uussi-Kamppa (2002) studied the nutrient load in water from a feedlot of eight suckler cows, by testing both percolating water and surface water in nearby ditches. They found that the highest nitrate (NO3) concentrations were two to three times greater than the limit for drinking water. The concentrations of TP, NH4, and total nitrogen (TN) in feedlot waters were as much as 10 to 20, 2,000 to 3,000, and 30 to 60 times higher, respectively, than levels expected in runoff from Finnish clay fields. At certain points in the experiment, levels of PO4 in the runoff were 10 to 30 times greater than runoff from a regular crop field (Uussi-Kamppa 2002). They also found that there were certain factors that affected runoff from cattle feedlots. They found that if the cattle grazed over a larger land area, the concentrations were higher and posed a greater threat to local waterways. They also found that having exercise yards for the cattle increased nutrient losses. This is particularly important because horses are kept on very large plots of land, seeing that they are larger and much more active. They also recommended that to decrease nutrient loss, manure must be removed before winter sets in (Uussi-Kamppa 2002). Lastly, they recognize that there is more research needed in this particular field.

In a study by Lambert et al. (2009), the effects of the feral horses of Assateague Island in Maryland were analyzed. Primarily, they were concerned with the impact of runoff on shellfish quality. Not only were water samples taken at random points on the island, but the levels of nutrients and heterotroph counts were measured in local shellfish (ribbed mussels, *Geukensia demissa*), as nutrients in the tissue of shellfish will bioaccumulate (Lambert et al. 2009). TP concentrations in the water exceeded the regulatory limit with the highest level being in June at 50 times greater than the regulatory limit (Lambert et al. 2009). This study is less reliable than previously referenced studies because the horses are feral and migratory. This makes it difficult to quantify how the manure loads of these horses were affecting the environment (Lambert et al. 2009).

III. Bacteria and Pathogens:

A serious health concern from farming operations in general is the bacteria contained in runoff that enters nearby waters. Manure contains bacteria thought to be particularly harmful to human health. The two most common indicators of fecal contamination are total coliform (TC) and fecal coliform (FC). In horse manure, for every 1,000 kg of horse mass, there are 490 TC colonies and 0.092 FC colonies. There are also 58 fecal streptococcus colonies, another indicator of bacterial contamination (ASAE 2003). For bacteria, consistencies between cattle and horse statistics begin to vary. For example, for every 1,000 kg of beef cattle mass, there are 63 TC colonies, 28 FC colonies, and 31 fecal streptococcus colonies. For dairy cows, the statistics are 1,100 TC colonies, 16 FC colonies, and 92 fecal streptococcus colonies. Other common concerns are the parasites *Cryptosporidium parvum* and Giardia, and the bacteria *Escherichia coli* (E. coli) and Salmonella.

Most findings regarding horse manure have not been alarming. Johnson et al. (1997) found no Cryptosporidia or Giardia in 91 horses that were studied. In another study, Atwill et al. (2002) used cow manure in a simulation to test buffer strips and Cryptosporidia oocysts were present. This may show that for parasites, such as Cryptosporidia, horse manure and cow manure are not comparable. Derlet and Carlson (2002) took 102 horse manure samples from trails in the Sierra Nevada in response to hikers concerned about the water on the trails. They found one specimen that tested positive for Giardia. In addition, 18.5% of the pack animal and 8.7% wild horse manure contained potential pathogens. The most common pathogens were Enterococcus and Bacillus (Derlet and Carlson 2002). While 31.7% of the pack horse manure was positive for E. coli, none contained E. coli O157:H7, the strain that poses the biggest threat to human health. There were also no traces of Salmonella in any of the manure samples (Derlet and Carlson 2002). They concluded that while pathogens were present, they have a low prevalence and possibly low risk to human health.

Weaver et al. (2005) tested cattle, sheep and horse manure for indicator bacteria E. coli and fecal streptococcus and the difference in levels between dry and fresh manure. Additionally, when testing cattle, they separated pasture and penned cattle. For horses, fecal streptococci were detected ($\log_{10}$/g of manure) in fresh and dry manure at 5.47 and 6.14 respectively. And E. coli existed at 4.79 and 5.08 $\log_{10}$/g, respectively. The findings for pasture cattle were similar, for E. coli in fresh and dry manure, there were 5.88 and 3.81 $\log_{10}$/g present and 5.15 and 4.68 for fecal streptococcus, respectively. The results for penned cattle varied more from the horse findings, which is to be expected considering paddock and lifestyle conditions for horses are more similar to pasture cattle than penned. This was especially so for the E. coli findings which were 7.72 and 6.00 $\log_{10}$/g in fresh and dry manure, respectively. The conclusions from this study were that E. coli and fecal streptococci for both cattle and horses are able to survive in the dry manure (Weaver et al. 2005). They also believe that their “results might help explain why streams may continue to be polluted by fecal bacteria long after the livestock have been removed” (Weaver et al. 2005).

Muirhead et al. (2006) studied the behavior of E. coli and soil particles in runoff. This is applicable to the effects equine operations have on runoff because it helps us understand why there are bacteria in our waters and even help explain how we can reduce their presence. It is believed that E. coli cells attach to large soil particles when moving in runoff, and this thwarts their travel (Muirhead et al. 2006). They also found this to be true, however, only in certain cases. They believe that the attachment of E. coli cells does not heavily affect their transport for two reasons: when under-saturated, E. coli cells are transported by advection and do not interact with the soil and in overland flow E. coli cells attached to small soil particles that do not settle, and thus the E. coli cells continue to be transported (Muirhead et al. 2006). Their recommendation was that the focus should be on the bacteria infiltration in the soil matrix, since bacteria has been shown unlikely to be removed by attachment (Muirhead et al. 2006).

Using antibiotic resistance and a reference database, Burnes (2003) tried to determine different sources of FC, among them cattle, horse, chicken, human, cat and dog. When they tried to identify sources, horse and cattle bacteria were often incorrectly identified. For example, 46% of the horse bacteria isolates were identified as cattle bacteria, using antibiotic resistance, and 23% of cattle isolates were identified as horse bacteria. The difficulty to discriminate between the two is because they have similar antibiotic resistances (Burnes 2003). However, when horses and cattle were grouped together under "livestock," identification was significantly more accurate with 97% of the livestock identified correctly (Burnes 2003). Implications of this study are that it is difficult to determine sources of FC polluting our water in certain places, especially for a watershed in a rural area with farms home to both cattle and horses using these methods. Additionally it could lead to an exclusion of specific regulations for equine operations, when they really require further study.

IV. Best Management Practices

Best management practices (BMPs) are behaviors or structures implemented to mitigate the release of nutrients as well as other pollutants carried via stormwater. Numerous structural BMPs have been designed in an effort to reduce the impact of agricultural pollution on water quality. BMPs for equine operations do exist, however, as with other studies reviewed, it seems that the emphasis is on cattle and other aspects of agriculture. This could be due to either a lack of information on equine operations or that it has been found that horses pose less of a risk than cattle or fertilizers do to the environment. For example, the equine section in a BMP plan for Hillsborough, FL remains "to be determined" while cattle regulations already exist (Hillsborough River Basin Working Group 2009). However in Orange and San Diego Counties, CA, detailed BMPs for equine facilities are available online (Equine BMPs 2004). When Nicholson and Murray (2005) did a report on the effectiveness of BMPs specific to equine operations, they found that facilities that implemented BMPs have less pathogens, nutrients, and sediment discharge. This was the case for 16 of the 18 equine facilities examined, 13 of which were using effective BMPs (Nicholson and Murray 2005). They also found that culverts to creeks and sheet flow into soil were ineffective BMPs (Nicholson and Murray 2005).

Despite the positive effects that Nicholson and Murray (2005) found that BMPs had on the environment, Parker et al. (2008) found that overall, BMPs had only minimal effects. Parker et al. (2008) monitored the base flow of a watershed that's usage was predominantly agricultural. Although they did not study cattle or horses specifically, they monitored BMPs that are commonly used for cattle and horse operations: vegetative buffer strips. They found that although certain measure could improve water quality, standards were not met (Parker et al.

2008). There was no major water quality improvement for the BMPs. Parker et al. (2008) determined that BMPs do reduce annual loadings, however there is only a minor improvement in water quality.

Inamdar et al. (2002) evaluated the effectiveness of BMPs on cattle farms over a 10 year period. They found that fecal coliform decreased at the watershed level, but increased at the subwatershed level, and that fecal streptococcus decreased at both levels (Inamdar et al. 2002). Since there was no definite or consistent increase in water quality, they believed it could be due to a lack of compliance (Inamdar et al. 2002). These results were more similar to the study performed by Parker et al. (2008).

V. Experimental Methods

Experimental methods used in the reviewed studies varied widely. Some were lab simulations; others were live and required grab samples. Others were focused on manure application, while some were concerned primarily on the direct effect of livestock operations.

Airaksinen et al. (2007) probably performed the most accurate and realistic experiment. They set up two stables, one cleaned daily and one left uncleaned. There were three sumps, one in the clean and two in the uncleaned stables to take the feeding areas into account. Measurements were taken in October, May and August. The samples were then tested for many parameters, among them TP, potassium, FC, TC and number of heterotrophs (Airaksinen et al. 2007).

Uussi-Kamppa et al. (2002) designed another realistic experiment studying cattle. They set up four pens each with eight cows for a total of 32 suckler cows. Soil samples were taken at different depths each fall and in different parts of the pen. Water was sampled two ways, first through a percolator and second, from a ditch next to a feed lot and flow was recorded. Samples were then tested for nutrients (TN, TP and NO3) (Uussi-Kamppa et al. 2002).

Derlet and Carlson (2002) developed a practical approach to studying horse feces. They traveled along the Sierra Nevada trails, taking samples every two miles that were within one mile from the trail. Samples were categorized into pack animal or wild animal using expert opinion and then screened for human pathogens, such as Cryptosporidium parvum, E. coli Ho157:H7 and Giardia (Derlet and Carlson 2002).

Atwill et al. (2002) used several different soil boxes with and without applied Cryptosporidium oocysts, which were obtained from a sample taken from an infected commercial dairy. Rainfall simulations were applied at different intensities. Because they used buffer strips, percent vegetative cover and height were also measured (Atwill et al. 2002). Finally, water was tested after moving through the buffer for Cryptosporidia to calculate the filtration efficiency (Atwill et al. 2002).

To study the prevalence of E. coli and fecal streptococcus, Weaver et al. (2005) collected three fresh and three dry manure patties from each pasture for the cattle experiment. For the horse experiment, there were four pastures, from which two fresh and two dry manure samples were taken and then tested for bacteria (Weaver et al. 2005).

VI. Conclusions

It is recommended that to lessen the impact of livestock operations, one should remain under the carrying capacity of the land, fence animals out of streams and lakes, and use riparian buffer systems, especially those that contain more than just grasses (Hubbard et al. 2004; Mawdsley et al. 2005). As seen by the potential pollutants measured in runoff from these types of facilities, these are important recommendations to keep in mind when working with equine operations or livestock operations in general.

There is a limited amount of information about the effects of equine operations on the environment, especially on water quality. There have been many studies focused on beef and dairy cows, most likely because the need for information is greater and the effects on the environment are more obvious. Cow manure is also more commonly applied to land than horse manure as a fertilizer. It is possible to take information from cattle manure and surface runoff studies and infer certain results. However, the accuracy of extrapolating this information to equine facilities is inadequate for the proper management of runoff generated by horse farms. It also is unclear as to how accurate the results from cattle operations are in regards to horse operations. Burnes (2003) showed similarities in the behavior of bacteria isolates from both cow and horse manure, confounding the issues of source tracking pollutants from horse facilities.

It also seems that there are gaps between even cattle operations studies. Many laboratory experiments measure runoff and gather helpful statistics, however the effects of manure runoff on watersheds was rarely studied or considered. There were also many studies that gave recommendations, such as vegetative buffer strips and culverts to control runoff. The large-scale effects were seldom taken into account. With equine facilities in abundance in states like New Jersey, there is a need to quantify the impacts of stormwater runoff on water quality, what BMPs can aid in lessening such impacts, and how to best incorporate sustainable environmental practices into horse facilities.

VII. References

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