Microbiological Systems involved in the Treatment of Swine Waste

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ABSTRACT

Swine are a key component to worldwide agriculture. As demand for lean white meat increases, the concentration of swine production facilities also increases in order to minimize costs. Meanwhile, rural areas are being encroached by residential development. This encroachment, also known as "urban sprawl", decreases the geographical area available for agricultural uses. Thus, swine waste production may exceed the capacity of a local or regional capacity to properly degrade this waste. Today, much research is being done on treatment of t components in swine waste. This report with focus on the biological treatments of odors, ammonia, and swine borne pathogens.

KEY WORDS

Hog/Swine Waste, Manure, Malodorous compounds, Nitrogen Fixation, Cryptosporidium, E. Coli, Salmonella, Yersinia

INTRODUCTION

Microsoft Encarta (2005) describes what is today known as a hog, more than likely descended from two types of wild swine. The first type was a wild swine from Europe. The second type was an Asian breed, first domesticated by China in 7000 B.C. Although many wild animals populated the Americas, the wild boar was not known to Native American Indians. Christopher Columbus first brought hogs to the West Indies in 1493, but it was Hernando De Soto who brought swine to North America.

Hogs play an important role in the history of the United States. On Manhattan Island, a long wall was constructed to keep control of the roaming hog herds. This is now the location of *Wall Street* (Ensminger and Parker, 1993). "The family farm may be the most important institution in American history" (www.edheritage.org, 2004). In America during the 1900's the West was being opened up. The government made promises of freedom to shape one's destiny. During this time, hogs were used as a food source, for leather, bristles for brushes, and the primary source of edible fat (Microsoft Encarta, 2005).

Hogs still play an important role in the World today. Hogs nowadays are mainly raised for lean meat and bacon. China leads the world in swine production with 457 million head of hogs. The United States is a distant second with 57 million head. In the United States, swine production is concentrated in the Midwest and the Corn Belt. Iowa leads the nation with 15 million head of hogs (Microsoft Encarta, 2005).

The family farms that once supported the ideals of freedom are rapidly decreasing. At the end of the 20th century, the swine production industry shifted to confinement production in order to minimize pork production cost and meet public demand (Walker, 2005). This concentrated the number of hogs in one location, thus concentrating the volume of waste. In the Netherlands, one square kilometer not only houses an average 435 people, but also 138 cattle, 412 pigs and 2765 poultry. "The pig industry is an important industry in many areas, with millions of pigs being produced and thousand of jobs being generated. Therefore, the disposal and treatment of effluent from this industry is now a very important issue and if treated properly it should provide opportunities rather than problems" (Kilgallen, 2001).

Odor from the storage and ground application of hog waste is the number one concern people neighboring hog operations. Although odors have no impact on drinking water quality or have no adverse health effects, odors give neighbors a constant reminder of their neighbors' source of income. Environmental scientists and water quality experts are more concerned with the levels of ammonia,

phosphorus, and swine borne pathogens in the hog waste that is applied to crop lands because of its effects on watersheds and drinking water sources.

Waste odors, nitrogen, and pathogens can all be dealt with chemically and microbiologically. The purpose of this report is to focus of the microbes in swine waste and involved in the treatment of the waste.

CURRENT REGULATION

Rules regarding environmental impacts in the United States began in the 1970's with the creation of the Environmental Protection Agency (EPA) and the passage of the National Environmental Policy Act (NEPA). Federal laws relating to water quality were soon installed with the Federal Water Pollution Control Act (FWPCA) in 1972 and the Safe Drinking Water Act (SDWA) in 1974. FWPCA and its three subsequent acts: The Clean Water Act, The Water Quality Act, and The Oil Pollution Act, resulted in a complex and comprehensive system of water pollution control. Water quality goals were clearly stated for the nation: "The objective of this Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters" (Kubasek and Silverman, 2005). The laws focused the majority of their regulatory activity on controlling individual discharges. "All discrete point sources of discharge into surface water, such as factories, pulp and paper mills, food-processing plants, and municipal waste-water treatment plants, are required to obtain a discharge permit" (Kubasek and Silverman, 2005). These permits are administered through the National Pollution Discharge Elimination System (NPDES) process. This process reflects the cooperative involvement of the EPA and the United States Department of Agriculture (USDA) to minimize the water quality and public health impacts of feeding operations.

Concentrated Animal Feeding Operations (CAFOs) are agricultural point sources that require permits. An operation must meet the definition of an animal feeding operation (AFO) before it is defined as a CAFO. AFO's are lots or facilities where:

- Animals have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period, and
- Crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility.

Previous EPA regulations based the definition of CAFOs on the number of "animal units" confined but now refers to the number of head confined (EPA, 2004). Table 1 helps define CAFOs sizes.

On Wednesday, February 12, 2003, the Environmental Protection Agency passed a final ruling on the regulatory requirements for CAFOs. The rule now requires all Concentrated Animal Feeding Operations to apply for an NPDES permit and develop a nutrient management plan. EPA believes that these regulations will significantly benefit human health and water quality by managing 300 million tons of manure. The rule also acknowledges the States' flexibility to assist small and medium-size CAFOs (Federal Register, 2003)

Table 1- Regulatory Definitions of Large CAFOs, Medium CAFO, and Small CAFOs
Source: http://www.epa.gov/npdes/pubs/sector_table.pdf

Animal Sector	Size Thresholds (number of animals)		
	Large CAFOs	Medium CAFOs1	Small CAFOs2
cattle or cow/calf pairs	1,000 or more	300 - 999	less than 300
mature dairy cattle	700 or more	200 - 699	less than 200
veal calves	1,000 or more	300 - 999	less than 300
swine (weighing over 55 pounds)	2,500 or more	750 - 2,499	less than 750
swine (weighing less than 55 pounds)	10,000 or more	3,000 - 9,999	less than 3,000
horses	500 or more	150 - 499	less than 150
sheep or lambs	10,000 or more	3,000 - 9,999	less than 3,000
turkeys	55,000 or more	16,500 - 54,999	less than 16,500
laying hens or broilers (liquid manure handling systems)	30,000 or more	9,000 - 29,999	less than 9,000
chickens other than laying hens (other than a liquid manure handling systems)	125,000 or more	37,500 - 124,999	less than 37,500
laying hens (other than a liquid manure handling systems)	82,000 or more	25,000 - 81,999	less than 25,000
ducks (other than a liquid manure handling systems)	30,000 or more	10,000 - 29,999	less than 10,000
ducks (liquid manure handling systems)	5,000 or more	1,500 - 4,999	less than 1,500

ODOR

There is no better gas detector than the human nose. The human nose can detect and discriminate odors at concentrations lower then those detectable by gas chromatography. Odor threshold values (OTV) are the minimum concentrations required for the human detection of odors. This detectable concentration is generally 500 times lower then the lowest toxic values (LTV). Therefore, most odors are detected long before their concentration becomes a health risk (Rappert and Muller, 2005).

Aesthetics, property values, and quality of life in communities with bothersome odors are significantly affected. According to D.C. Hardwick, 50% of all odor complaints are associated with land application of wastes, with 20% associated with waste storage and the remaining 30% associated with production buildings. Malodorous components of swine waste can be divided into four classes: volatile fatty acids, indoles and phenols, ammonia and volatile amines, and volatile sulfur compounds. Each of these components is formed microbially through fermentative bacteria.

Odors from swine waste can be treated in several ways, each with their disadvantages. Aerobic activated sludge systems require large amounts of energy with a large byproduct of unbeneficial biomass. Malodorous compounds can be biodegraded by many respiratory microbial species. However, their activity is inhibited by the availability of suitable electron acceptors. Anaerobic treatment processes using methanogenic bioreactors are slow due to the long doubling times of the fatty-acid degrading bacteria. Sulfate- or nitrate-reducing bacteria could be faster, but are unfavorable because they can produce noxious and toxic products.

In a report by Coates et al. (2005), they discussed the use of Fe (III)-reducing bacteria (FeRB) to treat the malodorous compounds associated with hogs waste. "Microbial Fe (III) reduction is an energetically favorable process, and in the natural environment, FeRB can out compete and inhibit both sulfate-reducing and methanogenic bacteria. FeRB also have diverse metabolisms". FeRB oxidized the simple fatty acids and alcohols as well as aromatic hydrocarbons, halogenated solvents, and chlorinated benzenes in a broad spectrum of situations. In pure cultures, FeRB is known to oxidize long-chain fatty acids and aromatics such as toluene and benzoate, as well as dehalogenate chlorinated solvents such as tetracholoromethane and tetrachloroethylene.

The procedure for Coates et al. (2005) was as follows:

> "In order to determine the potential applicability of strain NU, or FeRB in general, to the treatment of swine manure odor, freshly collected waste from the SIUC primary lagoon was dispensed in 1-liter aliquots into three 2-liter bottles under an aerobic headspace and sealed with thick butyl rubber stoppers. One of the prepared bottles was inoculated (10% by volume) with an active acetate-oxidizing Fe (III)-reducing culture of strain NU and amended with approximately 100 mM amorphous Fe (III) oxide, one bottle was merely amended with approximately 100 mM amorphous Fe (III) oxide, and the third bottle was unamended. All bottles were incubated in the dark at 30°C. Headspace samples were collected at various intervals for methane analysis. Liquid samples were also collected at various intervals for analyses of VFA, pH, and Fe (II) and total iron content."

From the results of Coates et al. (2005), it is observed that all of the *Geobactor* species tested, except *G. sulfurreducens,* were able to oxidize the primary VFAs Butyrate, Isobutyrate, and Valerate. *Geovibrio ferrireducens* and *Geothrix fermentens* also degraded the VFAs, showing a variety of Fe (III) reducers.

Table 2 - Degradation of the prominent malodorous VFAs associated with weine waste by varoius phylogenetically diverse Fe (III) reducing bacteria
Source: Coates et al. (2005)

	Growth on:		
Fe(III) reducing organism	Butyrate	Isobutyrate	Valerate
Geobacter metallireducens	+	+	+
Geobacter humireducens	+	+	+
Geobacter sulfurreducens	-	-	-
Geobacter grbiciae	+	+	+
Shewanella Algae	-	-	-
Geothrix Fermentans	+	+	-
Geovibrio ferrireducens	-	+	+

The use of Fe (III) reducing bacteria is not ready for worldwide application. There are however, some practical ideas for odor control. Every year *National Hog Farmer* and the National Pork Board sponsors an environmental recognition program called Environmental Stewards of the Pork Industry. In 2001, Maple Grove Pork Company of North English, Iowa was recognized for its "odor eater". This 12.8 x 44.2 meter (42 x 145 ft) hoop structure covers a 3.5 meter (11.5 foot) deep concrete pit. Designed by Iowa State University graduate Dan Meyer, this structure works as a "solar manure digester". The translucent cover raises temperatures and stimulates bacteria growth. This growth helps break down the manure solids before the effluent is discharged into a lagoon (*National Hog Farmer*, 2001)

Along with their "odor eater", Maple Grove Pork has advanced environmental aspects in the pork producing industry with their testing protocols, backup systems, and emergency action plan.

NITROGEN

Nitrogen is a chemical element found in the periodic table. It has the symbol N and the atomic number 7. In its pure form, it is a colorless, odorless, tasteless non-metal gas. According to Wikipedia.org (2005) the Earth's atmosphere is 78% nitrogen and is the mineral nutrient most in demand by microorganism and plants. Maier et al. states in their book *Environmental Microbiology (*2000), nitrogen is the 4th most common element found in cells and is included in nitrogen fixation, ammonium oxidation, assimilatory and dissimilatory nitrate reduction, ammonification, and ammonium assimilation. Nitrogen, in its molecular form, is relatively non-reactive in the atmosphere (N_2). Nitrogen is an essential part of amino and nucleic acids. Amino and nucleic acid are vital to all life, which makes nitrogen vital to all life. In nature, nitrogen is slowly biologically converted to useful compounds for living organisms.

The shift from small farms to industrial-type production facilities is forcing changes on the treatment of animal wastes. Land spreading and lagoons are common treatment and disposal techniques for small farms, but the land requirements for a large farm are excessive. Large-scale farms cannot treat their concentrated waste by land-based treatment systems. They often produce odors as mentioned above, and release of nutrients into the water sources (Pagilla et al., 2005). The increase in available nutrients promotes plant growth, favoring certain species over others. In aquatic environments, enhanced growth of choking aquatic vegetation leads to eutrophication. According to Wikipedia online encyclopedia, eutrophication is the gradual increase and enrichment of an ecosystem by nutrients such as nitrogen and phosphorus which disrupts the normal functioning of the ecosystem, causing a variety of problems (en.wikipedia.org, 2005).

Today, nitrogen is industrially converted through the processes of fertilizer manufacturing. The ability to combine or fix nitrogen is where nitrogen is converted into ammonia, which in turn can be used directly as fertilizer (en.wikipedia.org, 2005). The manufacturing of fertilizers accounts for 15% of the nitrogen fixation. Fertilizer manufacturing is an energy dependent process, and thus expensive. As fossil fuel prices increase, the more attractive manure management plans have become (Maier et al., 2000). Wastewater reuse is an especially popular because the people who have livestock wastewater are often the same people who have land that needs fertilizer. Nitrogen fixation provides ammonia. Ammonia (NH_3) can be is used directly has a fertilizer or reacted to form ammonia nitrate, which is also used as a fertilizer (Maier et al., 2000). Finding a way to fix ammonia from nitrogen while using a small amount of energy, is a major field of research.

Table 3 - Representative Genera of Free-Living Nitrogen Fixers

Status with Respect to Oxygen	Mode of Energy Generation	Genus
Aerobe	Heterotrophic	*Azotobactor*
		Beijerinckia
		Acetobacter
		Pseudomonas
	Phototrophic	*Anabaena*
		Nostoc
Facultative anaerobe	Heterotrophic	*Klebsiella*
		Bacillus
Microaerophile	Heterotrophic	*Xanthobacteria*
		Azospirillum

"Nitrogen is fixed into ammonia by over 100 different free-living bacteria, both aerobic and anaerobic, as well as some actinomycets and cyanobacteria" (Maier et al., 2000). Table 3 shows a respresentative sample of Nitrogen fixers. Aerobic bacteria require the present of oxygen to live. Aeration of waste liquid will supply the aerobic bacteria with the oxygen they need to grow. Being a heterotrophic organism means organic compounds are required as a source of energy. A phototrophic bacteria uses the suns radiation as a source of energy. Anaerobic require the lack of oxygen to servive. Facultative anaerobes can live in both aerobic and anaerobic conditions.

Although all the required bacteria is present and the conditions are right for nitrogen fixation, why aren't more hog farmers treating their waste producing homemade ammonia to spread on their fields? The

baisc issue is money. Most of the reseach papers writen today on the treatment of swine waste, are on how to make it econmical for hog farmers to treat their waste.

In a paper by James W. Blackburn (2001), the profitability of an aerobic thermophic process was studied. The system used was a very low cost design that reduced the initial costs to pork producers. It made use of batch operations, with minimal system insulation, and without regeneration heat exchangers. Two waste concentrations were considered: 80 and 120 g/L dry solids. Most production facilities have more diluted effluent than this, whick would require a larger volume system for the same solids rate.

A flow diagram of the system is presented in Figure 1. Numbers designate the individual paths. This system is relatively small compared to the area of a lagoon that would be used to treat the same volume of wastewater. The description of the system as explained by Blackburn is as follows:

> "A lined in-ground reactor pit is covered with a lightweight structure to contain the biogas air from the reactor pit. Initially, the pit is loaded with hog waste from production building storage (1). It is warmed (2) with heat recovered from processed product (9) before the product is land spread or stored (10). Energy is released in the reactor under aerobic thermophilic biooxidation and the heat released must be extracted as hot water through a heat exchanger (11). This hot water stream provides the useful energy that can be easily used as a source of heating for building or in heating aquaculture tanks or greenhouses. Work is underway to investigate alternative uses for the energy in the hot months. For aerobic thermophilic processing, oxygen must be added. This is done through one of the several possible types of aeration systems. The one selected forth is design is known for its ability to provide high oxygen transfer rates in systems of high solids concentration and enables air recycle with ease. This type is called an agitated sparger ring system. Fresh air (5) is added with a blower system designed to recycle some air from the reactor (4). The recycle air is a key to the energy production of the system since it enables the transfer of high percentages of the oxygen in the fresh air with the ultimate lessening of water vapor lost from the air flowing from the system (5).
>
> An agitator is needed to help maximize the heat transfer, solids mixing, and oxygen transfer. The air leaving the reactor cover (5) passes through an ammonia scrubber system to recover ammonia as a high-grade ammonium sulfate solution fertilizer (8). Concentrated sulfuric acid is added to the scrubber solution (7). Alternatively, it is possible to make ammonium phosphate or other valuable fertilizer solutions using other acids. This may be either saved for special use or sale, or mixed into the finished aerobic thermophilic treatment product to restore its nitrogen level. Odor-reduced air is emitted from the scrubber to the atmosphere (6). Heat must be removed from the reactor to maintain 55ºC so that the action of the thermophilic bacteria is maximized. "

Conclusions from Blackburn's study can be condensed into Fgure 2 which shows the capital cost estimated for an aerobic thermophilic system. Capital costs do increase as waste concentrations decreases. Therefore the intergration of sludge thickening may be reguired.

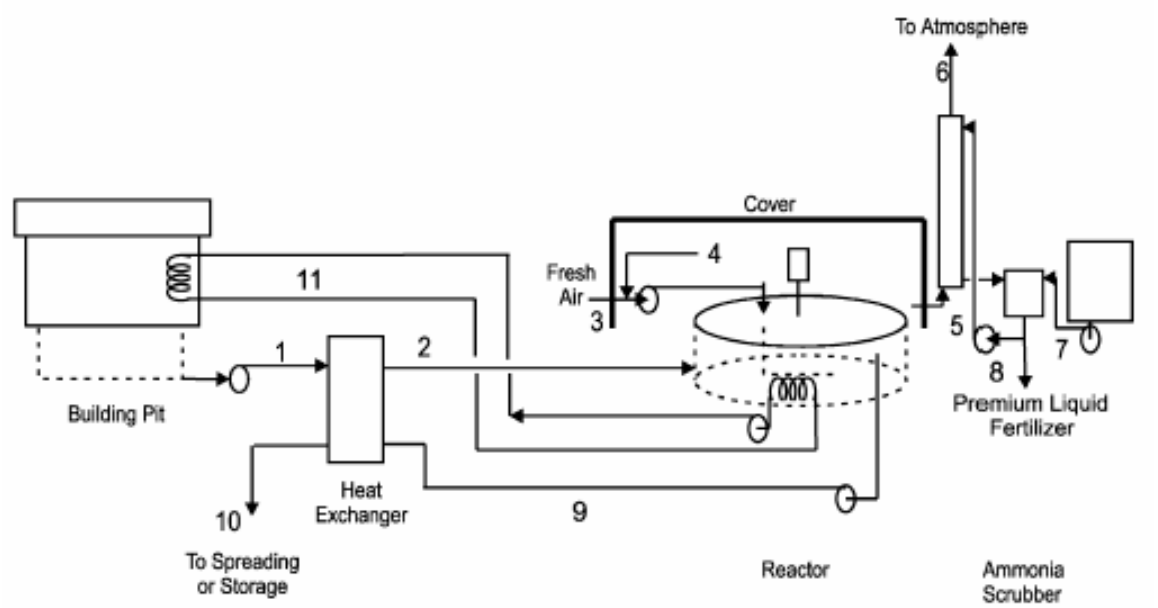

Figure 1 – Flowsheet of an advanced aerobic thermophilic system for swine waste processing
Source: Blackburn (2001)

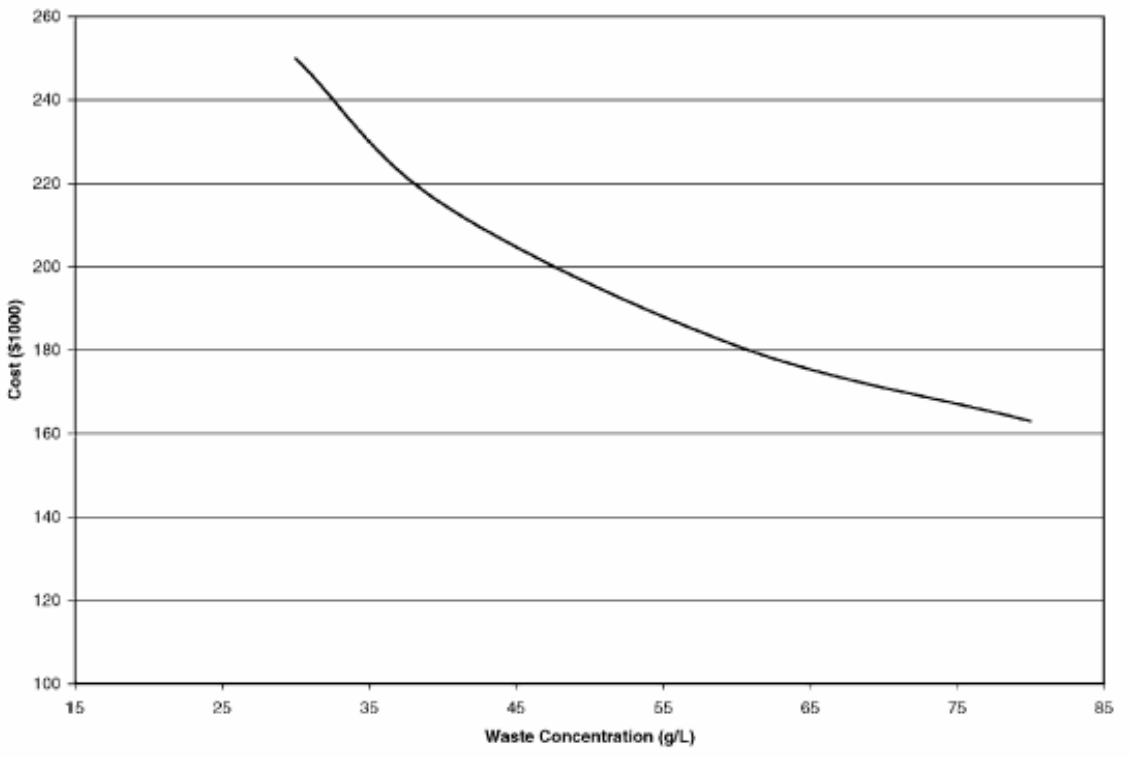

Figure 2 – Capital costs of aerobic thermophilic processing for a 10 000 hog operation
Source: Blackburn (2001)

PATHOGENS

The treatment of swine waste is important when it comes to pathogens. Cryptosporidium, E. coli, Salmonella, and Yersinia are all pathogens found in the intestines of swine, as well as other animals. These pathogens are fecal-oral transmitted and can be transmitted to humans through water supplies if untreated waste mixes with water sources. Procedures in swine waste treatment are one way to help reduce the pathogen treatment needed during water distribution.

"Waterborne diseases are those transmitted through the ingestion of contaminated water that serves as the passive carrier of the infectious agent" (Maier et al., 2000). Table 4 below displays some characteristics of enteric pathogens. "Microorganisms transmitted by the fecal-oral route are referred to as enteric pathogens" (Maier et al., 2000). The incubation period is the time between when an organism is infected with the pathogen, to when it has signs or symptoms.

Table 4 - Incubatioin time for Common Enteric Pathogens
Source: Maier et al., 2000

Agent	Incubation Period	Modes of transmission	Duration of Illness
Cryptosporidium	2-14 days	Food or water ingestion, direct and indirect contact	Weeks, Months
Escherichia coli			
ETEC	16-72 hr	Food of water ingestions	3-5 days
EPEC	16-48 hr	Food or water ingestion, direct and indirect contact	5-15 days
EHEC	72-120 hr	Food ingestion, direct or indirect contact	2-12 days
Salmonella	16-72 hr	Food ingestion, direct or indirect contact	2-7 days
Yerinia enterocolitica	3-7 days	Food ingestion, direct contact	1-3 weeks

Cryptosporidium

According to the Center for Disease Control (CDC, 2005), *Cryptosporidum* is the genus name for a group of protozoans that live in the intestines of animals and humans. Protected by an outer shell, the sporulates oocysts passes in the bowel movement (Maier et al. 2000). This outer shell allows it to survive outside the body and be extremely resistant to disinfectants containing chlorine.

Identified as a human pathogen in 1976, *Cryptosporidum* enters the environment via human and animal waste. There has been several waterborne outbreaks since 1976, with the most well know being the Milwaukee outbreak in April 1993. This outbreak infected over 400 000 people and killed more then 50 (Maier et al., 2000).

E. coli

Escherichia coli (E. coli) is found in the intestines of all warm-blooded animals. These rod-shaped, gram-negative bacteria are the main source of traveler's diarrhea and diarrhea in infants and children (Maier et al. 2000). Most E. coli outbreaks are do to improper sanitation during food processing and handling, but some cases have been associated with wastewater contaminating the water supply.

Salmonella

Maier et al. (2000) describes *salmonella* as the genus name for a group of more then 2000 rod-shaped, gram-negative bacteria. *Salmonella* can infect a large variety of animals and are all pathogenic to humans. *S. typhi* is the bacteria involved in typhoid fever. Although it was once the leading cause of death for soldiers in the Civil War, typhoid fever is rarely found in the United States. After the introduction of chlorination of U.S. water supplies the death rate of typhoid fever dropped from 36 in 100 000 people to only 5.

Salmonella is the second most common cause of food borne illness, but because the "route of transmission is fecal-oral, any food or water contaminated with feces may transmit the organism to a new host" (Maier et al., 2000).

Yersinia

According to Maier et al. (2000), *Yersinia* are small rod-shaped, gram-negative bacteria. Associated with symptoms such as diarrheas and/or vomiting, this bacterium inhabits animals including pigs, birds, beaver, cats, and dogs, with pigs being the primary reservoir. Primarily a food-borne contaminate, Yersinia could contaminate a water source if came in contact with.

Pathogen Control

Pathogen control is a secondary concern compared to "nutrient stabilization, volume reduction, and temporary storage benefits" (Vanotti et al. 2005). Stabilization of infectious microorganisms before application of solids to land is well known, but little is known about the rates of pathogen reduction in liquid waste.

An alternative for the anaerobic lagoon was developed by Vanotti, Szogi, and Hunt in 2001. This manure treatment system consisted of the following steps:

1) Polymer enhanced solid-liquid separation
2) Biological nitrogen removal using nitrifying bacteria
3) Addition of chemicals to reach a pH value of 10.5 to optimize step 4
4) Phosphorus extraction using a lime precipitation process
5) Flocculation of solids from liquid manure

In the 2005 paper by Vanotti et al., they reported on how each of the processing units affected the survival of pathogens in liquid swine manure. The total number of fecal coli forms, enterococci, and salmonella were counted for each step of the treatment system described above. "Fecal coli forms and presumptive E. Coli were enumerated by using MacConkey's agar plates, incubated at 44.5 ºC. Total coli forms were enumerated on MacConkey's agar incubated at 37ºC overnight. Enterococci were enumerated on modified Enterococcus agar incubated at 37 ºC overnight. Salmonellae were enumerated by spiral plating on XLT4 agar and incubating the plates at 37 ºC" (Vanotti et al., 2005).

Results, summarized in Table 5, show a reduction in fecal coli forms, enterococci, and salmonella. In the nitrification-denitrification conditions, elimination of COD and TKN as well as alternating oxic and anoxic, effectively decreased the number of pathogens. Alkali treatment during the phosphorus removal "produced a sanitized effluent".

Table 5 – Microbiological analyses of liquid manure effluent before treatment and at each step of the treatment system. Source: Vanotti et al. (2005)

Microbiological analyses of liquid manure effluent before treatment and at each step of the treatment system[a]

Sampling point[b]	Total coliforms (log_{10}/ml)	Fecal coliforms (log_{10}/ml)	Enterococci (log_{10}/ml)	Confirmed *Salmonellae*[c] (log_{10}/ml)
Lagoon wash water	3.40 (0.58)	4.18 (0.40)	3.46 (0.27)	2.61 (1.06)
Homogenization tank	6.79 (0.45)	6.23 (0.24)	5.73 (0.44)	3.89 (0.87)
Post-separation	6.07 (0.50)	5.75 (0.08)	4.78 (0.73)	3.27 (1.01)
Post-nitrification/denitrification	2.25 (0.49)	1.88 (0.35)	1.63 (0.34)	1.54 (0.87)
Post-phosphorus removal	<0.30	<0.30	<0.30	<0.30

[a] Values are mean (standard deviation) of log_{10} colony forming units (cfu) per ml for duplicate samples for five runs of the system; < indicates there were no colonies to count, thus only the upper threshold limit value can be calculated. To compare means in a column, $LSD_{0.05} = 0.42, 0.31, 0.40$, and 0.88 log_{10}/ml for total coliforms, fecal coliforms, Enterococci and Salmonellae, respectively.

[b] Lagoon supernatant liquid (1) was used to flush manure from barns. Flushed raw manure was collected and mixed in homogenization tank (2) and passed through the multi-step treatment system consisting of solid–liquid separation (3), biological N removal (4) and phosphorus removal (5).

[c] Presumptively positive salmonellae were confirmed by serological test.

There have been a few studies done on the effectiveness of pathogen removal in anaerobic digestion. Bendixen (1994) resulted in the destruction of pathogens at thermophlic temperatures (20-70°C) but the presence of pathogens at mesophilic temperatures (20-40°C). Côté et al. (2005) studied pathogen removal at psychrophilic temperatures (0-20°C) and found 97.94-100% removal.

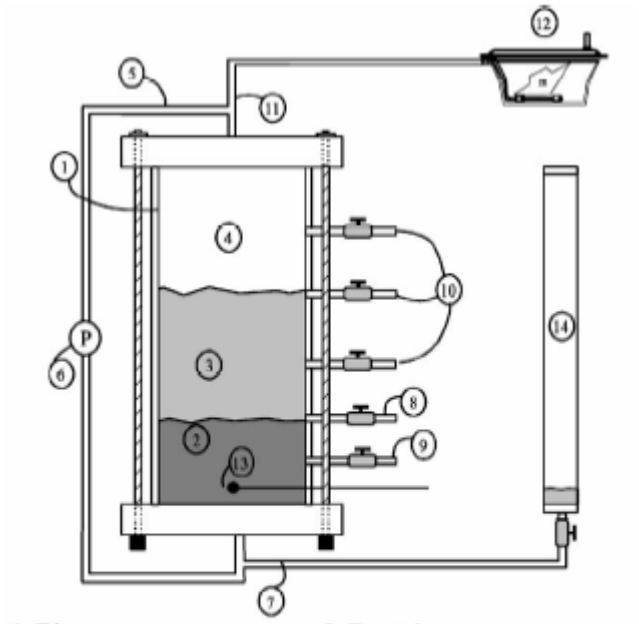

Figure 3 – Schematic of Sequencing Batch Reactor
Source: Cote et al. 2005

The study conducted by Côté et al. "evaluated the efficiency of the psychrophilic anaerobic digestion process in a sequencing batch reactor (SBR)". The schematic of the scale SBR used is seen in Figure 3. Fresh slurries, obtained from a variety of sources, were used in the laboratory digesters. Manure can from transfer tanks and long term storages for commercial growing-finishing, nursery, and maternity hog operation. "Some manure slurry was so diluted that the bioreactor was not large enough to receive sufficient volume to reach the design organic loading rate of 2.00 g COD/l d" (Côté et al., 2005).

"In order to verify the presence of E. coli O:157, 25 g of the sample were incubated in 225 ml of modified Tryptic soy broth with novobiocin for 24 h at 42 ºC...Salmonella was detected by incubating 25 g of the samples in 225 ml of nutrient broth (Difco Laboratories) overnight at 3 ºC...For the detection of Y. enterocolitica, 10 g of samples were incubated in 90 ml of phosphate-buffered saline containing sorbitol (2%) and biliary salts (0.15%) at 4ºC for 21 days...The detection of Cryptosporidium and Giardia was done using Enzyme-linked immunosorbent assays (ELISA)" (Côté et al., 2005).

Although the characteristics of the fresh slurries varied, it was successfully treated with psychrophilic anaerobic digestion in sequencing batch reactors. The data collected by Côté et al. are summarized in Table 6 below.

Table 6 - Indicator and pathogenic microorganisms content of raw and treated effluent
Source: Cote et al. 2005

Total Coliforms			Escherichia Coli			Salmonella		Cryptosporidium		Giardia	
Before	After	% removed	Before	After	% removed	Before	After	Before	After	Before	After
550000	0	100%	360000	0	100%	+	-	-	-	-	-
14600	0	100%	12000	0	100%	+	-	-	-	-	-
120000	0	100%	84000	0	100%	+	-	-	-	-	-
20000	0	100%	6000	0	100%	n/a	-	+	-	-	-
14500	20	99.86%	8200	0	100%	+	-	+	-	-	-
42000	40	99.90%	27000	30	100%	+	-	+	-	-	-
109000	10	99.99%	51000	0	100%	+	-	+	-	-	-
170000	10	99.99%	160000	0	100%	-	-	-	-	-	-
30000	20	99.93%	21000	10	100%	-	-	-	-	-	-
3400	70	97.94%	3000	10	100%	-	-	-	-	+	-
0	0		0	0		-	-	-	-	-	-
22000	10	99.95%	17000	0	100%	-	-	-	-	-	-
660000	120	99.98%	500000	60	100%	-	-	-	-	-	-
3300000	450	99.99%	2600000	180	100%	-	-	-	-	+	-
35000	0	100%	22000	0	100%	-	-	-	-	-	-
25000	30	99.88%	14000	0	100%	-	-	-	-	-	-
4000	0	100%	2900	0	100%	+	-	-	-	-	-
26000	0	100%	22000	0	100%	-	-	-	-	-	-
60000	0	100%	52000	0	100%	-	-	-	-	-	-

CONCLUSION

Swine are an important component of life in Iowa, the United States, and the World. As technology increase, the understanding of odors, ammonia, and pathogens associated with swine waste also increase. Pigs were once free roaming animals used for meat, lard, and leather production. Today, pigs are mainly used for the production of lean meat, but they are confined to massive buildings with a capacity for thousands.

As swine production has concentrated to small areas, so has the volume of waste that needs to be handled. With “urban sprawl” continuing, swine producers have less land to adequacy treat their waste. Despite new regulations, implication of new treatment technologies is lagging. There is a lot of current information regarding the treatment of swine waste; however more research is needed for practical treatment options.

REFERENCES

Bendixen, H.J. (1994). "Safeguards against pathogens in Danish biogas plants". *Water Science Technology,* **30**, 12, 171

Blackburn, James W. (2001) "Effect of swine waste concentration on energy production and profitability of aerobic thermophilic processing"**.** *Biomass and Bioenergy*, **21**, 1, 43

Center for Disease Control and Prevention (2005). "Parasite Disease Information – Cryptosporidium". http://www.cdc.gov/ncidod/dpd/parasites/cryptosporidiosis/factsht_cryptosporidiosis.htm Accessed 11/28/05

Coates, J. D.; Cole, K. A.; Michaelidou, U.; Patrick, J.; McInerney, M. J. and Achenbach, L.A. (2005) "Biological Control of Hog Waste Odor through Stimulated Microbial Fe(III) Reduction". *Applied and Environmental Microbiology*, **71**, 8, 4728.

Côté, Caroline; Masse, D.I.; and Quessy, S. (2005). "Reduction of indicator and pathogenic microorganisms by psychrophilic anaerobic digestion in swine slurries". *Bioresource Technology,* In Press.

Ensminger, M. E. and Parker, R.O. (1997) In *Swine Science, Sixth edition*. Interstate Publishers, Inc., Danville, Illinois.

Environmental Protection Agency (2004). "Animal Feeding Operations". National Pollutant Discharge Elimination System. http://cfpub1.epa.gov/npdes/home.cfm Accessed 11/9/05

"The Family Farm, in Montana's History" (2004). http://www.edheritage.org/1910/folkways/familyfarm.htm Accessed 11/10/05

Federal Register, Vol. 68, No. 29. Wednesday February 12, 2003. Rules and Regulation. Environmental Protection Agency. 40 CFR Parts 9, 122, 123 and 412.

Hardwick, D.C. (1985). Agricultural problems related to odor prevention and control. In: V.C. Nielsen, J.H. Voorburg and P.L. Hermite, Editors, *Odour Prevention and Control of Organic Sludge and Livestock Farming*, Elsevier Applied Science Publishers, New York

"Hog" (2005). Microsoft Encarta. http://Encarta.msn.com Accessed 11/8/05

Juteau, P.; Tremblay, D.; Ould-Moulaye, C.B.; Bisaillon, J.G. and Beaudet, R. (2004) "Swine Waste Treatment by self-heating aerobic thermophilic bioreactor". *Water Research,* **38**, 2004, 539.

Kilgallen, P. and O'Shea, J. (2001) "Effluent Treatment Options for Treating Pig Slurry". *Concepts in Pig Science 2001*, p97-104.

Kubasek, N.K. and Silverman, G.S.. (2005) In *Environmental Law*. Pearson Prentice Hill, Upper Saddle River, New Jersey.

Maier, R.M.; Pepper, I.L.; and Gerba, C.P. (2000) In *Environmental Microbiology*. Academic Press, San Diego, California.

National Hog Farmer. (2001) "Environmental Stewardship Awards of the Industry". September 15, 2001, pE6-E15.

"Nitrogen" (2005). http://en.wikipedia.org/wiki/Nitrogen Accessed 11/13/05

Pagilla, K.R.; Kim, H. and Cheunbarn, T. (2000) "Aerobic Thermophilic and Anaerobic Mesophilic Treatment of Swine Waste". *Water Research*, **34**, 10, 2747.

Rappert, S. and Müller, R. (2005) Odor compounds in waste gas emissions from agricultural operations and food industries. *Waste Management,* **25**, 9, 887

Walker, Paul and Kelly, Tim. (2005) "Comparison of a static gravity screen-roll press combination separator to a PAM-assisted gravity belt thickener system for swine waste slurry solids separation". *Bioresource Technolog*, **71**.

Vanotti, Matias B.; Millner, P. D.; Hunt, P.G.; Ellison, A.Q. (2005). "Removal of pathogen and indicator microorganisms from liquid swine manure in multi-step biological and chemical treatment". *Bioresource Technology,* **96**, 2, 209

Vanotti, M.B.; Szogi, A.A.; and Hunt, P.G. (2001). Wastewater treatment system. Patent Application Serial No. 09/903,620, allowed April 21, 2004. US Patent and Trademark Office, Washington, DC.