I. 90-2 Summary form

OHIO SEA GRANT AND DEPARTMENT OF HIGHER EDUCATION PROJECT SUMMARY FORM (90-2)

PROJECT TITLE: Evaluation of the effects of changing on-farm manure management practices on reduction of dissolved phosphorus runoff
INSTITUTION: The Ohio State University

DEPARTMENT OF HIGHER EDUCATION FUNDS:
MATCHING FUNDS:

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OBJECTIVES: The ultimate goal of this research is to reduce phosphorus (P) runoff via improving manure management practices (focus on storage and liquid-solid separation) and reduce total P and dissolved P in manure prior to land application. To meet this goal, four specific objectives are proposed:
1. Conduct fundamental lab-scale study on manure storage, including the effects of storage duration, agitation duration and frequency, and seasonal effects (temperature, rainfall) on manure P solubility, nitrogen (N) loss, gas emissions, particle size distribution and liquid-solid separation efficiency;
2. Collect and analyze manures from Ohio’s dairy and swine farms to document manure management practices and manure characteristics;
3. Model impacts of potential changes in manure storage and timeliness of application on P reduction within watersheds during and after application;
4. Present the findings through education and outreach programs and document feedback from farmers on the likelihood of adopting new practices.

METHODOLOGY: The proposed study will be conducted for dairy manure and swine manure due to their high water contents and the large quantities generated on farms (Smeltz, 2012). Manure samples will be collected from farms with 100 or more animal units and liquid/slurry manure systems, and will include: 1) raw manure without liquid-solid separation, 2) the liquid portion of manure from gravity separation, and 3) the liquid portion of manure after mechanical liquid-solid separation. Separated solids from 2 and 3 will also be tested. The manure systems and factors of interest are summarized in Fig. 1.

Fig. 1 Project scope and factors (F1, F2, F3) to be considered during the evaluation.
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Task 1: Fundamental study of the effects of storage conditions on liquid manure characteristics and environmental emissions

Liquid manure will be collected from one dairy and one grower/finisher swine operation and stored in sealed 5-gallon buckets. To study the long-term storage process, tests will be started in November (fall) and May (spring) to emulate typical times for emptying and refilling manure storage systems. Dairy manure (fresh and separated effluent) and swine manure will be collected at each time period, stored under ambient conditions and sampled at 1 week, 1 month, 3 months, 6 months, and 12 months. A 10 L gas bag will be connected to each bucket to collect gas samples and prevent pressure buildup. An additional set of swine manure will be stored at the same condition to study agitation frequency and duration. At 6 months and 12 months, total P and dissolved P concentrations will be determined for agitation duration of 0, 1, 2 and 4 hours. Effects of freeze-thaw of 1-3 cycles will be evaluated using sealed plastic bags in a -4 °C freezer and a 4 °C refrigerator. Both frozen and thawed stages will last for 1 week and then samples will be collected for analysis. Gas samples will not be collected for frozen samples. Each treatment will have 3 replicates. Samples will be analyzed for total P, dissolved P, total solids content, pH, ammonia, and particle size distribution to predict liquid-solid separation efficiency and P runoff potential.

Task 2: Collect data from dairy and swine farms to document manure management practices and manure characteristics

Farms located in the Western Lake Erie Basin (WLEB) and GLSM that do and do not use liquid-solid separation will be identified by working with Ohio State Extension, Cooper Farms (swine integrator), and W.D. Farms (custom applicator). A total of 20 farms, 10 dairy and 10 swine, will be sampled for raw manure, liquid and solid streams for separated manure, and stored manure before land application, and the particle size distribution, total P, and dissolved P of each manure sample will be analyzed. Throughout the storage time (12 months), environmental conditions, solid-liquid separation activity, and storage time will be documented. The results will be compared with data collected in Task 1 to verify the lab scale tests and identify other possible important factors.

Task 3: Model the impact of potential changes in manure storage and timeliness of application on P reduction within the Grand Lake St. Marys (GLSM) watershed

Working with Ohio NRCS, ODA-Division of Soil and Water Conservation (DSWC), and OSU Extension personnel, the demographics of livestock farms and manure management practices within the watershed will be characterized. Using data from tasks 1 and 2, coupled with the demographics, the large scale impacts of changing manure storage time and/or implementing liquid-solid separation on P runoff will be evaluated. Results will be used to develop recommendations for livestock farmers.

Task 4: Present the findings through education and outreach programs and document feedback from farmers on the likelihood of adopting new practices

The information collected from this research will be organized and made available to livestock farmers, government agencies, OSU Extension personnel, custom manure applicators, and consultants via workshops, presentations, flyers, and other outreach programs, such as the Manure Science Review and Ohio Composting and Manure Management (OCAMM) website and listserv (425+). During education and outreach programs, questionnaires will be distributed to collect information from farmers regarding their likelihood of adopting the proposed changes and provide feedback on the feasibility of the proposed management practices.

RATIONALE: Eutrophication of waterways resulting from increased nutrient loading has become one of the major environmental issues worldwide. Land application of manure has been a significant contributor to the severe outbreaks of harmful algal blooms in Lake Erie and many Ohio lakes (Mina et al., 2017; Wines, 2015). One specific example of freshwater eutrophication is Ohio’s largest inland lake, Grand Lake St. Marys (GLSM), where livestock manure applied on cropland in the lake’s watershed is one of the primary causes for nutrient over-loading. The algal blooms in GLSM have generated health concerns for surrounding residents and directly affected the fishing and tourism industries, which play a significant role in the local economy. Unfortunately, on many farms, land application of animal manure remains the most
common, or even the only viable option. Freshly applied manure, especially if surface-spread, significantly contributes to nutrient runoff (Dou et al., 2003), and adoption of manure injection is relatively uncommon due to equipment costs and unfavorable soil characteristics (Mina et al., 2017). Also, even with incorporation, nutrients in manure can potentially transfer to infiltrating water flowing to tile lines and discharge into waterways.

Runoff of total and dissolved Phosphorus (P): P is the limiting nutrient in fresh water eutrophication. Since animal manure is typically applied to meet crop nitrogen (N) demand, P application is usually much higher than the amount that crops can uptake (Kleinman et al., 2015). Among different forms of P, dissolved P, comprised mostly of orthophosphate, is immediately available for uptake by algae and aquatic plants and is therefore of particular concern for waterways (Zhang et al., 2004). Dissolved P also appears to have a higher risk for runoff due to its high mobility (Kleinman et al., 2005). Thus, reducing the dissolved P in manure is another key aspect to control P runoff and reduce outbreaks of algal blooms associated with manure land application. With the significant reduction of total P by various management practices implemented since 1975, dissolved P loads to the Western Lake Erie Watersheds (WLEW) have increased since 1995 and have become a major trigger of harmful algal blooms in Ohio lakes (Kleinman et al., 2015).

Reducing dissolved P by manure management: Manure management has been an area of active research, outreach, and extension to reduce P runoff (Mina et al., 2017). The timing and rate of manure land application has been restricted in northwest Ohio regions due to the high nutrient concentration, especially P, in the soil. There is an opportunity to develop management strategies and practices to help farmers manage manure P in a way that is environmentally acceptable and economically sustainable. Currently, most manure management practices focus on reducing the total P loading from manure, while new approaches on how to reduce dissolved P from liquid manure land application have yet to be explored.

Manure liquid-solid separation: Mechanical liquid-solid separation can remove up to 70% total P and 30% total N from liquid manure before land application, and the solid portion can be recycled or be more economically transported outside of the watershed (Møllér et al., 2002). In addition, a recent study conducted by the PI’s team showed that liquid-solid separation by a screw press can significantly reduce the ratio of dissolved P to total P in dairy manure from around 50% to 15-20%, and the solids can be reused for bedding (Lawson, 2017). This result has the potential to economically reduce the dissolved P run off for farms that cannot perform manure injection. The separation technology and equipment are currently available, and the treatment does not require addition of any chemicals or generate harmful wastes.

Effect of manure storage temperature, duration, and agitation: Manure is usually stored from a few days to up to one year before land application. During storage, microbial activities and physiochemical processes, such as mineralization, coagulation, and precipitation continuously change the chemical and physical properties of manure. Previous studies have shown that the freeze-thaw process can significantly enhance the liquid-solid separation of manure and thus reduce the P concentration in the liquid stream (Sabri, 2017). An 8-month storage of swine manure significantly reduced the fine particles and enhanced the solids settlement (Kunz et al., 2009). Changes in storage temperature, duration and agitation may affect the properties of manure in terms of liquid-solid separation efficiency and P solubility, as well as the emission of harmful gases during manure storage.

Knowledge gaps and potential work: Previous studies regarding manure storage were mostly focused on nitrogen loss or greenhouse gas emissions. The effects of different storage conditions on the changes of P solubility and ease of liquid-solid separation have not been systematically studied. Considering that these two factors significantly affect the P runoff potential of manure and the cost of manure management, a thorough study using controlled lab scale experiments will provide useful information to improve current manure management systems. Based on preliminary data and literature review, effects of manure storage conditions, including temperature, water content, storage time, and agitation frequency and duration during storage on the solubility of P in manure and the ease of liquid-solid separation of manure will be investigated. In addition, manure samples from farms in the GLSM watershed and WLEW will be collected at the time of land application to analyze for dissolved P levels. The research findings will be used to suggest best management strategies to mitigate P runoff. The knowledge from this research will be distributed through outreach programs, and the feedback from participants will provide insight into the feasibility of the proposed management system.