Evaluating the Reuse of Swine Lagoon Effluent and Reclaimed Municipal Water for Agricultural Production

1. **Statement of critical regional or State water problem.** Include an explanation of the need for the project, who wants it, and why.

   Significant amount of water in Oklahoma is used for crop irrigation. Water shortage in Oklahoma and the Southern Great Plains has become a major limitation for crop production and other uses, which will have a major impact on local economy. Therefore, alternative sources of irrigation water need to be explored. Treated municipal wastewater (TWW) is one of the most readily available alternative water sources, although infrastructures to use TWW for crop irrigation are lacking in most places and public acceptance is probably low because of the lack of field evaluations in the state. Currently, most TWW in the state is directly discharged to streams and rivers rather than recycled for crop production. Treated swine lagoon effluent is also available in west Oklahoma and other regions. Although swine effluent has been used to irrigate crops, more water use efficient application techniques need to be evaluated and promoted.

   In recent years, drought conditions have caused Oklahoma municipalities to rethink the reuse of wastewater through irrigation. OSU and the City of Chickasha have entered into an agreement to test the use of the recyclable municipal water for irrigation at the South Central Research Station near Chickasha. The reclaimed municipal wastewater can be a valuable water source for irrigation, but it contains common salts and other compounds. Baseline of soil salinity needs to be established and continuously monitored in order to sustain the practice. Knowledge gained from this project can be used by the City of Chickasha to expand its use of treated wastewater for other agricultural purposes. It can also guide other communities to safely recycle their treated wastewater.

   Oklahoma has over 2-million hogs and generates a great amount of effluent annually. Odor emission and nutrient loss are major challenges face swine producers. Oklahoma State University (OSU) built a state-of-the-art swine facility 10 years ago in order to demonstrate efficient and environmentally friendly management practices for swine production. Subsurface drip irrigation of the lagoon effluent has been used to increase water and nutrient use efficiency, reduce nutrient loss in runoff and to mitigate odor. The effluent from the two-stage anaerobic digestion lagoon has been applied to a 27-acre adjacent field through subsurface drip irrigation at 18-inch depth to produce forage, primarily bermudagrass since the construction of the facility. However, the effluent is continuously applied to the field but the nutrient use efficiency, distribution of N, P and salts in the soil profile, and leaching potential of nitrate have not been evaluated since the facility began operation in 2004. Many hog farmers in the Oklahoma Panhandle are considering installing subsurface drip irrigation system to improve water use efficiency, and lessons learned from this pilot project will ensure their successful transition from center pivot irrigation to subsurface drip system.
This proposal addresses the 2016 Water Research Funding Priorities 5 (Conservation) and 6 (Marginal Quality and Reuse Water) as well as soil health under Priority 8 (Ecosystem Services).

2. **Statement of results or benefits.** Specify the type of information that is to be gained and how it will be used.

   With the thorough evaluation of nutrient, pH and salinity distribution of the field used to land apply swine effluent from OSU Swine Facility and the physical condition of the irrigation tape and pipes, we will have a better understanding of how sustainable subsurface drip irrigation is and what measure needs to be taken to improve its efficiency and longevity. We’ll also know the nutrient use efficiency and potential impact of applied nutrients on the environment, such as if N, P and salt have been built-up in the soil and if significant amount of nitrate has moved out of the topsoil towards groundwater. If those potentials exist, recommendations will be made to the facility manager as to what can be done to alleviate the problem. Findings of the study will be disseminated at OSU in-service trainings, NRCS nutrient management training, and other extension programs. A factsheet on subsurface irrigation with swine effluent will be produced and disseminated widely. Similar findings are expected from the recycled wastewater irrigation site and recommendations on the appropriate amount and timing of irrigation will be developed based on monitoring data and disseminated to other municipalities with potential to recycle wastewater. Through this project we will develop a better understanding of land application of wastewater, by thoroughly examining field conditions at the start of one project and 11 years into the life of another. Lessons learned from the effluent site can be applied to the new site or other locations to avoid any negative agronomic and environmental impacts.

3. **Nature, scope, and objectives of the project.** Include a timeline of activities.

   This project is to further evaluate the benefits and negative impacts of 2 alternative irrigation water sources. The first is an ongoing subsurface drip irrigation system using swine effluent and the other is a surface application of treated municipal wastewater. Nutrient and salt distribution and movement in soil profiles will be thoroughly examined. Phosphorus can be built up in the soil if animal manure and municipal wastewater is repeatedly applied to agricultural land and the loss of P in runoff will be escalated. In addition, nitrate can be leached into groundwater and contaminate water resources. Both swine effluent and treated municipal wastewater contain soluble salts and have the potential to buildup to detrimental level under arid and semi-arid climate. The sustainability of both of those systems has not been thoroughly evaluated in Oklahoma, and it is impractical to recommend those water reuse methods to farmers without knowing the fate of nutrients and potential contaminants, and the durability of the subsurface drip irrigation components. Thus, we propose to thoroughly evaluate the swine effluent subsurface drip irrigation system already in use for 11 years near the Swine Research Facility in Stillwater by monitoring nutrient inputs (nutrient concentration and quantity of effluent applied annually and the total amount since the beginning), outputs (forage removal), residual nutrients in the surface and subsurface soils, and nutrient movement in soil profiles; and to begin monitor the proposed municipal wastewater reuse project
located at the South Central Research Station in Chickasha by establishing a baseline of nutrients and major contaminants at the beginning of the project, and monitor changes of those parameters every 6-month thereafter. A computer model (HYDRUS) will be used to simulate water and nutrients dynamics in the soil.

Both projects will be conducted simultaneously beginning March 1, 2016 or as soon as the funding is available. Although the fund requested is for one year, we have other resources available and will continue the study for at least 2 years. Initial soil samples will be collected in March and April 2016. Lysimeters will be installed in May before irrigation starts. Continuous water and plant sampling will take place during the year. Samples will be processed and analyzed shortly after they are collected. Data analysis and the preliminary report writing will take place in January and February 2017.

4. **Methods, procedures, and facilities.** Provide enough information to permit evaluation of the technical adequacy of the approach to satisfy the objectives.

The field where the subsurface drip irrigation of swine effluent was installed is shown in Figure 1. We conducted a one-acre grid soil sampling (0-6” only) before the sub-surface irrigation was installed and we have the detailed information of surface soil nutrient status before the effluent was applied to the field. Therefore, we will use those data as the baseline for the evaluation. A new set of grid soil samples up to 1 m deep will be collected from the same acre-grid to assess current nutrient status of the surface and subsurface soils. The profile samples will be separated into 0-6”, 6-12”, 12-24” and 24-36” segments. One of the acre-grids (Grid 15) will be further divided into 25 sub-grids for a higher resolution soil testing (shown on the right side of the field map on Figure 1). Soil samples will be analyzed for pH, plant available N, P, K and electrical conductivity (EC). Five pairs of lysimeters will be installed at selected locations at 2 and 4 feet deep, and water samples from lysimeters will be collected to monitor nitrate leaching potential to groundwater. Nutrient and EC maps will be generated using GIS software and plotted vertically with soil depth. Forage yield and quality, and effluent application quantity and timing will be determined and closely monitored during the study. Past and present effluent and forage analysis data will be used to calculate the nutrient balance of the entire system. The conditions and effectiveness of the irrigation tape after 11 years in operation will be evaluated as well.
Figure 1. Aerial view and geo-referenced points for grid sampling the 26.9-acre field. Expanded view of cell-15 shows “high resolution” cell designations.

Similar soil and plant health monitoring will also be conducted at the South Central Research Station in Chickasha where the reclaimed municipal wastewater will be used for irrigation. Soil samples will be collected to 1 m deep at the beginning of the project, and 0-6” soil samples will be collected every 6-month thereafter. Meter deep soil sampling will be repeated 2 to 3 years from the beginning of the study. Lysimeters will be installed at the beginning of the project and water samples will be collected and analyzed monthly if samples are available. This site was recently equipped with two variable-rate sprinkler irrigation systems: a linear move and a center pivot. The fact that these systems allow a variable rate of application enables us to investigate the impact of different wastewater application rates on soil chemical and physical properties. Figure 2 demonstrates an aerial view of this site.
Figure 2. Aerial view of the municipal wastewater reuse site near the city of Chickasha, where two sprinkler irrigation systems are installed. The straight purple line shows the location of current underground pipe that takes the municipal wastewater from the treatment facility and discharges into the Washita River.

In addition to the field sampling and measurements, the HYDRUS computer model will be used to simulate water and nutrients dynamics in the soil. HYDRUS numerically solves the Richards equation and can model the movement of up to fifteen solutes in the variably-saturated soil medium while accounting for any uptake by crop roots (Šimůnek et al., 2011). Once this model is validated for the specific conditions of the two study sites near Stillwater and Chickasha, it can be run for hypothetical scenarios such as variable precipitation and irrigation (wastewater) application depths.

5. **Related research.** Show by literature and/or communication citations the similarities and dissimilarities of the proposed project to completed or on-going work on the same topic.

Animal manure can be an asset rather than a liability for producers when effectively managed and properly used on field crops (Richards et al., 2011; Tang et al., 2007; Zhang et al., 1998). Besides providing valuable macro- and micro-nutrients to the soil, manure supplies organic matter to improve the soil’s physical and chemical properties. It also increases infiltration of water and enhances retention of nutrients, reduces wind and water erosion, and promotes growth of beneficial organisms (Zhang, 2009). Lagoon effluent can be a good source of water and
nutrients for crop production if it is managed properly (Carreira, et al., 2006). Although nutrient concentrations in lagoon effluent tend to be low, large volumes of effluent are often available from concentrated animal feeding operations. Therefore, the total potential nutrient for crop production is quite high (Zhang, 2014). Almost all the treated swine effluent generated in the US is land applied using high-volume sprinkler irrigation system and little is distributed with the more efficient subsurface drip irrigation (SDI). Challenges and concerns with sprinkler irrigation of swine effluent are water losses, odors, ammonia emissions especially under hot and dry conditions, and potential pathogen contamination of waterbodies (Stone et al., 2008). Limited research done so far on subsurface drip irrigation has been based on short term and small plot experiments (Carreira et al., 2006; Lamm et al., 2002; Lamm et al., 2012; Stone et al., 2008). The proposed project has been in place for 11 years and makes it one of the longest similar systems to be evaluated. In general, SDI losses less water and achieves higher crop or forage yields compared to the center pivot irrigation system. However, fields under SDI may have higher residual nitrate nitrogen in soil due to less N losses (Lamm et al., 2002 and Stone et al., 2008). Nitrate N in the soil subjects to leaching loss towards groundwater. This may be a potential threat to groundwater quality. We will be able to verify if nitrate movement is a threat to groundwater quality through the proposed evaluations. Historically, rates of manure application were based on the N requirement of the crop, and the amount of P in the soil or the requirement of P by plants was typically not considered when deciding manure application rates. This practice has resulted in a significant increase in soil P since the N/P ratio of manure is typically lower than what is required by plants (Pote et al., 1996; Gotcher et al., 2014)). Hence, fertilizing crops with manure based on the agronomic N needs will result in over applying P. Over time, this practice may saturate the soil’s P sorption capacity near the soil surface and in deeper layers, causing an increase in soil P which has been shown to increase dissolved P in runoff (Sharpley et al., 1994; Wang et al., 2010). No studies, however, have evaluated the buildup and distribution of phosphorus in soil profiles under SDI since the irrigation tape is buried 18” below soil surface, which makes the proposed project unique and highly valuable.

Reclaimed wastewater from sewage treatment plants have been widely used for various purposes in the world especially used for irrigating croplands in arid and semi-arid regions (Pedrero et al., 2010; Qadir et al., 2010; Xu et al., 2010). The treated wastewater irrigation is considered an important supplement water supply, but it has both positive and negative impacts on the receiving land and the environment (Qadir et al., 2010). Treated wastewater contains organic matter and essential plant nutrients such as nitrogen, phosphorus and potassium. Therefore, it will improve soil fertility and productivity of the effluent-irrigated soils (Xu et al., 2010). Irrigation with TWW increased soil organic matter, and total nitrogen contents as well as EDTA-extractable micronutrients in the soil (Rusan et al., 2007; Xu et al., 2010). Cirelli et al. (2012) found that TWW irrigation not only significantly increased the total yields of tomato and eggplant but also increased the number of marketable fruits. However, TWW also contains salts, heavy metals and organic chemicals such as pharmaceuticals and personal care products. Long-term irrigation with TWW
lowered soil pH and elevated soil electrical conductivity (EC) suggesting soluble buildup in the soil (Xu et al., 2010). Both of those changes can negatively impact soil quality and productivity. Xu et al. (2010) also concluded that trace contaminants such as heavy metals may be accumulated in the soil and lead to deterioration of soil and groundwater quality. Therefore, it is important to properly manage wastewater irrigation and periodically monitor soil and plant quality parameters. As far as we know, there has been no evaluation of using treated municipal wastewater as irrigation water done in this state. Many people are skeptical about using it to produce forage or field crops. It is urgently needed to demonstrate the benefits and potential problems of using TWW for agricultural production so that another alternative water source is available to farmers.

References:

6. **Training potential.** Estimate the number of graduate and undergraduate students, by degree level, who are expected to receive training in the project.

   One MS graduate student will be recruited for this project. And several undergraduate students will be hired to assist in sample collection and lab analyses. In addition, field tours and in-service trainings will be offered to extension educators and famers to further disseminate the project findings.

7. **Investigator’s qualifications.** Include a resume(s) of all principal investigator(s). No resume shall exceed two pages or list more than 15 pertinent publications.

   Attached below.
HAILIN ZHANG  
368 Agriculture Hall  
Dept. of Plant and Soil Sciences, Oklahoma State University, Stillwater, OK 74078  
405-744-9566, 405-747-7786 (cell) Hailin.zhang@okstate.edu

Position Held
7/2011 – Present: Regents Professor and Arthur L. Reed Chair, Extension Nutrient Management Specialist and the Director of Soil, Water and Forage Analytical Laboratory (SWFAL), Department of Plant and Soil Sciences, Oklahoma State University.
7/2007 – 6/2011: Santelmann/Warth Distinguished Professor, Extension Nutrient Management Specialist and the Director of SWFAL, OSU.
7/2004 – 6/2007: Professor, Extension Nutrient Management Specialist and the Director of SWFAL, OSU.
7/2001 – 6/2004: Associate Professor, Nutrient Management Specialist and the Director of SWFAL, OSU.
8/1996 – 6/2001: Assistant Professor, Nutrient Management Specialist and the Director of SWFAL, OSU.

Education
Ph.D., 1990 - University of Minnesota, Soil Chemistry.  
M.S., 1986 - Iowa State University, Soil Chemistry.  
B.S., 1982 - Nanjing Agricultural University, P. R. China,

Professional Activities
4. Associate Editor, Journal of Environmental Quality, 2014-  
5. Technical Editor, Agricultural and Environmental Letters. 2015-

Recent Honors and Awards
1. The James Whatley Award for Meritorious Research in Agriculture, Division of Agricultural Sciences and Natural Resources, OSU, 2005;  
2. Santelmann/Warth Professorship, OSU, 2007-2011;  
3. Fellow of the American Society of Agronomy. 2008;  
4. Regents Distinguished Research Award. OSU, 2008;  
5. Fellow of Soil Science Society of Agronomy. 2009;  
6. Regents Professor, OSU Board of Regents. 2011;  
7. The Arthur L. Reed Endowed Chair, OSU. 2011-present;  
8. Sarkeys Distinguished Professor Award, Division of Agricultural Sciences and Natural Resources, OSU, 2013.

Selected Peer Reviewed Publications (134 total)


Saleh Taghvaeian  
(405) 744-8395  
saleh.taghvaeian@okstate.edu  
Curriculum Vitae

Education  
PhD: Irrigation Engineering (2011)  
Civil and Environmental Engineering Department, Utah State University, Logan, UT  
Master of Science: Irrigation Engineering (2006)  
Irrigation and Drainage Engineering Department, Ferdowsi University, Mashhad, Iran  
Bachelor of Science: Irrigation Engineering (2003)  
Irrigation and Drainage Engineering Department, Ferdowsi University, Mashhad, Iran

Professional Experience  
Assistant Professor & Extension Specialist (Jul 2015 – Present)  
Biosystems and Agricultural Engineering Department, Oklahoma State University, Stillwater, OK  
Biosystems and Agricultural Engineering Department, Oklahoma State University, Stillwater, OK  
Postdoctoral Fellow (Jul 2011 – Oct 2013)  
Civil and Environmental Engineering Department, Colorado State University, Fort Collins, CO  
Research and Teaching Assistant (Apr 2007 – Jun 2011)  
Remote Sensing Services Laboratory, Civil and Environmental Engineering Department, Utah State University, Logan, UT  
Teaching Assistant (Jun 2007 – Jun 2011)  
Utah Water Research Laboratory, Utah State University, Logan, UT

Awarded Research Grants  
| PI   | $181,000  
| Co-PI | $359,000  
| Total | $540,000

Professional Affiliations
American Geophysical Union (AGU)
American Society of Civil Engineers (ASCE)
  o Active member of Irrigation and Drainage Council
Soil and Water Conservation Society (SWCS)
U.S. Committee on Irrigation and Drainage (USCID)
American Society of Biological and Agricultural Engineers (ASABE)

Awards
- The ASA Excellent Extension Materials Award for “Smart Irrigation Technology: Controllers and Sensors”
- The ASABE Educational Aids Blue Ribbon Award in the Electronic Delivery category for “Foundations of Oklahoma Water”
- The ASABE Educational Aids Blue Ribbon Award in the Electronic Delivery category for “Garden Irrigation Kit”

Publications

Peer-Reviewed Journal Articles

Book Chapter
Douglas W. Hamilton, Ph.D. P.E.
Associate Professor and Extension Waste Management Specialist.
Biosystems and Agricultural Engineering. Oklahoma State University
Stillwater, OK  74078
dhamilt@okstate.edu  405-744-7089
http://osuwastemanage.bae.okstate.edu  www.youtube.com/osuwastemanagement

EDUCATION
Ph. D.  Agricultural Engineering  Pennsylvania State University. 1992
M.S.  Agricultural Engineering  Iowa State University. 1985
B.S.  Agricultural Engineering  University of Arkansas. 1983

PROFESSIONAL EXPERIENCE
Associate Professor  Biosystems and Agricultural Engineering and Extension Waste Management Specialist  Oklahoma State University 2000-present
Assistant Professor  Biosystems and Agricultural Engineering and Extension Waste Management Specialist  Oklahoma State University 1995-2000
Assistant Professor  Biosystems and Agricultural Engineering and Extension Soil and Water Specialist  University of Tennessee. 1992-1995.
Inspection Engineer II  Department of Pollution Control and Ecology  State of Arkansas 1985-1988

PROFESSIONAL REGISTRATION
Tennessee:  PE # 00101266

AWARDS
Secretary of Agriculture Honor Award.  2002. Leadership of Oklahoma Poultry Waste Management Education Team.

PROFESSIONAL ASSOCIATIONS
American Society of Agricultural and Biological Engineers
Water Environment Federation
Air and Waste Management Association

ELECTED SCIENTIFIC AND SERVICE COMMITTEES.

SELECTED PUBLICATIONS


SCOTT D. CARTER, Ph.D.

EDUCATION:
1995    Ph.D. in Swine Nutrition, University of Kentucky, Lexington, KY
1989    B.S. in Animal Science, Oklahoma State University, Stillwater, OK

EMPLOYMENT HISTORY:
7/03 – Present  Associate Professor, Oklahoma State University, Stillwater, OK
8/97 – 6/03  Assistant Professor, Oklahoma State University, Stillwater, OK
1995 - 7/97  Assistant Professor, North Dakota State University, Fargo, ND.
1989 - 1995  Graduate Research Assistant, Univ. of Kentucky, Lexington, KY.

PROFESSIONAL ACTIVITIES:
American Society of Animal Science
  Associate Editor – Animal Production (2008 – 2010)
National Swine Nutrition Guide Steering Committee
N CCC-42 Committee on Swine Nutrition.
S-1044 Committee on Sow Nutrition.
Oklahoma Pork Council, Ex-Officio Board Member

TEACHING RESPONSIBILITIES:
ANSI 3543  Principles of Nutrition
ANSI 4643  Swine Science
ANSI 5110  Special Problems – Adv. Swine Nutrition
ANSI 5773  Protein Nutrition
ANSI 5783 Vitamin and Mineral Nutrition

DEPARTMENTAL RESPONSIBILITIES:
Animal Quadrathlon Competition Chair
Teaching Committee
Awards Committee
Institutional Animal Care and Use Committee Member
Faculty Advisor for OSU Swine Research and Education Center
OSU Swine Club Advisor

RECENT SELECTED PUBLICATIONS:


