Hog Waste Lagoons in North Carolina Prove to be an Inefficient Waste Management System as Demonstrated through Multiple Focus Studies

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DEDICATION

This study is dedicated to the Waterkeeper Alliance, affiliated Waterkeeper programs, and the Waterkeepers that have so courageously and diligently fought for the keystone of our existence and continuity through the protection and preservation of that which we would not persist: Water. I also dedicate this study to all those brave citizens that have put their lives and livelihoods in jeopardy in order to fight for environmental justice.

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I wish to thank American Public University and the dedicated staff that have expertly guided me through each course on my path to earning my Master's in Science. For they have served as a lighthouse in my most stormy navigations.

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Abstract

Coastal North Carolina is home to an absorbent amount of concentrated animal feeding operations (CAFOs); largely hog and poultry. Throughout the years researchers have documented impacts to public health, environmental quality, environmental justice, and residential property costs to show the inefficiencies of the waste management systems used by the industrial farming industry. The hog industry in particular has yet to innovatively adopt new waste management systems. Some hog CAFOs have ended operations yet left behind waste lagoons without any further environmental restoration to prevent leaking into nearby waterways or contamination of residential water wells. While thousands more still utilize the hog waste lagoon and spray method of hog waste management.

This thesis uses extant data to examine the extent of hog waste lagoon inefficiencies and highlights the need for further innovative research on hog waste management systems. The latest data on hog waste lagoons research were published in 2015 and was completed by the United States Geological Survey in conjunction with the North Carolina Department of Environment and Natural Resources' Division of Water Resources. The data produced by this study is displayed on the North Carolina Animal Feeding Operation (AFO) page for North Carolina Department of Environmental Quality (NCDEQ) as the latest water quality information regarding CAFOs. However, the NCDEQ states that the study in no way concludes that CAFOs are in violation of water quality standards while the study concludes that North Carolina waterways are measurably impacted by CAFOs.

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LIST OF ABBREVIATIONS

BAV	Beach Action Values
CAFO	Concentrated Animal Feeding Operation
CFU	Colony-Forming Unit
FTIR	Fourier Transform Infrared
GIS	Geological Information System
IFAP	Industrial Feed Animal Production
mFC	Modified Fecal Coliform
mL	Milliliter
MST	Microbial Source-Tracking
POC	People of Color
SSLW	Steady State Live Weight
VOCs	Volatile Organic Compounds

Introduction

A Background of Hog Farming in North Carolina

Historically, dating before 1979, in North Carolina hog farms were small family-owned agricultural operations that gave families the flexibility to trade their hogs, use the hog waste as fertilizer, and eat the hogs the families have raised and traded (McKown, 1999). This practice took a major turn when corporate owners began signing contracts with these families to run a different sort of operation with higher output (McKown, 1999). The state encouraged this evolution in farming by offering incentives to the contracted farmers, making the changes appealing, and mostly necessary, to keep the farms "family farms" so to speak (McKown, 1999). The hog operations result in more capital outside of the local community rather than contributing directly to the community positively (Bullers, 2005). Small family farms cannot compete with such large scale hog operations and have been mostly eliminated by larger, corporate operations (Bullers, 2005).

However, the waste management of these farms failed to evolve as the numbers of individual livestock rose with these corporately owned large scale hog farm operations. The State failed to address these environmental implications, and in 1995 Oceanview Farms experienced a hog waste manure spill resulting in approximately 25 million gallons of hog waste into Onslow County, North Carolina's New River (McKown, 1999). This massive hog waste spill triggered the General Assembly to enact a Moratorium, halting the construction of new hog waste management systems, the expansion of hog farms, and giving counties the authority to enact zoning regulations (McKown, 1999). In spite of this, today there are still pending investigations

into hog farms located in North Carolina alleging the antiquated hog waste management systems result in human and environmental harm (McKown, 1999). Lagoon breaches occur with or without natural disasters and have caused fish kills, simultaneous mass deaths of fish within an area.

The corporate hog industry argues that the industrial farm practices are comparable to traditional agricultural methods (Bullers, 2005). An industrial hog operation may house approximately 10,000 head of hog, which can produce the same amount of waste as a city with a population of 25,000 individuals (Bullers, 2005). Just as it would be unsanitary to store the amount of waste produced by 25,000 individuals in an open-air pit to later be sprayed raw onto a spray field, it would also prove to be an inadequate waste management process for 10,000 heads of hog, logically (Bullers, 2005).

Hog Farming in North Carolina Today

An acrid smell permeates the air throughout Duplin County, North Carolina. Driving through the county the source is not immediately always evident through the tree lines. Thanks to Duplin County citizens and aerial photographs taken by environmental non-profit groups, the earthen open-air hog waste lagoons and spraying technique are pinpointed as the source of this stomach churning smell. These unlined pits contain millions of gallons of raw hog waste that is later sprayed onto a nearby field called a “spray field”. As waste management systems go, this process is hardly innovative.

According to a late 1990’s estimate, North Carolina is home to about 2,400 large-scale hog farms called concentrated animal feeding operations (CAFOs) (Waterkeeper Alliance,

2017). The southeasterly coastal reaches of North Carolina house the most concentrated area of these hog CAFOs in the world (Waterkeeper Alliance, 2017). The coastal areas in the south eastern part of the United States are routinely hit by tropical storms and are prone to flooding. This is one of the myriad reasons the utilization of open-air pits as hog waste management systems has come into question in multiple studies throughout the last several decades.

The battle to enforce water quality protections and social justice for minorities, whom are disproportionately impacted by these hog CAFOs has been more recently adopted by environmental and social justice groups. Among them are Waterkeeper Alliance and the Environmental Working Group. The Waterkeeper Alliance and Environmental Working Group jointly worked on and published an interactive map of comprehensive data exposing the locations and details of each CAFO in North Carolina. These data show that approximately "10 billion pounds of wet animal waste" is generated in North Carolina alone on an annual basis (Waterkeeper Alliance, 2017). This research paper examines the extant data publically available to comprehensively evaluate the water quality results pertinent to the waterways adjacent to such CAFO hog waste management systems and serves to document to what extent these hog waste management systems contaminate the waterways with nutrients and impact human and environmental health.

Major Topics of Concern
Odor
Respiratory Health
Ground Water Quality/Contaminated Well
Violations of Regulations

Waste Getting on Property
General Health
Traffic

Table 1. Major topics of concern as reported by agricultural and permitting agencies in descending order (Fry, Laestadius, Crechis, Nachman, and Neff, 2014)

Literature Review

A History of Legal Cases Involving Hog CAFOs

One of the first legal actions to make it to North Carolina Court of Appeals against a hog farm is *Parker v. Barefoot.* In this case, twenty-seven community members in North Carolina came together against a 95 acre hog farm with four hog houses and approximately 2,880 hogs owned by Terry and Rita Barefoot to file a "nuisance suit" (McKown, 1999). Citizens complained that the waste from the hog farm was permeating through the community and causing physical harm to the citizens by impacting their respiratory systems and burning their eyes (McKown, 1999). The counter-argument by the farmers was that they were using the latest technology and equipment to manage their hog waste (McKown, 1999). The Plaintiffs implored the trial judge to inform the jury that a state-of-the-arts technology defense is not applicable to this particular suit, as North Carolina does not recognize such a defense (McKown, 1999). However, the jury ruled in favor of the Defendants and the Plaintiffs countered with an appeal (McKown, 1999). The Plaintiffs were granted a new trial due to the determination that the jury

trial judge acted on reversible error by failing to present to the jury that the neighbors could legally still file a nuisance suit if the farm's emissions were negatively impacting the Defendant's property regardless of whether the Barefoot's used state-of-the-art technology (McKown, 1999). In appellate court the judge determined that the jury could be influenced by the state-of-the-art technology details put forth. However, in the new trial the judge, Judge Martin, determined that the neighbor's appeal was not convincing (McKown, 1999). The judge ruled in favor of the Defendants (McKown, 1999).

While this case ended with a ruling in favor of the hog farm's owner, it also set a standard for determining nuisance suits in that a jury must be instructed that a state-of-the-art defense is not an adequate standalone defense for noxious farm emissions (McKown, 1999). Inevitably where there are human health complaints in cases such as *Parker vs. Barefoot* there are in conjunction with these also environmental impacts, as the particles are carried by air, water, or soil. This case took place around the same time that new hog farm and water quality amendments were being added to the *right to farm* legislature by the North Carolina General Assembly in response to the massive Oceanview Farms hog waste spill into the New River. While this gave Counties more authority to respond to citizen's complaints regarding hog farms, the *right to farm* legislation made hog farms exempt from ordinances, complicating interpretation (McKown, 1999).

Environmental Impacts and Residential Property Values

Palmquist, Roka, and Vukina (1997) analyzed the impact of hog CAFOs on the environment and the subsequent property value impacts due to degraded environment and human

health of those residents near large scale hog operations. What these researchers noted was the concern local citizens harbored for the excessive odors and possible ground and surface water contamination stemming from hog operations near their residences (Palmquist, Roka, and Vukina, 1997). And to do this a hedonic methodology was used. Hedonic regression is the process in which the value of a home is directly linked to a number of characteristic tied to the residence and the value placed on those qualities by residents; for example, environmental quality (Palmquist, Roka, and Vukina, 1997).

Nine south eastern North Carolina counties were included in this study: Bladen, Duplin, Greene, Johnson, Lenoir, Pender, Pitt, Sampson, and Wayne (Palmquist, Roka, and Vukina, 1997). The calculation for number of hogs in Duplin County in 1993 was approximately ten times greater than Pender County according to the North Carolina Department of Agriculture (Palmquist, Roka, and Vukina, 1997). Data on home sales for these nine counties were collected for 237 individual sales over the course of one year and seven months between 1992 and 1993 (Palmquist, Roka, and Vukina, 1997). A number of characteristics were included in this analysis. Due to geographic location being pertinent to the study this meant hog farm data were allowed to be incorporated (Palmquist, Roka, and Vukina, 1997). At the time of this study hog farm locations were, by law, confidential. Instead, number of herd and heads of herd were produced courtesy of the State Veterinarian's office of North Carolina and these data were used to quantify amount of hog waste produced annually. The result was 1 and ½ tons of hog waste per year. In conclusion to the study it was determined that within ½ mile of a hog operation home value decreased by 4.75%, with less of an impact to home value further out from the hog operation, leading to a decrease of approximately ½ a percent at two miles out (Palmquist, Roka, and Vukina, 1997). It is notable that out of 237 home sales 232 homes had a hog operation within

two miles of the residence (Palmquist, Roka, and Vukina, 1997). Below is a table provided by Palmquist, Roka, and Vukina indicating predicted house value in relation to the locations of distribution to hog operations. This is important as an environmental indicator provided by housing markets, highlighting the presence of hog manure.

MAN	Location in Distribution	Predicted House Value		Predicted Change in House Value When a New Operation Located within:		
				$\frac{1}{2}$ Mile	1 Mile	2 Miles
.725	$\frac{1}{8}$	$63,272	$ change	−$5,339	−$2,279	−$2,266
			% change	−8.44%	−3.60%	−3.58%
2.309	$\frac{1}{4}$	$62,517	$ change	−$4,585	−$1,563	−$1,551
		($61,948–$63,086)[a]	% change	−7.33%	−2.50%	−2.48%
13.563	$\frac{3}{8}$	$61,381	$ change	−$3,450	−$649	−$641
		($60,029–$ 62,733)	% change	−5.62%	−1.06%	−1.04%
33.107	$\frac{1}{2}$	$60,816	$ change	−$2,889	−$346	−$340
		($59,078–$62,554)	% change	−4.75%	−0.57%	−0.56%
50.025	$\frac{5}{8}$	$60,557	$ change	−$2,632	−$248	−$244
		($58,642–$62,472)	% change	−4.35%	−0.41%	−0.40%
118.82	$\frac{3}{4}$	$60,016	$ change	−$2,103	−$116	−$113
		($57,736–$62,296)	% change	−3.50%	−0.19%	−0.19%
311.47	$\frac{7}{8}$	$59,420	$ change	−$1,537	−$46	−$45
		($56,742–$62,098)	% change	−2.59%	−0.08%	−0.08%
11,016.0	1	$57,266	$ change	−$167	−$1	−$1
		($53,182–$61,350)	% change	−0.29%	−0.00%	−0.00%

Table 2. Home values in relation to proximity to hog operations in nine south eastern North Carolina counties (Palmquist, Roka, and Vukina, 1997).

Disproportionate Environmental Impacts to Minority Communities

The hog waste lagoon and spray waste management systems result in air pollutants that reach nearby residences and cause a myriad of human health impacts; including anxiety, stress, respiratory illness, impaired lung function, and even systolic blood pressure elevation (Wing and

Johnson, 2014). This study uses State records of permitted hog CAFOs to determine size and locations of the hog CAFOs (Wing and Johnson, 2014). With this data, the researchers were able to quantify amount of feces and urine produced by the hogs that are housed on these CAFOs (Wing and Johnson, 2014). The 2010 United States Census was used to gather data race and ethnicity and block levels (Wing and Johnson, 2014). The number of Blacks, Hispanics, and American Indians located within a 3 mile area of a hog CAFO was documented (Wing and Johnson, 2014). Then the relationship between the presence of one of the minority groups and one or more hog CAFO was quantified (Wing and Johnson, 2014).

The emissions from a hog waste lagoon will include many irritants, among them are ammonia, hydrogen sulfide, volatile organic compounds (VOCs), endotoxins, respiratory irritants, and bioaerosols (Wing and Johnson, 2014). Previous studies of note here include research showing higher instances of asthma symptoms in middle school children going to school within 3 miles of a facility and hydrogen sulfide levels that negatively impact neighboring communities' ability to engage in everyday life activities (Wing and Johnson, 2014).

Environmental pollutants result from leaking hog waste lagoons, agricultural run-off, atmospheric deposition, lagoon breaches, rain events, or flooding (Wing and Johnson, 2014). The North Carolina Division of Emergency Management provided satellite imagery that confirmed approximately 237 hog CAFOs are located in flooded areas (Wing and Johnson, 2014). In addition to these environmental contaminates antibiotics used for weight gain causes antibiotic resistance strains of bacteria that may spread to human hosts and resulting in hard to treat infections such as *Staphylococcus aureus* (Wing and Johnson, 2014). These antibiotic resistant strains can be transmitted by insects that land on the lagoons and carry them to other animal or human hosts (Wing and Johnson, 2014).

Hog CAFOs under a General Permit as reported on January 24th, 2013 were counted and non-hog facilities were excluded, as well as expired permits or permits for CAFOs with an animal count equivalent to zero (Wing and Johnson, 2014). The total steady state live weight (SSLW) was taken into account for hog size accuracy in order to calculate the waste produced (Wing and Johnson, 2014).

In the results 19.9% of people of color (POC) lived within 3 miles of a CAFO, making the percentage of POC 1.52 times higher than the presence of non-Hispanics Whites (Wing and Johnson, 2014). The ratios prove to be statistically significant when compared to the entire state of North Carolina's population showed that Blacks, Hispanics, and American Indians that live near CAFOs is 1.38, 1.40, and 2.39 higher than non-Hispanic Whites (Wing and Johnson, 2014). In conclusion minority citizens have reported impacts due to the hog CAFOs and have been met with intimidation and violence. It is understood by residents that the industry has close ties to local and state government officials, causing lax to no response in cases of reporting (Wing and Johnson, 2014).

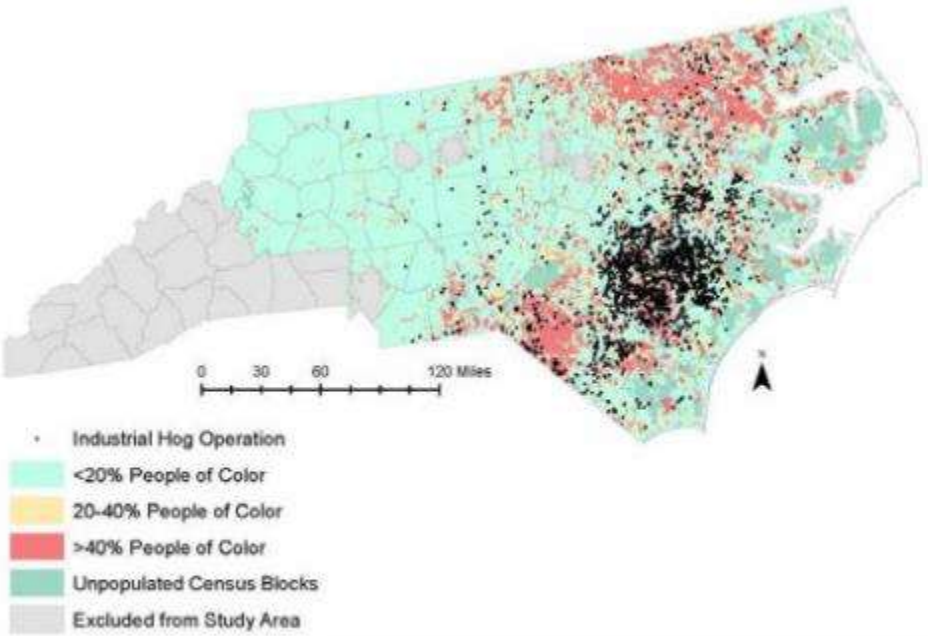

Figure 1. Composition of racial and ethnic census blocks and permitted hog CAFOs in NC (Wing and Johnson, 2014).

The Presence of Hog Fecal Waste in Waterways Proximal to Hog CAFOs

Heaney, Myers, Wing, Hall, Baron, and Stewart (2015) published a study titled *Source tracking swine fecal waste proximal to swine concentrated animal feeding operations.* The objective of this study was to use fecal and bacterial testing to show impacts of these contaminants to surface waters in waters adjacent to the swine CAFOs (Heaney, Myers, Wing,

Hall, Baron…, 2015). In this study it is noted that agricultural experts, residents living near CAFOs, and governmental officials all expressed concern that large scale mass production of swine would result in an overabundance of manure that would subsequently overload the spray fields upon application and result in fecal contamination of the waterways adjacent to these spray fields. It is important to note, as well, that North Carolina Department of Environmental Quality (formerly known as the North Carolina Department of Environment and Natural Resources (NCDENR)) for the purposed of permitting consider swine CAFOs non-discharge facilities (Heaney et al, 2015). In conclusion to this study the surface waters nearby areas with a density of swine CAFOs were found to have poor water quality (Heaney et al, 2015).

Surface water samples were taken in locations both up and downstream of swine CAFOs and tested for *Escherichia coli* and *Enterococcus* fecal coliforms and swine specific bacteria using microbial source-tracking (MST) markers (Heaney et al, 2015). These swine specific markers differentiate bacteria typical of swine feces from bacteria specific to other animal or human fecal bacteria. The swine specific MST markers were as follows: Pig-1-Bac, Pig-2-Bac, and Pig-Bac-2 and methanogen P23-2(Heaney et al, 2015).

In the sampling process, for the purpose of denoting upstream and downstream locations, the letter A was used to mark upstream locations and B was used to mark the downstream locations (Heaney et al, 2015). There were 187 sample sites chosen, none of which were absent upstream CAFOs because there were no identifiable sampling locations where CAFOs were not present (Heaney et al, 2015). Of the 187 samples 76 were taken upstream and 109 were taken from downstream (Heaney et al, 2015). Two samples were omitted because of missing designations (Heaney et al, 2015). Surface water sampling took place for the span of one year

between the months of February 2010 to August 2010 and September 2010 to January 2011 (Heaney et al, 2015).

To collect the surface water samples 4 liter Nalgene bottles that had been washed and sterilized in an autoclave set to 121 ^{o}C for 15 minutes were used (Heaney et al, 2015). The bottles were labeled using code so that during the laboratory processing no biases would be introduced when testing for fecal coliforms (Heaney et al, 2015). Once these samples were collected they were placed in ice and transported to a laboratory where within 24 hours they were processed to test for fecal coliform bacteria (Heaney et al, 2015). In addition to the surface water samples collected, rainfall data were collected via the State Climate Office of North Carolina's weather station to include amount of cumulative rainfall during this sampling period (Heaney, 2015).

The results of this study conclude poor water quality due to surface water contamination indicating swine fecal bacteria at levels exceeding state and federal recreation water quality standards at both up and downstream locations (Heaney, 2015). Site B locations, downstream sites, show the maximum density of fecal contamination of both *E. coli* and *Enterococci* at 140,000, 5,400, and 10,400 colony-forming unit (CFU) per 100 mL (Heaney et al, 2015). These maximum density coliform samples were collected during spring and summer (Heaney et al, 2015). Upstream sites may have been impacted by more than one CAFO located above the sampling sites (Heaney et al, 2015). The Pig-1-Bac was approximately 2 and half times greater in downstream locations, indicating that the swine CAFO waste application within proximity of the sampling location was responsible for the poor water quality (Heaney et al, 2015).

It is important to note that North Carolina State legislature states that agricultural waste management may not legally impact the waters of the State except where there is a 25-year or

24-hour storm. As indicated by the data collected from the State Climate Office of North Carolina's weather station the maximum accumulative rainfall during 48 hours was approximately 2.94 inches, which is indicative of little rain present during the sampling periods (Heaney et al, 2015). Though, the frequency in presence of Pig-1-Bac and Pig-2-Bac were three times greater during periods of rainfall (Heaney et al, 2015).

United States Geological Survey 2015 Study

In 2015 the United States Geological Survey (USGS) in collaboration with the North Carolina Department of Environment and Natural Resources' Division of Water Resources published a study titled *Surface-Water Quality in Agricultural Watershed of the North Carolina Coastal Plain Associated with Concentrated animal Feeding Operations*. In this study 54 streams sites located near agricultural activity in the North Carolina Coastal Plain were sampled in 6 bimonthly periods between June 2012 and April 2013 (Harden, 2015). For supplemental water quality data, 23 additional sites were sampled (Harden, 2015). Three types of sites were sampled:

- 18 BK Sites – Sites within a watershed with no active CAFOs
- 18 SW Sites – Sites with one or more active swine CAFO, but no poultry
- 18 SP Sites – Sites with a minimum of both one swine CAFO and one poultry CAFO

There were three objectives to this study: 1) Compare water quality of streams where CAFOs are present to streams where CAFOs are not present; 2) Chemical constituents as a measure of CAFO impacts to water quality; and 3) Assess the environmental factors present

where CAFO impacts are and are not measurable (Harden, 2015). The environmental factors taken into consideration include the characteristics of the CAFOs, soil drainage class, and land cover (Harden, 2015).

Onsite the water quality parameters for stream sites included dissolved oxygen, pH, specific conductance and water temperature (Harden, 2015). Offsite samples were analyzed for additional parameters including major ions, nutrients, and stable isotopes (Harden, 2015). These major ions, nutrients, and isotopes were nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur (Harden, 2015). The results for these showed that when comparing water quality data from the BK sites to SW and SP sites, the SW and SP sites showed measurable impact from CAFO manure (Harden, 2015). The SW and SP site results showed higher median values for nitrogen fractions, specific conductance, and several major ions (Harden, 2015). The results also showed that some SW and SP sites presented no measurable impacts from CAFO manure (Harden, 2015). The highest level of CAFO manure impact was found in sites with less wetlands surrounding the site, higher number of CAFO density, and larger spray fields (Harden, 2015).

According to the Environmental Protection Agency's National Water Quality Inventory Report to Congress, agriculture is likely the greatest contributor to impaired rivers and streams (Harden, 2015). Agricultural application of manure can result in high nitrogen and phosphorus in nearby waterways causing nutrient overload. This nutrient overload produces nutrient-sensitive waters that cause eutrophication, algal blooms, and the presence of toxic dinoflagellates (Harden, 2015).

In January of 2013 it was estimated that there are 2,356 permitted animal feeding operations in North Carolina (Harden, 2015). It is not a notably different number of operations as

the 1990s estimate. Ninety percent of the 2,356 animal feeding operations are swine CAFOs (Harden, 2015).

Waste lagoons in existence before 1993 were not lined with clay as the latter pits have been (Harden, 2015). This has resulted in higher than average levels of ammonia and nitrate in shallow groundwater near these unlined lagoons (Harden, 2015). Calcium, chloride, magnesium, potassium, and sodium have been found to be higher in the groundwater located beneath the spray fields (Harden, 2015). The concentrations of these nutrients have been found to be abundantly higher where both swine and poultry CAFOs are denser, regardless of whether they were tested during stormflow or baseflow, than streams tested in areas absent of CAFOs (Harden, 2015). Groundwater makes up approximately 55% of water feeding in to streams (Harden, 2015).

One method of agricultural nutrients migrating from field application to stream is the movement of nutrients into the shallow groundwater and feeding into these streams (Harden, 2015). Additionally, ditches are used around an agricultural field for draining the fields, and this is another pathway for nutrients to streams (Harden, 2015). And environmental feature prevalent among sample sites is prominent riparian buffers, which suggests that heavy nitrate levels are a result of overland application of manure that migrates to stream sites (Harden, 2015). Sample sites all had similar environmental attributes, documented using geological information system (GIS), overall and varying degrees of nutrient presence in water quality samples which is indicative that the agricultural operations are responsible for the nutrient presence in samples collected (Harden, 2015).

Water quality data for this study included precipitation and streamflow (Harden, 2015). The USGS raingage monitoring states for the North Carolina Coastal Plain region provided the

precipitation data that were used for this study (Harden, 2015). This provided the study with details about whether the surface water sampling included wet or dry weather (Harden, 2015). The surface water samples were then transported to the USGS National Water Quality Laboratory (NWQL) where the sample levels of major ions were measured and chemical analysis were completed (Harden, 2015). The surface water samples were also transported to the USGS Reston Stable Isotope Laboratory (RSIL) to examine stable isotopes Harden, 2015). To determine is bias were present or samples were altered or contaminated during sampling and in transport field blanks were also sampled and included in the samples (Harden, 2015). Of the samples 13% we quality control samples (Harden, 2015). According to these field blanks, no quality assurances issues were identified (Harden, 2015). Eighty-nine percent of non-field blank samples measured above the highest level of ammonia present in field blanks, and 75% of the non-field blank samples had twice the amount of ammonia present than the ammonia in field blank samples (Harden, 2015).

This 2015 study concluded that most SW and SP sites had water quality impacts that were measurably indicative of CAFO nutrient attributes (Harden, 2015). It goes further to state that the results of this study solidly point out that on the North Carolina Coastal Plain ion changes and nutrient chemistry are influenced by the land application of swine manure (Harden, 2015).

Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with CAFOs

Table 13. Water-quality results for the April 2013 sample period used to examine waste-manure influences at the primary and secondary study sites.

[CAFO, concentrated animal feeding operation; mg/L, milligram per liter; $\delta^{15}N$, delta nitrogen-15; ‰, per mil; <, less than; na, not analyzed]

Study site (site maps in appendix A1)	Potential to be influenced by CAFOs	Dissolved oxygen (mg/L)	Nitrate + nitrite (mg/L)	Sodium + potassium (mg/L)	$\delta^{15}N$ of nitrate + nitrite (‰)	$\delta^{18}O$ of nitrate + nitrite (‰)	Are the results interpreted to reflect CAFO waste manure influences at the site? (see appendix A5)
SW-04A	Yes, near upgradient edge of swine spray field	6.3	0.307	7.96	15.80	11.09	Unclear
SW-04B	Yes, 1 swine CAFO	7.4	3.31	16.10	19.37	10.34	Yes
SW-04	Yes, 1 swine CAFO	3.4	1.09	16.66	22.16	10.62	Yes
SW-05A	Yes, 1 swine CAFO	0.08	0.052	10.01	na	na	No
SW-05B	No, background agricultural fields	4.2	1.70	7.28	9.66	8.43	No
SW-05C	Yes, 1 swine CAFO	5.4	3.40	19.16	21.68	10.78	Yes
SW-05	Yes, 4 swine CAFOs	2.9	0.795	12.42	17.05	8.87	Yes
SW-08A	Yes, 5 active and 1 inactive swine CAFOs	0.1	<0.040	16.41	na	na	Unclear
SW-08B	Yes, 1 swine CAFO	0.8	0.681	12.67	7.42	7.89	No
SW-08C	Yes, 3 swine CAFOs	4.0	1.22	16.40	24.56	10.05	Yes
SW-08D	No, background agricultural fields	6.3	2.74	9.95	5.44	6.27	No
SW-08	Yes, 12 active and 2 inactive swine CAFOs	0.02	<0.040	16.70	na	na	Unclear
SW-13A	Yes, 1 swine CAFO	5.9	35.4	65.70	18.92	9.95	Yes
SW-13B	Yes, 2 swine CAFOs	7.0	27.5	51.80	19.98	10.42	Yes
SW-13	Yes, 3 swine CAFOs	3.0	0.390	33.10	22.04	9.16	Yes
SP-01A	No, background agricultural fields	9.3	<0.040	5.19	na	na	No
SP-01B	Yes, 1 swine and 1 poultry CAFOs	10.6	<0.040	5.93	na	na	No
SP-01C	Yes, 2 swine CAFOs	11.8	0.592	31.10	27.99	9.74	Yes
SP-01	Yes, 6 swine and 1 poultry CAFOs	10.1	0.103	10.63	8.94	4.96	No
SP-04A	No, background agricultural fields	2.3	0.877	9.25	12.52	10.79	No
SP-04B	Yes, 2 swine and 1 poultry CAFOs	4.2	1.86	22.74	22.54	10.58	Yes
SP-04	Yes, 4 swine and 1 poultry CAFOs	2.1	0.110	21.24	17.01	9.58	Yes
SP-05A	Yes, 1 swine CAFO	7.1	3.50	12.06	7.93	5.20	No
SP-05B	Yes, 1 swine and 1 poultry CAFOs	9.2	2.62	12.16	8.75	6.91	No
SP-05	Yes, 1 swine and 3 poultry CAFOs	5.9	4.13	11.84	8.00	6.75	No
SP-09A	Yes, 3 swine and 1 poultry CAFOs	5.9	3.20	43.60	23.02	14.21	Yes
SP-09	Yes, 3 swine and 1 poultry CAFOs	5.4	1.94	33.70	23.13	14.72	Yes
SP-11A	Yes, 2 swine CAFOs	3.7	1.11	32.60	25.57	13.32	Yes
SP-11B	Yes, 4 swine CAFOs	1.4	1.73	32.50	28.96	9.67	Yes
SP-11C	Yes, 1 swine CAFO	9.5	2.98	12.66	11.91	8.63	Yes
SP-11D	Yes, 6 swine CAFOs	4.8	1.01	31.10	24.21	6.69	Yes
SP-11	Yes, 9 swine and 1 poultry CAFOs	0.3	<0.040	22.80	na	na	Yes

Table 3. Water Quality Results for 2015 NCDENR, DWR, and USGS study Surface-Water Quality in Agricultural Watersheds of the North Carolina Coastal Plain Associated with Concentrated Animal Feeding Operations. (Harden, 2015).

Ammonia Emissions from Swine Farms

Aneja, Arya, Kim, Rumsey, Arkinson, Semunegus, and Bajwa (2008) published a study in which ammonia fluxes were analyzed for two hog waste lagoons in eastern North Carolina. This was done using a mobile laboratory with Fourier transform infrared (FTIR) spectrometers during the fall and winter months (Aneja, Arya, Kim, Rumsey, Arkinson, Semunegus, and Bajwa, 2008). The two farms tested utilized two difference ventilation systems months (Aneja et al, 2008). The Moore Brothers farm used fans for ventilations while the Stokes farm let the barns air out naturally with no fans present (Aneja et al, 2008). The sampling took place from September 2002 to October 2002 and January 2003 to February 2003 (Aneja et al, 2008). Statistically seasonal fluxes of ammonia were found in conjunction with increased temperatures (Aneja et al, 2008).

Urea present in animal waste will become ammonia and carbon dioxide when deconstructed naturally (Aneja et al, 2008). Once deposited atmospherically the ammonia has the potential to become nitrogen and readily deposits into nearby waterways causing eutrophication then harmful algal blooms (Aneja et al, 2008). A major source of atmospheric ammonia and resulting nitrogen deposition is hog waste lagoon and spray systems Aneja et al, 2008). However, there are four ways in which the atmospheric deposition of ammonia can occur in relation to hog waste lagoon and spray systems. These are: 1) the farm buildings themselves that house the hogs; 2) the open pit storage of the hog waste; 3) the spraying of the hog waste onto the spray field; and 4) biogenic emissions (Aneja et al, 2008).

The parameters measured in this study included the air temperature, lagoon temperature, pH, total Kjeldahl nitrogen (TKN), and wind speed (Aneja et al, 2008). The purpose of seasonal

variation in sampling was to examine the impact of temperatures on the parameters measured (Aneja et al, 2008).

To measure the temperature of the lagoons Campbell Scientific Instruments model 107 temperature probes were used (Aneja et al, 2008). To measure the pH of the lagoons Innovative Sensors pH probes were used (Aneja et al, 2008). To measure the ambient air temperature, RH, solar radiation, wind speed and direction a Campbell Scientific Instruments CS500 temperature and relative humidity (RH) probe, a LI-Cor200SZ pyranometer, and a Campbell Scientific Instruments Met One 034A-LC Windset integrated cup anemometer and wind vane were attached to a 10 meter meteorological tower (Aneja et al, 2008). Samples collected from the waste lagoons were sent to Weaver Laboratory of the Biological and Agricultural Engineering Department at North Carolina State University (Aneja et al, 2008). Water quality samples were collected daily from the waste lagoons in 50 mL bottles and analyzed for NH_3—N, nitrate, pH, and TKN (Aneja et al, 2008). The NH_3 lagoon fluxes were measured for two weeks per season using a dynamic flow-through flux chamber (Aneja et al, 2008).

Significant NH_3 fluzes were measured from season to season, with the fall season measuring higher average fluxes at both farms (Aneja et al, 2008). Where there were low lagoon temperatures large variations in fluxes were found (Aneja et al, 2008).

Experimental Farms	Season Sampling Periods	NH_3 Flux (μg-N $m^{-2}min^{-1}$)	Lagoon Temperature (°C)	Lagoon pH	TKN (mg-N L^{-1})	TAN (mg-N · L^{-1})
Stokes	Fall	2349.4 ± 986.4	26.5 ± 1.3	8.1 ± 0.1	561.3 ± 33.3	442.4 ± 18.1
	September 9–20, 2002	(1602.1–9423.5)	(24.7–33.6)	(7.7–8.3)	(498–599)	(410–477)
		n = 599	n = 599	n = 599	N^a = 9	N^a = 9
	Winter	152.7 ± 52.4	7.2 ± 1.0	8.4 ± 0.1	700.0 ± 18.3	560.0 ± 19.4
	January 6–17, 2003	(22.6–288.6)	(4.8–9.3)	(8.1–8.5)	(681–723)	(545–593)
		n = 865	n = 865	n = 865	N^b = 6	N^b = 5
Moore	Fall	1685.4 ± 516.4	25.0 ± 1.6	8.2 ± 0.1	582.5 ± 135.6	363.5 ± 35.9
	September 30 to	(712.9–3495.6)	(21.2–30.0)	(7.9–8.5)	(487–774)	(316–409)
	October 11, 2002	n = 766	n = 766	n = 766	N^c = 9	N^c = 9
	Winter	370.5 ± 147.1	7.2 ± 2.5	8.1 ± 0.1	782.0 ± 38.9	635.5 ± 36.9
	January 27 to	(49.8–672.8)	(1.7–12.0)	(7.9–8.3)	(680–815)	(545–665)
	February 2, 2003	n = 684	n = 684	n = 333	N^d = 9	N^d = 9
Farm 10[e]	Summer	4017 ± 987	30 ± 3.3	7.5 ± 0.2	648.1 ± 27.7	
Sampson, NC	August 1–15, 1997	(2358–8526)	(25.3–39.1)	(7.1–7.8)	(587–695)	N/A
Aneja et al.	Fall	844 ± 401	11.6 ± 2.2	8.0 ± 0.1	663.3 ± 33.7	
(2000)[22]	December 1–17, 1997	(369–1913)	(8.4–15.3)	(7.9–8.1)	(599–715)	N/A
	Winter	305 ± 154	12.1 ± 2.1	7.8 ± 0.1	641.7 ± 39.0	
	February 1–26, 1998	(90–695)	(8.8–15.1)	(7.7–8.0)	(580–727)	N/A
	Spring	1706 ± 552	24.7 ± 3.2	7.7 ± 0.1	603.3 ± 48.2	
	May 16–27, 1998	(851–3594)	(20.4–35.9)	(7.6–7.8)	(540–720)	N/A

Notes: Numbers in parentheses are ranges of the data. n represents the number of data in 15-min average during the sampling periods. N represents the total number of lagoon waste samples for TKN. A lagoon waste sample was collected daily between 12:00 and 13:00 Eastern Standard Time. The water sampling days were: [a]September 10–18, 2002; [b]January 7–10, 14, 15, 2003; [c]October 1–9, 2002; [d]January 27–31, and February 1–5, 2003. [e]Farm 10 (another commercial LST) values are provided for comparison.[22]N/A = not applicable.

Table 4. Average lagoon NH_3 fluxes, temperatures, pH, TKN, TAN (Aneja et al, 2008).

Wilson and Serre (2006) completed a study using passive samplers in order to measure atmospheric ammonia levels in large scale industrial hog farms and community areas in eastern North Carolina to effectively measure amount of airborne ammonia coming from hog farms. The major air pollutants emerging from industrial hog facilities in this study are ammonia (NH_3), bioaerosols, carbon dioxide, carbon monoxide, hydrogen sulfide, methane, particulate matter, sulfuric oxide (SO_2), and volatile organic compounds (VOCs) (Wilson and Serre, 2006). At the time this study was completed limited information existed on atmospheric ammonia emissions from hog CAFOs. Six counties were assessed: Bladen, Duplin, Greene, Lenoir, Sampson, and Wayne (Wilson and Serre, 2006). Twenty sites were sampled in weekly intervals using three passive diffusion tubes to gather ammonia between the months of October 2003 and May 2004 (Wilson and Serre, 2006). To determine which of those sites chosen for sampling area considered

“exposed” a measurement of 2 kilometers near a CAFO are dubbed “exposed” and those sampling sites more than 2 kilometers away from a CAFO are dubbed “not exposed” (Wilson and Serre, 2006).

The sampling phases took place in October 2003 through May 2004 and July 2004 through October 2004 (Wilson and Serre, 2006). For the chosen sampling sites Duplin, Greene, and Lenoir counties are the highest density in emissions and Edgecombe, Nash, and Wilson are the lowest in emissions (Wilson and Serre, 2006).

Notification Requirements for Violations

Concentrated Animal Feeding operations in North Carolina are required to apply for a National Pollution Discharge Elimination System (NPDES) permit and operate within compliance of these set standards, yet only if deemed to do so under the direction of the NC Environmental Management Commission (NC Department of Environmental Quality, (n.d.a). The NC Environmental Management Commission issues a state general permit titled the Swine Waste Management General Permit, which is effective until September 30th 2019 (NCDEQ, n.d.a). This permit must be submitted 180 days before farm’s operation of the waste management system (NCDEQ, n.d.b) Individuals permitted under the G.S. 143-215.1 for Public Livestock Market are exempt from this permit. The farm operator is required to obtain a permit via the General Assembly only if the NC Environmental Management Commission deems it is required, outlining standards for discharge determined by number of facility animals and other factors as per 40 Code of Federal Regulations § 122, as amended at 73 Federal Register 70418 (November

20, 2008) (NCDEQ, n.d.b). Otherwise, the animal feeding operation deemed by the NC Environmental Management Commission as unnecessary to permit under 40 Code of Federal Regulations § 122, as amended at 73 Federal Register 70418 (November 20, 2008) or an already existing animal waste management system may not discharge pollutants into State waters unless impacted by a 25 year or 24 hour storm (NCDEQ, n.d.b) New facilities permitted under 40 Code of Federal Regulations § 122, as amended at 73 Federal Register 70418 (November 20, 2008) shall be designed and operated so as not to discharge pollutants into State waters (NCDEQ, n.d.b)

The permitting process requires an animal waste management plan that includes a checklist for determining odor and insect minimization, mortality disposal, and soils testing for Nitrogen, Phosphorous, and heavy metals at least every three years (NCDEQ, n.d.b) If an animal waste operation discharges more than 1,000 gallons of water into State surface waters the operator is responsible for issuing a release of notification to the public within 48 hours of said discharge and retains records of the release (NCDEQ, n.d.b) If the discharge of waste is 15,000 gallons of more than notification via a release to the public has to take place in the county where it occurred as well as the counties impacted downstream as determined by the Secretary within 30 days (NCDEQ, n.d.b)

Additionally, the 15A NCAC 02T .1307 Swine Waste Management System Performance Standards' intention is to eliminate swine waste discharges into surface water and groundwater, presumably lessening the possibility for violations (NCDEQ, n.d.a). To do this hog waste lagoons are to incorporate a liner between the waste and the earth (NCDEQ, n.d.a). Though, swine waste lagoons already in existence lack this protective barrier. These requirements include that an annual average discharge not exceed 7,000 fecal coliform colonies per 100ml of sample

and that facilities substantially reduce air emissions from the boundary of the farm and beyond the boundary line (NCDEQ, n.d.a). While the permitting process is solely determined by the Commission, these requirements notably place the responsibility of reporting a violation squarely on the would-be violator's shoulders, essentially allowing the fox to guard the henhouse so to speak.

How is permitting aiding in public health and environmental concerns? As shown in Figure 1 hog farms have decreased overall while heads of hogs have increased. Fry, Laestadius, Crechis, Nachman, and Neff (2014) reached out to 12 state agencies to conduct qualitative interviews in order to determine how public health concerns garner response and what steps are taken to reduce any impediments to agency involvement in such matters. The results included many impediments; among them were limited resources, too narrow of regulations, and inadequate knowledge on public health (Fry, Laestadius, Crechis, Nachman, and Neff, 2014).

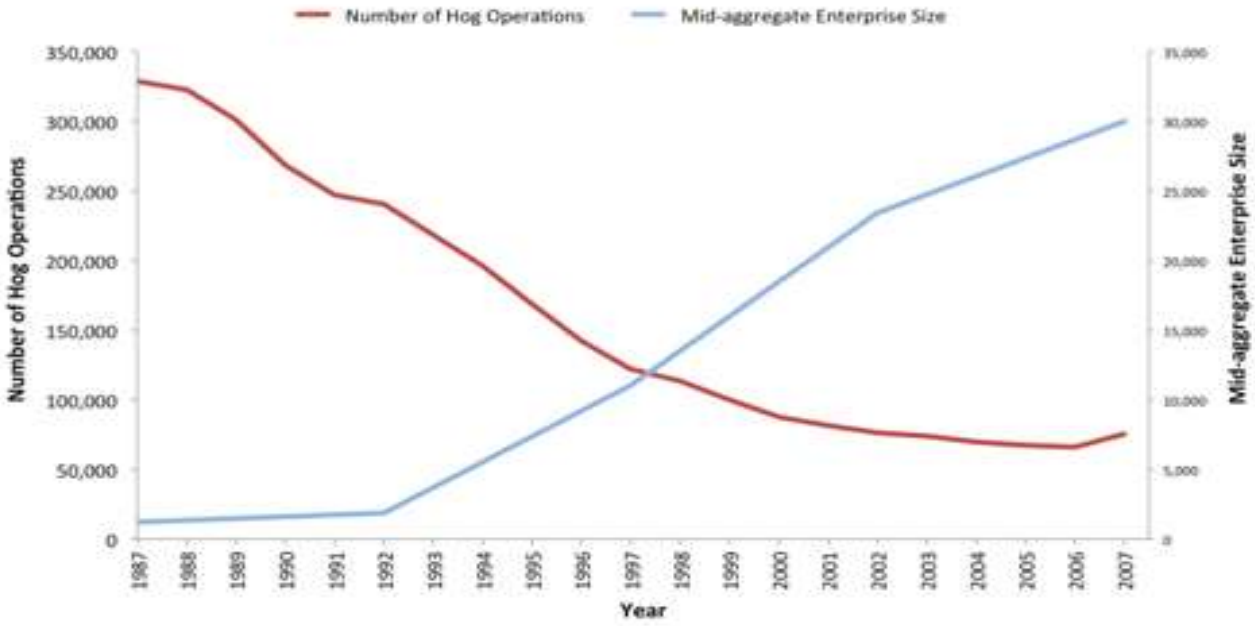

Figure 2. Number of hog operations and operation growth from 1987 to 2007 (Fry, Laestadius, Crechis, Nachman, and Neff, 2014).

The Environmental Protection Agency (EPA) gives states the authority to regulate CAFOs and thereby de facto power over permitting the facilities as well as determining which facilities require permits (Fry et al, 2014). Depending on resources available, states ability to enact enforcements or provide penalty is limited (Fry et al, 2014). In this case the authors focused on industrial food animal production (IFAP), farm operations that had grown in size to an industrial production model rather than traditional farming yet not documented as a CAFO (Fry et al, 2014). For all intents and purposes, an IFAP is as indicative of environmental degradation as a CAFO given that the CAFO is typically a larger operation in comparison.

The researchers chose the top fifteen hog producing counties in eight U.S. states and conducted interviews using a purposive sampling strategy (Fry et al, 2014). These interviews

included the agricultural and permitting agencies as appointed by National Conference on State Legislatures' Survey of State Policies on CAFOs (Fry et al, 2014). Setbacks, qualifications for the farming operations to keep specific boundaries at a predetermined distance from schools, churches, and drinking water wells, are necessary legally (Fry et al, 2014). These are established as a means to less exposure for the public to the air particulates (Fry et al, 2014). However, there is no standard for quantitative measurement taken by the agricultural sectors of local government agencies in most cases, some states citing lack of funding or minimal inspections triggered by complaints (Fry et al, 2014). One solution to this suggested by many of the agricultural and permitting agencies is to give health departments some authority in regulatory action (Fry et al, 2014). The challenge with this solution is that agricultural agencies lack jurisdiction over public health concerns and health departments lack jurisdiction over agricultural operations (Fry et al, 2014). However health departments report that they refer concerned individuals to the agricultural or permitting agencies where the individual may or may not receive any help (Fry et al, 2014). In conclusion this regulatory gap between the agricultural and permitting agencies versus the health departments is where agencies fall short of protecting citizens from public health concerns when it comes to pollution resulting from agricultural operations.

Hypothesis and Questions

Hypothesis

The hypothesis proposed in this thesis is hog waste lagoon and spray systems utilized in eastern North Carolina are an inadequate hog waste management system that result in

compromised human health and environmental conditions as well as economic losses within the community.

Questions

- To what extent do hog waste lagoon and spray systems impact human and environmental health?
- Do animal feeding operations impact property values in adjacent residences?
- Are animal feeding operation permitting and enforcement practices addressing community and environmental impact?

Methods

Procedures

In conducting the research for references 13 resources of information ranging from governmental and environmental non-profit websites and journal articles were obtained. Data used in this research study were collected via the American Public University Systems' (APUS) Library. Through the APUS Library in the *Articles & Databases* search bar the terms "hog", "lagoon", "waste", "CAFO", "pollution", and "North Carolina" were searched and limited by choosing *Scholarly & Peer-Review* and *Journal Article* and both without a date range limitation

and with a date range limitation of "*Last five years*" . Studies that date back to longer than 5 years ago are included to highlight pertinent water quality data that is relevant to the current day waste operations. The articles referenced from APUS include the history of CAFOs, human health impacts, comparison to human waste in quantity and treatment needs, permitting and enforcement data, property values, atmospheric ammonia, and fecal coliforms. Some study links appeared in the APUS Library search but proved to be inoperable. Those studies were copied and pasted into Google Scholar to get the full text. In addition to utilizing the APUS Library Google Scholar provided scholarly study results of relevance. This search resulted in studies highlighting human and environmental health results, avenues for which hog waste contaminates the environment, disproportionate impacts to minority communities, and fecal coliforms. In the Google Scholar search the limiter "Since 2013" was chosen.

The environmental non-profit advocacy group website page for Waterkeeper Alliance titled *Pure farms, Pure waters: North Carolina* provided an up-to-date estimate of number of hog CAFOs in North Carolina, an image of a hog waste lagoon pictured in Figure 4, and an estimate for annual production of "wet waste" in North Carolina. This website can be found at waterkeeper.org.

The governmental website used is the official website of North Carolina Department of Environmental Quality (NCDEQ). This reference provided permitting information for animal feeding operations.

Data Analysis

Extant data were analyzed from multiple focus studies and current permitting and enforcement policy and procedures were included to determine the extent to which communities and the local environment are impacted. Residential property values were noted to decrease in areas within 3 miles of hog CAFOs. The data provided was compared and it is noted that property values within ½ mile show the most in decreased value. In many of the studies the citizens near the large scale hog operations (CAFOs) reported human health impacts. The types of health impacts reports were analyzed for across the board reporting in studies and noted in the results. The chemical and ion makeup of sampling sites proximal to hog CAFOs were analyzed. It is noted that in some cases ammonia levels and fecal coliforms exceed federal and state water quality standards. The fecal coliform recreation water quality standard is 200 colony forming units (cfu) per 100 mL of sample. This standard is compared in Table 6 to stream samples that were proximal to hog CAFOs. Additionally, some key water quality parameters are examined in Table 5, where the asterisks provided denotes significant differences in water quality parameters. Water quality parameters examined here for pinpointing pollution due to agricultural runoff include calcium, temperature, dissolved oxygen, nitrate, nitrites, phosphorus, ammonia, *Escherichia coli and Enterococcus*, nitrogen, potassium, magnesium, and sulfur, to name a few. Animal feeding operation permitting and agriculture agencies as well as public health officials that agreed to interview in the extant data presented here are in agreement on topics they deem "of concern" relative to CAFOs. This interview data is compared to human health impact reporting and water quality data. The concerns listed match the extant results from the other studies chosen for this research paper.

Results

Home Values

The impact of home values due to proximity to concentrated animal feeding operations has been compiled and published in 1997 by Palmquist, Roka, and Vukina. Research shows that home values near hog farms are impacted most when they are within half a mile of an operation. The highest monetary loss in a residential property within half a mile of a CAFO documented in the above research is $5,339 while the lowest is $167 (Palmquist, Roka, and Vukina, 1997). Yet even a residential property 2 miles away had a documented loss of $2,266 in value (Palmquist, Roka, and Vukina, 1997). This information is indicative that while living proximal to a CAFO may impact the residential property value there are variants determining the level of monetary impact aside from proximity and these other factors account for level of loss in value. These variants are the environmental quality that is degraded beyond the boundaries of the CAFOS by way of air particulates causing excessive odor.

Human Health

While excessive odor may be unpleasant, it can also physically and psychologically impair the residents living nearby. This is evident in many of the studies presented here. Harden (2015) points out nutrient overload produces nutrient-sensitive waters that cause eutrophication, algal blooms, and the presence of toxic dinoflagellates. McKown (1999) reports that 27 citizens came together in the *Parker v. Barefoot* “nuisance suit” to argue that the farm was impacting their respiratory systems and burning their eyes. Though their case was lost to the industry,

respiratory issues and burning eyes or hay fever like symptoms are common around hog CAFOS. Minority communities located in the south eastern coastal North Carolina get hit the hardest according to the study *Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians* published by Wing and Johnson, 2014, which used Census Data to determine the location of minority communities in relation to CAFOS. In this study Wing and Johnson (2014) explain that the human impacts range from anxiety, stress, respiratory illness, impaired lung function, and even systolic blood pressure elevation.

Environmental Quality

These human health impacts are a direct result of the degradation of the local environmental quality. Many studies have quantified the air pollution or water pollution proximal to hog CAFOs. The most recently published of these is the United States Geological Survey (USGS) study completed in collaboration with the North Carolina Department of Environment and Natural Resources' Division of Water Resources titled *Surface-Water Quality in Agricultural Watershed of the North Carolina Coastal Plain Associated with Concentrated animal Feeding Operations*. These data highlighted in this study, and found on the North Carolina Animal Feeding Operation website, conclude that waterways adjacent to hog CAFOs have been impacted by way of change in the ion and chemical structure (Harden, 2015). Fifty eight percent of SW and SP sites show a distinct difference in water quality comparatively to BK sites (Harden, 2015). These data can be found in Table 3, Figure 3 and Table 5, respectively.

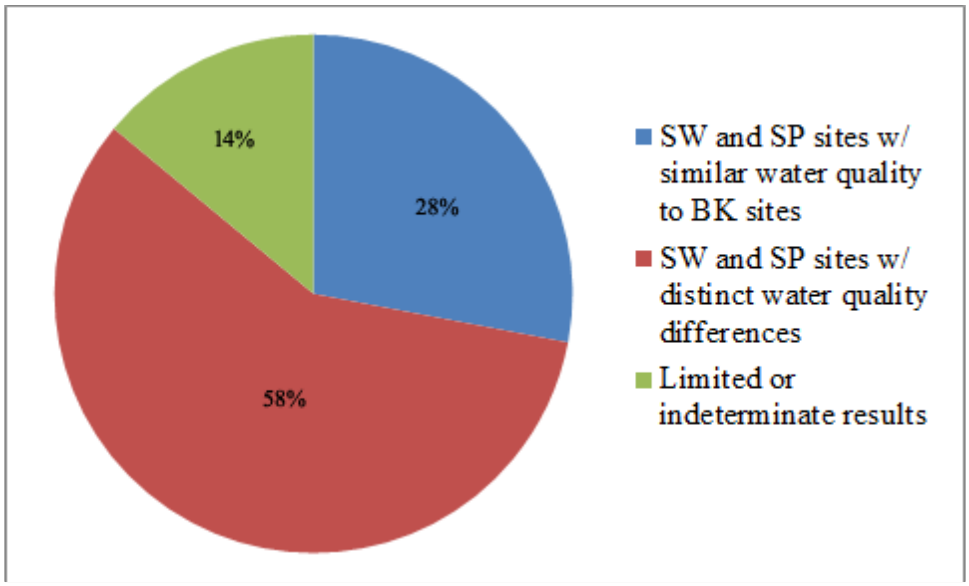

Figure 3. Percentage of SW and SP sites that have similar water quality to BK sites, distinct water quality difference when compared to BK sites, or limited or indeterminate results (Harden, 2015).

Water Quality Parameters

The USGS and NCDENRs' DWR discovered significant differences in ion and chemical make-up of most of the sites sampled compared to BK sites. In the tables below the significant differences are denoted using an asterisk. Each field, water temperature, specific conductance, dissolved oxygen, pH, calcium, magnesium, sodium, potassium, chloride, sulfate, ammonia +

organic nitrogen, ammonia, total organic nitrogen, nitrate + nitrite, total nitrogen, orthophosphate, total phosphorous, delta nitrogen-15 of nitrate + nitrite, and delta oxygen-18 of nitrate + nitrite (Harden, 2015).

	p-Values for water quality properties			p-Values for major ions						
Exaplantory grouping variable	Water temperature	Specific conductance	Dissolved oxygen	pH	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate
Sampling period	<0.001*	0.001*	<0.001*	0.015*	0.22	0.039*	<0.001*	<0.001*	<0.001*	<0.001*
Land use type	0.254	<0.001*	0.157	<0.001*	0.084	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
Sampling period: Land use type	0.224	0.936	0.751	0.977	0.996	0.98	0.921	0.8	0.367	0.778

	p-values for nutrients							p-values for isotopes	
Exaplantory grouping variable	Ammonia + organic N	Ammonia	Total organic N	Nitrate + nitrite	Total N	Orthophosphate	Total P	Δ Nitrogen-15 of nitrate + nitrite	Δ Oxygen-18 of nitrate + nitrite
Sampling period	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	0.625	0.484
Land use type	0.007*	<0.001*	0.166	<0.001*	<0.001*	0.533	0.106	<0.001*	0.221
Sampling period: Land use type	0.322	0.405	0.335	0.906	0.457	0.755	0.726	0.954	0.721

Table 5. Summary of water quality properties and constituents based on sampling period and land use.

Key	
*	Indicates a significant difference
N	Nitrogen
P	Phosphorous

Water Quality cont…

The study completed by Heaney et al (2014) show that 74 of the 187 sites sampled exceeded both federal and state recreational water quality guidance values of 200 colony forming units per 100 mL of sample. The highest results of exceeding fecal, *E.coli*, and *Enterococcus* standards were found downstream of CAFOs and the accompanying spray fields during the Spring and Summer months (Heaney et al, 2014). The populations of CAFOs in the region were so dense that no upstream sample sites could be considered pristine non-impacted sites (Heaney et al, 2014).

	Fecal coliforms	*E. coli*	*Enterococcus*
	(200 CFU/100 mL)a	(235 CFU/100 mL)b	(70 CFU/100 mL)b
	N exceed/total (%)	N exceed/total (%)	N exceed/total (%)
All sites	74/187 (40)	43/187 (23)	112/185 (61)
All A sites 1-3	24/76 (32)	13/76 (17)	40/75 (53)
All B sites 1-3	35/76 (46)	20/76 (26)	47/75 (63)
All B sites 4-6	15/33 (46)	10/33 (30)	25/33 (76)

Key	
a	Based on NCDENR surface water standards
b	Based on 2012 EPA recreational water quality criteria beach action values (BAV)

*Note: Site A locations are proximal upstream sampling locations. Site B locations are proximal downstream sampling locations (Heaney et al, 2014).

Table 6. Federal and state recreational water quality standard data exceedances for fecal, *E. coli*, and *Enterococcus* (Heaney et al, 2014).

Permitting and Enforcement Practices

Fry, Laestadius, Crechis, Nachman, and Neff (2014) document in their published research *Investigating the role of state permitting and agriculture agencies in addressing public health concerns related to industrial food animal production* in descending order a list that agricultural and permitting agencies have deemed top concerns regarding industrial food animal production. This list is as follows: Odor, respiratory health, ground water quality/contaminated well, violations of regulations, waste getting on property, general health, and traffic (Fry et al, 2014). All of these topics cover human health (whether it be psychological well-being due to excessive traffic or lung health), environmental quality, and property degrading pollution. State permitting agencies report limited resources, too narrow of regulations, and inadequate knowledge on public health (Fry et al, 2014). A state agency's ability to respond to reports of violations or provide n enforcement is limited to resources and funding (Fry et al, 2014). The example of the "nuisance suit", *Parker v. Barfoot*, and the self-reporting by the agricultural, permitting, and public health agencies is indicative of the gap in enforcement and lack of an established method of response when citizens come forward with public health concerns.

In conclusion, the hog waste lagoon and spray systems fail at addressing hog waste management. Little more than a pit and industrial spraying of raw hog feces, these systems merely provide more pathways for contaminants to impact community health, housing markets, recreational and drinking water quality, air quality, aquatic ecosystems, and more.

Discussion

Problem/Findings

The hog waste lagoon and spray systems as a method of hog waste management has not adequately been addressed as a residential home depreciation issue, a racial justice issue, an environmental quality issue, or a public health issue. Even the permitting, agricultural, and health agencies attest to finding issue with the odor, lung function reduction, and water quality near hog CAFOS. The findings point toward contaminated air causing breathing issues, contaminated water quality causing oxygen depleting algal blooms in nearby streams, whole generations of people of color finding themselves surrounded by hog CAFOs which subsequently rob them of their home values and livelihoods, and no easy to follow protocol for citizens or agency officials to follow up with resolutions.

Solutions

To begin, establishing a reclamation process for dealing with closed hog farm's waste lagoon pits is a top priority. These lagoons are no longer maintenanced by farmers and have a higher chance of breaching or leeching into nearby waterways or drinking wells due to the lack of a clay lining. Studies show that existing hog waste lagoons that are still in use create airborne emissions, run-off, and leaks that impact local environmental and human health; from changing heart rates, reduced lung function, and algal blooms in nearby waterways that impact the water

quality as well as the ecosystem. To address the airborne emissions, run-off, and leaks it is necessary to look at the sheer quantity of nutrients being added to the ecosystems and develop a waste management plan that acknowledges the quantity and composition of this waste. The most viable type of operation that would handle waste management at this capacity would be to treat the hog waste as one would the waste treatment for a city of 20,000 individuals or more and incorporate waste management treatment systems similar to the waste management facilities used for human populations.

It has often been suggested that trapping the gases from hog waste lagoons and converting it into energy that can power the farm is one method of dealing with hog waste lagoons. This does not address airborne emissions during the industrial spraying phase, public health, residential property values, or the potential to leak and therefore should be dismissed as a solution on its own.

Resources and funds are limited for agricultural and permitting agencies. To supplement water quality data certified non-profit organizations may use state training and state certified laboratories to provide water quality samples. Having routine water and air quality sampling at each hog CAFO not only helps farmers keep track of the functionality of the hog waste lagoons and sprayers, but provides pertinent data for upload to public health facilities. The public health facilities may be trained in federal and state air and water quality standards in order to recognize when either of these are in exceedance in the system.

Racial justice, too, is of concern given that the minority communities are disproportionately impacted through water contamination, health impacts, impact to well-being, and residential property impacts. This is a concern not only for the permitting agencies to address through permit refusal in densely packed areas, but also a concern for local authorities to

address. Minorities that report neighboring hog CAFOs should remain anonymous and never be exposed to intimidation by farmers or local authorities. In cases where a minority feels strongly enough to report the negative impacts they and their families experience they need to be taken seriously. Protocol for protecting the anonymity of those that report, as well as providing follow up after reporting to determine negative or positive changes in circumstances, may help reduce the intimidation they face.

Substantial riparian buffers for protecting nearby streams have been documented at many of CAFO sites. This suggests that even with proactive environmental measure the contaminants resulting from hog waste lagoons is so great that additional measures need take place. This can be an issue that is resolved with the above mention waste management systems similar to human waste management systems. Short of hog waste lagoon innovation, the well documented impacts that exist today will not make any significant progress toward resolution.

Alternative Explanations of the Findings

An alternative explanation that is often proposed for exceedances in fecal coliforms in waterways nearby hog CAFOs is the possibility of the fecal contamination being the result of wild animal feces or a human waste treatment facility leak. Having documented results in the study involving hog specific bacteria Pig-1-Bac, Pig-2-Bac, and Pig-Bac-2 and methanogen P23-2, these point toward hog CAFOs as the culprit. It is easy to use a resource such as Google Earth to aerially locate streams proximal to a hog CAFO versus streams proximal to a waste treatment facility to rule this out as a possibility.

Limitations

The limitations in this study include an inability to actively prepare water quality samples due to the dangers involved in sampling near CAFOs and the expenses for analyses at a state certified laboratory. There are many studies available on hog CAFOs. Narrowing the study down to water quality is difficult when the water proximal to hog CAFOs is impacted also through airborne emission, and suddenly air quality becomes a focus. This limited the ability to go more in depth on any one factor.

Suggestions for Further Research

Further research is needed on this topic of the impacts from CAFOs in order to solidify actionable solutions. Studies to determine improvements to hog waste management systems with the previous environmental quality study results in mind may act to reduce airborne emissions and water contamination. Social justice studies to eliminate disparity in minority communities may serve to improve public health and livelihood. There are many avenues a researcher may take in resolving the issue of antiquated hog waste lagoon and spray systems. It is apparent that change is necessary.

Figure 4. Hog waste lagoon in North Carolina. (Waterkeeper Alliance, 2017).

References

Aneja, V. P., Arya, S. P., Kim, D.., Rumsey, I. C., Arkinson, H. L., Semunegus, H., . . . Williams, C. M. (2008). Characterizing ammonia emissions from swine farms in eastern North Carolina: Part 1-conventional lagoon and spray technology for waste treatment. *Journal of the Air & Waste Management Association*, *58*(9), 1130. doi:10.3155/1047 3289.58.9.1130

Arfken, A. M., Song, B., & Mallin, M. A. (2015). Assessing hog lagoon waste contamination in the Cape Fear watershed using bacteroidetes 16S rRNA gene pyrosequencing. *Applied Microbiology and Biotechnology*, *99*(17), 7283-7293. doi:10.1007/s00253-015-6784-x

Bullers, S. (2005). Environmental stressors, perceived control, and health: The case of residents near large-scale hog farms in eastern North Carolina. *Human Ecology*, *33*(1), 1-16. doi:10.1007/s10745-005-1653-3

Fry, J. P., Laestadius, L. I., Grechis, C., Nachman, K. E., & Neff, R. A. (2014). Investigating the role of state permitting and agriculture agencies in addressing public health concerns related to industrial food animal production. *PloS One*, *9*(2), e89870. doi:10.1371/journal.pone.0089870

Heaney, C. D., Myers, K., Wing, S., Hall, D., Baron, D., & Stewart, J. R. (2015). Source tracking swine fecal waste in surface water proximal to swine concentrated animal feeding operations. *Science of the Total Environment*, *511*, 676-683. doi:10.1016/j.scitotenv.2014.12.062

Harden, S. L. (2015). Surface-water quality in agricultural watersheds of the North Carolina Coastal Plain associated with concentrated animal feeding operations. *Scientific Investigations Report*. doi:10.3133/sir20155080

McKown, A. M. (1999). Hog farms and nuisance law: Has North Carolina become a hog heaven and waste lagoon? *North Carolina Law Review*, *77*(6), 2355. Retrieved from http://nationalaglawcenter.org/wp-content/uploads/assets/bibarticles/mckown_hog.pdf

NC Department of Environmental Quality (NCDEQ). (n.d.a) *Animal feeding operation permits.* Retrieved from https://deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/animal-feeding-operation-permits/permits

NC Department of Environmental Quality (NCDEQ). (n.d.b). *News and updates*. Retrieved from https://deq.nc.gov/about/divisions/water-resources/water-resources-permits/wastewater-branch/animal-feeding-operation-permits/news-updates

Palmquist, R. B., Roka, F. M., & Vukina, T. (1997). Hog operations, environmental effects, and residential property values. *Land Economics*, *73*(1), 114-124.

Waterkeeper Alliance. (2017). *Pure farms, Pure waters: North Carolina*. Retrieved from https://waterkeeper.org/campaign/pure-farms-pure-waters/north-carolina/

Wilson, S. M., & Serre, M. L. (2007). Use of passive samplers to measure atmospheric ammonia levels in a high-density industrial hog farm area of eastern North Carolina. *Atmospheric Environment*, *41*(28), 6074-6086. doi:10.1016/j.atmosenv.2007.03.004

Wing, S and Johnston, J. (2014, August 29). Industrial Hog Operations in North Carolina Disproportionately Impact African-Americans, Hispanics and American Indians. *Department of Epidemiology the University of North Carolina at Chapel Hill*. Retrieved from http://www.ncpolicywatch.com/wp-content/uploads/2014/09/UNC-Report.pdf