CITY OF BAY CITY

MINUTES • DECEMBER 12, 2023

COUNCIL CHAMBERS | 1901 5th Street	City Council Regular Meeting	6:30 PM

1901 5TH STREET
BAY CITY TX,77414

Mayor

Robert K. Nelson

Mayor Pro Tem

Blayne Finlay

Councilman

Bradley Westmoreland

Councilwoman

Becca Sitz

Councilman

Jim Folse

Councilman

Benjamin Flores

Through a united and collaborative effort, we seek to grow the City of Bay City with a diverse culture that is proud to call Bay City home. We envision a thriving family-centered community where citizens are involved in the future development of our city. We desire our citizens to work, play, worship and shop in the community in which we live. Visitors are welcomed and encouraged to enjoy the friendly environment and amenities the citizens and business owners have created together.

CALL TO ORDER AND CERTIFICATION OF QUORUM

The meeting was called to order by Mayor Robert K. Nelson at 6:48 a.m.

PRESENT
Mayor Robert K. Nelson
Mayor Pro Tem Blayne Finlay
Councilman Jim Folse
Councilwoman Becca Sitz

ABSENT
Councilman Brad Westmoreland

INVOCATION & PLEDGE

Texas State Flag Pledge: *"Honor The Texas Flag; I Pledge Allegiance To Thee, Texas, One State Under God, One And Indivisible."*

Councilman Jim Folse

MISSION STATEMENT

The City of Bay City is committed to fostering future economic growth by collaborating with our citizens, employers, current and future businesses, as well as the Community and Economic Development Centers. We strive to deliver superior municipal services and to invest in quality-of-life initiatives such as housing, businesses, jobs and activities for all citizens. We make a concerted effort to respond to resident's concerns in a timely and professional manner in order to achieve customer satisfaction.

Councilman Jim Folse

APPROVAL OF AGENDA

Motion made by Councilman Flores to approve the agenda and tabling item number nine (9) indefinitely, Seconded by Councilwoman Sitz. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

PUBLIC COMMENTS

Kim Brown, 5112 FM 2668, provided supporting documentation to Council (included per City Attorney Request). Ms. Brown stated that she is a neighbor of Ben Flores and their property borders his. Ms. Brown claimed that Mr. Flores' pig farm is on a flood plain and will contaminate her water. Ms. Brown stated that she has provided government studies on pig contamination, adding that the City Ordinance protects City wells and why not hers.

Jason Morrison, 5112 FM 2668, stated he's concerned regarding swine. He feels that Ben Flores has loosely interpreted the law to benefit himself. Mr. Morrison asked Council to continue to investigate and explore.

Terri Rafter, Chaparral Road, stated that she is concerned that Mr. Flores' pigs will get out. Ms. Rafter added that her property has flooded from that creek so she knows his will, adding that she is concerned about hurricanes in regards to the keeping of pigs.

PROCLAMATIONS

1. **Proclamation ~ Recognition of Mark Finlay for his years of service to the City of Bay City as a Municipal Court Judge.** Robert K. Nelson, Mayor

   Mayor Nelson read the proclamation recognizing Mark Finlay and his years of service. Judge Suzan Thompson expressed her gratitude to Mark Finlay and his services. Mayor Pro Tem Blayne Finlay expressed his pride in his fathers achievements.

ACKNOWLEDGEMENT FROM CITY MANAGER

2. **Acknowledgement of staff for successfully passing TCEQ Comprehensive Compliance Inspection**

   Shawna Burkhart, City Manager, acknowledge the achievements of the following staff: Krystal Mason, Ozzie Martinez, Terry Myren, Johnny Cervantes, Jose DeLeon, Anthony Morales, and Ramon Hernandez.

ITEMS / COMMENTS FROM THE MAYOR AND COUNCIL MEMBERS

Councilman Folse stated that he enjoyed the Shop with a Cop event and glad he was invited. Mayor Pro Tem Finlay thanked crews for cleaning up trash on Norvell. Mayor Pro Tem Finlay inquired about wide loads going through town and Chief Rodriguez stated that restrictions are now in effect. Mayor Pro Tem Finlay thanked Parks & Rec for their work regarding the rescheduling of the parade to the 14th, adding that Chick-fil-A opening was a success and recognized Tidehaven Highschool football team going to State. Councilwoman Sitz request a report on streets at the next meeting. Mayor Nelson stated that Willie Rollins had passed and he will be missed by the community.

REGULAR ITEMS FOR DISCUSSION, CONSIDERATION AND/OR APPROVAL

3. **Appointment ~ Consider, and/or approve the appointment of Associate Municipal Court Judge Suzanne Sullivan.**

   Suzan Thompson, Municipal Court Judge, stated that she and Judge Finlay both agreed on Suzanne Sullivan to replace Judge Finlay as the Associate Municipal Court Judge.Motion made by Councilwoman Sitz to approve the appointment of Suzanne Sullivan as the Associate Municipal Court Judge, Seconded by Mayor Pro Tem Finlay. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

   Suzanne Sullivan was sworn in by Judge Mark Finlay.

4. **Report ~ Presentation of Day of Dead Event report.**

P. Darve Smith, Tourism Manager, provided Council with a report of the Day of the Dead event, adding that this year was a two day event that was attended by 2,012. Councilwoman Sitz stated that she had enjoyed the event and Councilman Flores stated that, as a vendor, he thought it was well organized.

5. **Personnel ~ Discuss, consider and/or approve amending an ordinance by amending the employee guidelines for City Employees.** Rhonda Clegg, Director of Human Resources

   Motion made by Mayor Pro Tem Finlay to approve the Ordinance amending the employee guidelines, Seconded by Councilman Folse. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

6. **Personnel ~ Discuss, consider, and/or approve an ordinance regarding the City of Bay City's Texas Municipal Retirement System Benefits: (1) Adopting non-retroactive repeating COLAs for retirees and their beneficiaries, and (2) authorizing annually accruing updated service credits and transfer updated service credits.** Rhonda Clegg, Human Resources Director

   Motion made by Councilwoman Sitz to approve an ordinance regarding the City of Bay City's Texas Municipal Retirement System Benefits: (1) Adopting non-retroactive repeating COLAs for retirees and their beneficiaries, and (2) authorizing annually accruing updated service credits and transfer updated service credits, Seconded by Councilman Flores. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

7. **Ordinance ~ Discuss, consider, and/or approve an Ordinance of the City of Bay City, Texas adopting a "Budget Amendment #3" to the "Annual Budget of the City of Bay City, Texas, for the Fiscal Year 2023"; providing for supplemental appropriation and/or transfer of certain funds; providing for severability; and providing other matters related to the subject.** Scotty Jones, Assistant City Manager

   Motion made by Mayor Pro Tem Finlay to approve an Ordinance of the City of Bay City, Texas adopting a "Budget Amendment #3", Seconded by Councilwoman Sitz. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

8. **Grants ~ Discuss, consider, and or approve various equipment to be funded by the American Rescue Plan Funds and authorize staff to proceed with procurement.** Christella Rodriguez, Chief of Police

   Motion made by Councilwoman Sitz to approve various equipment to be funded by the American Rescue Plan Funds and authorize staff to proceed with procurement, Seconded by Councilman Folse. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried.

9. ~ Commentary of Executive Session held on November 14, 2023 and subsequent vote to allocate funds to hire a health consultant. Ben Flores, Councilmember

Item Tabled

10. ~ Deliberations and action on hiring a consultant regarding pigs in city limits.

Shawna Burkhart, City Manager, stated that after the last meeting coming out of the closed session, Councilman Flores had several questions regarding the hiring of a health consultant. Ms. Burkhart added that at this time the City has not taken action on finding a consultant. Anne Marie Odefey, City Attorney, clarified that the City has not halted action but extended process to do additional leg work as to what kind of consultant. Councilman Flores stated that he wanted clarification on the process for public interest.

Councilman Folse stated that he is dis-hearted and surprised on the attempt to stop the City on doing it's due diligence to support our citizens and their concerns. Councilman Folse stated that he made the previous motion and stands by it. Councilman Folse made a motion to hire a consultant to evaluate the pig farm to determine if any actions that are needed and/or recommendations on how to deal with it , with the previous stated amount of $10,000 or less. Councilwoman Sitz and Mayor Pro Tem Finlay both second the motion.

Mayor Nelson stated that he had questions and voted against the item the last time, asking what are we going to gain. Ms. Odefey replied that it is required by law that if you are wanting to enforce regulation you have to have a health consultant say what needs to be done, what their recommendations and least restrictive manner in the way of doing it to enforce any of the City's rules regarding farming and right-to-farm.

Motion made by Councilman Folse to hire a consultant regarding pigs in city limits, Seconded by Councilwoman Sitz. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Folse, Councilwoman Sitz. Voting Abstaining: Councilman Flores. Motion carried.

ITEMS / COMMENTS FROM THE MAYOR, COUNCIL MEMBERS AND CITY MANAGER

Announcement made reminding Council of the parade on the 14th and to be at City Hall at 6:30 p.m.

ADJOURNMENT

Motion made by Councilman Flores to adjourn, Seconded by Councilwoman Sitz. Voting Yea: Mayor Nelson, Mayor Pro Tem Finlay, Councilman Flores, Councilman Folse, Councilwoman Sitz. Motion carried and Council adjourned at 7:58 p.m.

PASSED AND APPROVED, this 9th day of January 2024.

ROBERT K. NELSON, MAYOR

CITY OF BAY CITY, TEXAS

JEANNA THOMPSON

CITY SECRETARY

Enclosed attachments provided to Council by Kim Brown during public comments

PLOS ONE

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PMCID: PMC4232307
PMID: 25397404

A Determination and Comparison of Urease Activity in Feces and Fresh Manure from Pig and Cattle in Relation to Ammonia Production and pH Changes

Xiaorong Dai and Henrik Karring *

François Blachier, Editor

Abstract

Ammonia emission from animal production is a major environmental problem and has impacts on the animal health and working environment inside production houses. Ammonia is formed in manure by the enzymatic degradation of urinary urea and catalyzed by urease that is present in feces. We have determined and compared the urease activity in feces and manure (a urine and feces mixture) from pigs and cattle at 25°C by using Michaelis-Menten kinetics. To obtain accurate estimates of kinetic parameters V_{max} and K'_m, we used a 5 min reaction time to determine the initial reaction velocities based on total ammoniacal nitrogen (TAN) concentrations. The resulting V_{max} value (mmol urea hydrolyzed per kg wet feces per min) was 2.06±0.08 mmol urea/kg/min and 0.80±0.04 mmol urea/kg/min for pig feces and cattle feces, respectively. The K'_m values were 32.59±5.65 mmol urea/l and 15.43±2.94 mmol urea/l for pig feces and cattle feces, respectively. Thus, our results reveal that both the V_{max} and K'_m values of the urease activity for pig feces are more than 2-fold higher than those for cattle feces. The difference in urea hydrolysis rates between animal species is even more significant in fresh manure. The initial velocities of TAN formation are 1.53 mM/min and 0.33 mM/min for pig and cattle manure, respectively. Furthermore, our investigation shows that the maximum urease activity for pig feces occurs at approximately pH 7, and in cattle feces it is closer to pH 8, indicating that the predominant fecal ureolytic bacteria species differ between animal species. We believe that our study contributes to a better understanding of the urea hydrolysis process in manure and provides a basis for more accurate and animal-specific prediction models for urea hydrolysis rates and ammonia concentration in manures and thus can be used to predict ammonia volatilization rates from animal production.

Introduction

The emission of ammonia (NH_3) from agricultural systems is a major environmental problem. Most NH_3 emissions come from animal production, especially from manure (a mixture of urine and feces). In addition, NH_3 emission affects human and animal health [1]–[3]. NH_3 in manure is formed by the hydrolysis of urinary urea ($CO(NH_2)_2$) and is catalyzed by microbial urease that is present in feces. The enzymatic decomposition of urea into carbonic acid (H_2CO_3) and volatile NH_3 is initiated when urine and feces contact one another after being excreted. Reaction 1 represents the overall catalytic hydrolysis of urea, which enables organisms to use urea as a nitrogen source [4], [5]. The enzymatic hydrolysis of urea has a half-time of 20 ms at 25°C, and urease is among the most proficient known enzymes [6]–[8].

Reaction 1.

$$CO(NH_2)_2 + 2H_2O \xrightarrow{Urease} H_2CO_3 + 2NH_3$$

In aqueous solutions, the carbonic acid and NH_3 generated from urea hydrolysis are in equilibrium with bicarbonate ($HCO_3^{\ -}$) and ammonium ($NH_4^{\ +}$) ions, respectively. Consequently, urea hydrolysis is associated with a subsequent increase in pH [4]. However, in the absence of active urease, urea is a very stable molecule with a half-time of approximately 40 years at 25°C [8], [9]. The non-catalytic decomposition of urea is not hydrolysis but proceeds through an elimination reaction to form isocyanate (HNCO) and NH_3 (Reaction 2).

Reaction 2.

$$CO(NH_2)_2 \longrightarrow HNCO + NH_3$$

The NH_3 emission level from manure depends on several factors including the animal species, urinary urea concentration, fecal urease activity, pH, temperature, manure management system, and air exchange rate. Therefore, NH_3 production and emission can be reduced by altering the dietary composition, adding urease inhibitors, acidifying or cooling the manure, and modifying the house interior [2], [10]–[15]. To develop accurate prediction models for NH_3 emission and efficient NH_3 emission-reducing strategies for both pig and cattle production systems, it is necessary to understand the enzymatic process of NH_3 formation in manure. However, accurate measurements of the urease activity in feces and manure from different animal species are still limited.

The aims of this study were to determine and compare the kinetics of urea hydrolysis as catalyzed by feces and manure from pigs and cattle and to make accurate estimates of kinetic parameters V_{max} and K'_m. In addition, we determined the initial chemical and physical properties of feces, urine, and fresh manure and investigated the effects of pH on animal fecal urease activity. Our work shed light on the urea hydrolysis process in manure from pigs and cattle and has provided the basis for animal-specific prediction models of urea hydrolysis rates and NH_3 concentrations in manures, and thus NH_3 volatilization rates from animal production.

Materials and Methods

Most chemicals and reagents were purchased from Sigma-Aldrich. Urea stock solutions (1 M and 4 M) were prepared by dissolving urea (Sigma 51459, puriss. p.a., ACS reagent, ≥99.5% (T)) in ultra pure water just before use. Phosphate buffer stock solutions (400 mM) were prepared by mixing phosphate salts $NaH_2PO_4{\cdot}H_2O$ (Sigma S9638, ACS reagent, 98.0–102.0%) and $Na_2HPO_4{\cdot}7H_2O$ (Sigma 30413, puriss. p.a., ACS reagent, ≥99%) in certain proportions to produce pH values of 6.0, 7.0, and 8.0 according to Ruzin [16]. In addition, citric acid-Na_2HPO_4-buffered stock solution (400 mM) pH 5.0 was prepared by mixing certain amounts of citric acid (Sigma 251275, ACS reagent, ≥99.5%) and $Na_2HPO_4{\cdot}7H_2O$. A 400 mM HEPES (Sigma H3375, ≥99.5%) buffer stock solution was titrated to pH 9.0 with 1 M NaOH. All stock solutions were prepared a few hours before each series of experiments. Concentrated (98%) sulfuric acid (100748, Merck KGaA, Germany), Kjeltab catalyst tablets (Thompson & Capper, UK), 32% sodium hydroxide (28225, VWR, Denmark), and boric acid (Sigma 31144) were used for the Kjeldahl analyses. A FOSS 2200 Kjeltec Auto Distillation apparatus was used for all distillations. A PHM210 pH meter with ±0.01 pH units of accuracy (Meterlab, Radiometer Analytical, Lyon, France) was used for all pH measurements. Ultra pure water from an Ultra Clear UV system (SG Water, Hamburg, Germany) was used in all experiments.

Collecting Urine and Feces Samples

Fresh urine and feces samples were collected from fattening pigs (70–100 kg) and beef cows (500–600 kg). The pigs were approximately 3-5 months of age, and they were kept in an intensive housing system with a slatted floor. The animals were given wet feed made from wheat, barley, and soya beans that was fortified with minerals and vitamins; they had free access to water. The cattle were a cross between Danish Red and Simmental races at 4–6 years of age. The cattle were kept in a loose-housing system and were primarily fed clover-grass silage supplemented with compound feed for dairy cattle. Feces and urine samples from individual animals were collected separately in clean plastic bags to ensure that there was no mixing prior to the experiments. Both the feces and urine samples were grabbed directly upon excretion from the animals to prevent any contact with the barn floor. All the samples were stored at 4°C during transportation. Equal amounts of feces from five specimens were pooled for both pigs and cattle. In addition, equal amounts of urine from five animals were pooled and used in the experiments. Half the feces and urine pools were saved at −80°C for later use in chemical analyses and for determining the relative urease activity at different pH values. All urease activity measurements in fresh feces and manure were conducted within two days after sample collection. The urine and feces pools were stored at 4°C until use. However, the urease activity in thawed feces pools that had been saved at −80°C was measured for comparison.

Ethics Statement

The urine and feces samples were collected by using a self-made "bucket on a stick" without touching the animals. The animals were never touched and were never stimulated or forced to excrete urine or feces. Because the animals experienced no "*pain, suffering, anxiety or lasting harm*", approval from the Danish Inspectorate for Animal Experiments was not necessary according to the relevant Danish legislation (Bekendtgørelse af lov om dyreforsøg). The urine and feces samples used in this study were collected with permission from the animal owners.

Chemical Analyses of Feces, Urine, and Fresh Manure

Three samples of pooled feces, pooled urine, and feces:urine mixtures (at a weight : volume (w : v) ratio of 1.0 : 3.0 for pigs and 3.0 : 2.0 for cattle) were analyzed for pH, dry matter, total Kjeldahl nitrogen (TKN = Organic-N + NH_3-N + $NH_4{}^+$-N) concentration, total ammoniacal nitrogen (TAN = NH_3-N + $NH_4{}^+$-N) concentration, and urea nitrogen (UN = Urea-N) concentration according to Table 1. Before the pH measurements of the feces, 10 g of fresh feces were thoroughly mixed with 30 ml of ultra pure water. For the dry matter determinations, fresh feces or manure samples were evaporated to dryness in an oven at 105°C for at least 24 h until the weights of the samples were constant. The TKN and TAN concentrations were determined by using 3 ml of urine or 2–3 g of feces or manure (samples were weighed before analysis) [17]–[19]. The initial urea concentration ([Urea]) in urine was calculated by subtracting the initial TAN concentration in urine [$TAN_{i,urine}$] from the final TAN concentration [$TAN_{f,urine}$] that was generated after the complete enzymatic hydrolysis of urea in urine by jack bean urease (Sigma 94282, activity ~35 units/mg) and then multiplying this difference by 0.5 according to Eq. 1 because two NH_3 molecules are generated from the hydrolysis of each urea molecule. For this determination, 56 ml of pooled urine was added to 4 ml of 400 mM phosphate buffer, pH 7.0 and 20 ml of jack bean urease solution (0.1 mg/ml equaling 3.5 units/ml) for a final concentration of 0.875 units/ml in the diluted urine solution to equal 1.25 units per ml of pure urine. The reaction mixture was incubated for 8 h at 25°C on a magnetic stirrer (mixing was performed during the first five minutes of incubation, and the reaction mixture was also stirred for 20 s at 300 rpm before each sampling). The TAN was determined after 5 min, 2 h, 4 h, 6 h, and 8 h of incubation, and at 8 h the reaction had reached completion. The final constant TAN reached upon the completion of the reaction was defined as the $TAN_{f,urine}$ (Figure S1).

Table 1

The chemical and physical properties of feces, urine, and manure samples (Mean±SD; n=3).

	Animal species	TKN		TAN		[UN]	[Urea]	Dry matter	pH
		(mmol/kg)	(mmol/l)	(mmol/kg)	(mmol/l)	(mmol/l)	(mmol/l)	(%)	
Feces	Pig	578.8±1.2	n.a[1]	39.6±4.6	n.a	n.a	n.a	15.32±0.09	6.89±0.(
	Cattle	337.8±33.0	n.a	21.2±0.4	n.a.	n.a.	n.a.	11.44±0.22	7.02±0.(
		P<0.001		P<0.01				P<0.001	P<0.001
Urine	Pig	n.a	350.2±2.1	n.a	23.6±1.0	198.4±5.0	99.2±2.5	1.86±0.84	7.69±0.(
	Cattle	n.a	261.3±0.9	n.a.	15.9±1.0	152.7±1.1	76.4±0.5	3.03±0.01	8.55±0.(
			P<0.001		P<0.001	P<0.001	P<0.001	P>0.05	P<0.001
Manure[4]	Pig	n.a	369.4±7.7	n.a	87.2±1.6	n.a.	n.a.	3.71±0.09	7.05±0.(
	Cattle	n.a	317.4±4.8	n.a	20.5±0.2	n.a	n.a	7.81±0.07	7.87±0.(
			P<0.001		P<0.001			P<0.001	P<0.001

The p-value obtained in each test of significance between the values for pigs and cattle is indicated below each pair of measurements. Thus, at a significance level of 0.05 all the measured properties are significantly different between pigs and cattle except the dry matter of urine (P>0.05).

[1]n.a.: not available.

[2]pH was measured in a mixture of 1:3 (wt:v) feces and water.

[3]pH was measured in a mixture of 3:2 (wt:v) feces and water.

[4]Pig manure was prepared by mixing feces and urine in a (wt:v)-ratio of 1:3, and cattle manure was prepared by mixing feces and urine in a 3:2 (wt:v)-ratio. TAN and pH were measured immediately after mixing the fresh feces and urine.

$$\begin{aligned}[Urea] &= 0.5 \times [UN] \\ &= 0.5 \times [TAN_{f,urine} - TAN_{i,urine}]\end{aligned} \quad (1)$$

Kinetic Measurements of Urease Activity in Feces

The amounts and ratios of feces and urine produced by animals depend on several factors including their diet and water supply [20], [21]. Some animal studies suggest that the (w:v)-ratio of feces:urine produced by fattening pigs is approximately 1:3 [20], [22] and that of cattle is approximately 3:2 [21], [23]. Thus, to determine the kinetics of urease activity in pig feces, mixtures (approximately 40 ml of total volume) containing 10 g of pooled feces and 30 ml of urea-phosphate buffer solution, pH 7.0 with different urea concentrations were incubated in 50 ml beakers with magnetic stirring. For the kinetic measurements of urease activity in cattle feces, mixtures (containing approximately 30 ml of total volume) containing 18 g of pooled feces and 12 ml of urea-phosphate buffer solution, pH 7.0 with different urea concentrations were incubated in beakers while stirring. The stirring rate for all these kinetic experiments was 300 rpm during the 5 min incubation. Two to three hours before the kinetic measurements, the fecal samples and all solutions were placed in a water bath at a constant temperature of 25°C. The feces samples were subsequently prepared for the kinetic experiments; for example, to obtain a final urea concentration of 400 mM urea in a 40 ml reaction sample, 10 g of fecal sample was added to 23 ml of ultra pure water before being titrated to pH 7.0 with approximately 0.1–0.2 ml of 1 M NaOH. Afterwards, 3 ml of 400 mM phosphate buffer, pH 7.0 and 4 ml of 4.0 M stock urea solution were added. The final urea concentrations were 0.0 mM, 20 mM, 40 mM, 80 mM, 100 mM, 200 mM, 400 mM, and 600 mM for the experiments with fresh pig feces, and 0.0 mM, 10 mM, 20 mM, 40 mM, 60 mM, 80 mM, 120 mM, and 160 mM for those with fresh cattle feces. The same procedure was used for the thawed feces samples except that the final urea concentrations in the experiments were 0.0 mM, 2.0 mM, 4.0 mM, 8.0 mM, 20 mM, 40 mM, 60 mM, and 80 mM for both species. The urea hydrolysis reactions were initiated by adding the amounts of stock urea solution (1.0 or 4.0 M) corresponding to the desired final urea concentrations of the mixtures. The 1.0 M urea stock solution was used to prepare the reactions with 2.0–100 mM urea, and the 4.0 M urea stock solution was used for reactions containing 120–600 mM urea. For each substrate (urea) concentration, the amount of NH_3 nitrogen generated during the 5 min reaction time was calculated by subtracting the initial amounts of ammoniacal nitrogen in feces and urea-buffer solutions from the final amount of ammoniacal nitrogen at the end of the reaction. Thus, for the kinetic measurements of urease activity in feces, 3 ml of sample was taken from each reaction mixture after reacting for 5 min and analyzed by Kjeldahl method to determine the TAN concentration [17]–[19]. Experiments showed that adding 75 ml of ultra pure water and 60 ml of 32% sodium hydroxide (NaOH) to the reactions as described in the Kjeldahl method [17]–[19] completely stops urease activity (there is no further increase in the TAN). Thus, no urea is hydrolyzed between the time of NaOH addition and the Kjeldahl distillation. To verify that the pH remained constant during the kinetic reaction, the pH of the mixture was measured throughout the whole reaction, from t=0 min to t=5 min. All experiments were performed in triplicate. The kinetics of urea hydrolysis by pig and cattle feces was characterized by determining the maximum reaction rate V_{max} and the apparent Michaelis constant K'_m according to Eq. 2 and Eq. 3.

Measurements of Urease Activity in Fresh Manure

To make fresh manure, pooled feces and pooled urine samples from five specimens were mixed in (w:v)-ratios of 1.0:3.0 and 3.0:2.0 for pigs and cattle, respectively. Thus, pig manure was made by mixing 20 g of pooled pig feces with 60 ml of pooled pig urine and cattle manure was made by mixing 60 g of pooled feces with 40 ml of pooled urine in 140 ml beakers. The fresh manure was then made homogenous by magnetic stirring at 300 rpm for 5 min before the beakers were covered with parafilm and incubated at 25°C. TAN concentration and pH of the manure samples were measured immediately after mixing (t~0), homogenization (t=5 min), and at incubation times of 30 min, 1 h, 2 h, 4 h, 6 h, 8 h, and up to approximately 100 h. The initial TAN of the manure (t=0) was calculated by adding the determined TAN value of urine with that of feces. The TAN concentrations were determined by Kjeldahl method [17]–[19] and all experiments were performed in triplicate.

Determining Fecal Urease Activity at Different pH Values

The fecal urease activity was determined under buffered conditions at pH values of 5.0, 6.0, 7.0, 8.0, and 9.0. Citric acid/Na_2HPO_4 buffer at a 40 mM final concentration was used in the mixture for pH 5.0, 40 mM phosphate buffers were used for pH 6.0, 7.0, and 8.0, and 40 mM HEPES was used as a buffer for pH 9.0. The temperatures of all samples and solutions were equilibrated in a water bath at 25°C before mixing. To directly compare the urease activity in feces from pigs and cattle, the same weights for feces and a 1.0 : 3.0 (w : v) ratio of feces:liquid were used for both species. According to the kinetic data, the rate of urea hydrolysis is close to a V_{max} at 0.2 M urea for both pig and cattle feces and, therefore, this urea concentration was used to determine the urease activity at different pH values. Thus, 10 g of pooled pig or cattle feces was mixed with 23 ml of ultra pure water in a 50 ml beaker and the pH was adjusted to the indicated pH value by adding sulfuric acid (1 M) or sodium hydroxide (1 M). Subsequently, 3 ml of 400 mM buffer stock solution (citric acid/Na_2HPO_4 buffer, phosphate buffer, or HEPES buffer) was added to keep the adjusted pH constant. The reaction was initiated by adding 4 ml of 2 M urea stock solution to a final concentration of 0.2 M and a total volume of 40 ml. The reactions were performed at 25°C while stirring at 300 rpm. After a reaction time of 5 min, the TAN concentration was determined [17]–[19]. The amount of ammoniacal nitrogen generated during the reaction was determined by subtracting the initial amounts of ammoniacal nitrogen present in feces and urea-buffer solutions. All the experiments were performed in triplicate.

Enzyme Kinetics and Statistical Analyses

Enzymatic reactions such as the hydrolysis of urea as catalyzed by urease can be described by Michaelis-Menten kinetics according to Eq. 2, where V is the rate of the enzymatic reaction, [S] is the substrate concentration, V_{max} is the maximum rate of the enzymatic reaction, and K'_m is the apparent Michaelis constant [24]. The data in Figure 1, Figure 2A, Figure 2B, Figure S3, Figure S4A, and Figure S4B were analyzed by using the Michaelis-Menten model.

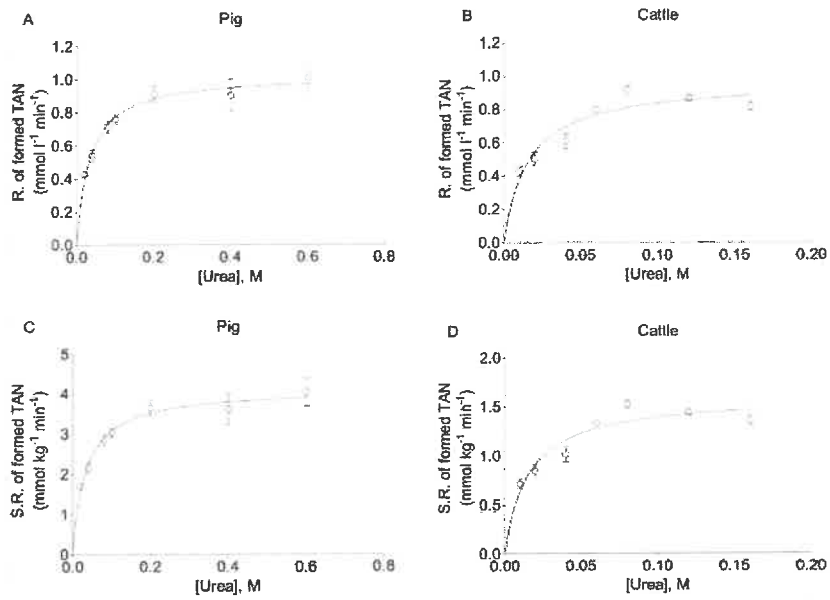

Figure 1

The rates of formed TAN as catalyzed by fresh pig and cattle feces.

The rate of TAN formed (R. of formed TAN; panels A and B) and specific rate of TAN formed (S.R. of formed TAN; panels C and D) as catalyzed by pig feces (panels A and C) and cattle feces (panels B and D) in reaction mixtures containing fresh feces and different concentrations of urea.

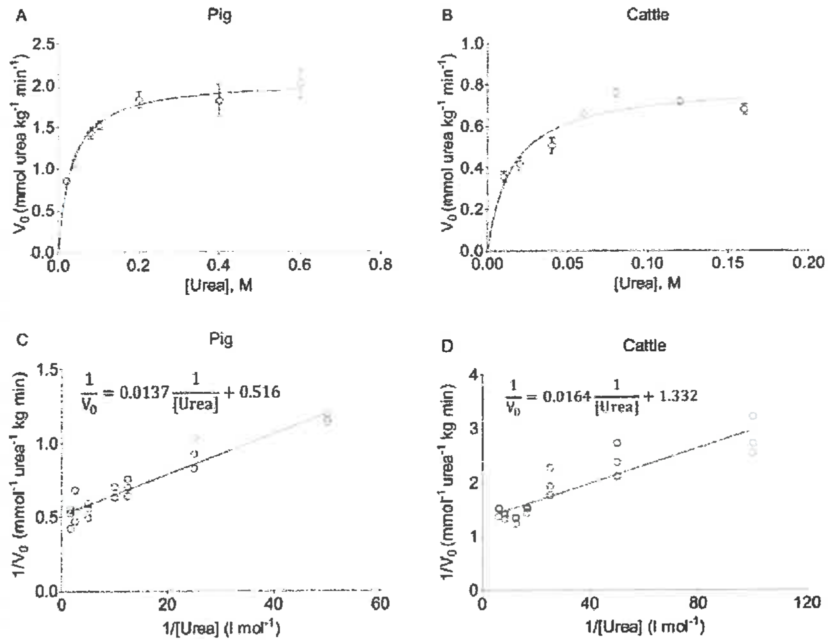

Figure 2

The Michaelis-Menten kinetics of the urease activity in fresh pig and cattle feces.

Michaelis-Menten curves (panels A and B) and Lineweaver-Burk plots (panels C and D) for the specific reaction velocities of hydrolyzed urea (V_0) as catalyzed by pig feces (panels A and C) and cattle feces (panels B and D). The curves are generated from Figure 1 data. The maximum specific V_{max} and K'_m values of the urease activity in fresh feces from pigs and cattle were determined from the graphic presentations. The goodness of fit values (R^2) were 0.84 (panel A) and 0.91 (panel C) for the pig feces and 0.82 (panel B) and 0.81 (panel D) for the cattle feces.

$$V = \frac{V_{max}[S]}{(K'_m + [S])} \quad (2)$$

By rearranging the Michaelis-Menten equation (Eq. 2) into the Lineweaver-Burk equation (Eq. 3), a linear regression of enzymatic reaction data $\left(\frac{1}{[S]}, \frac{1}{V}\right)$ can be used to determine the V_{max} and K'_m values for the fecal urease activity in a Lineweaver-Burk plot [25]. The data in Figure 2C, Figure 2D, Figure S4C, and Figure S4D were analyzed according to the Lineweaver-Burk equation.

$$\frac{1}{V} = \frac{K'_m}{V_{max}[S]} + \frac{1}{V_{max}} \quad (3)$$

A Student's t-test was used to determine if the nitrogen content, dry matter, and pH values for feces, urine, and manure samples are significantly different between pigs and cattle (Table 1), and to compare the urease kinetic values for V_{max} and K'_m between pig and cattle feces at a significance level of α=0.05 (Table 2 and Table S1). A regression analysis by phase exponential association was used to determine the maximum TAN formation level as shown in Figure 3A, Figure 3B, and Figure S1. The pH change over time was determined by the one phase association and one phase decay regression in Figures 3A and 3B. All statistical analyses were performed with GraphPad Prism.

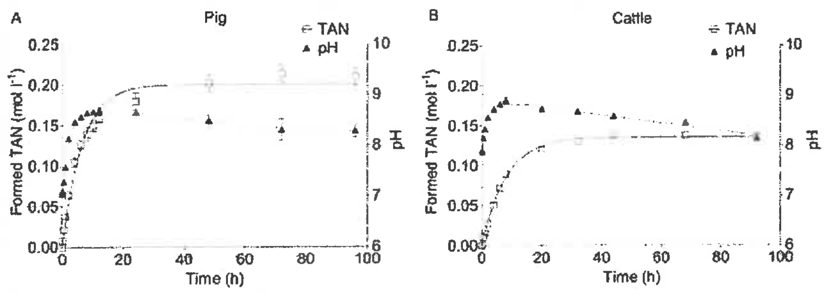

Figure 3

Urease activity in fresh manure from pigs and cattle.

The formed TAN and changes in pH over time in fresh pig manure (panel A) and fresh cattle manure (panel B). During the first hours after mixing urine and feces, the concentration of formed TAN (open squares) and pH (filled triangles) increase rapidly in both pig and cattle manures. However, the rate of TAN formation in pig manure is significantly faster than it is in cattle manure and the TAN concentration reaches a higher plateau in pig manure than in cattle manure. In both manures, the pH decrease continuously after reaching a maximum.

Table 2

Kinetic parameters of the urease activity in fresh feces.

Animal species	Temperature (°C)	V_{max} (mmol urea/kg/min)	K'_m (mM)	R^2 Goodness of fit
Pig	25	2.06±0.08	32.59±5.65	0.84
Cattle	25	0.80±0.04	15.43±2.94	0.82
		P<0.001	P>0.05	

The V_{max} and K'_m values of fecal urease activity from pigs and cattle were determined by Michaelis-Menten kinetic analysis (Mean±S.E.).

Results

Comparing the Chemical and Physical Properties of Feces, Urine, and Fresh Manure from Pigs and Cattle

The initial properties including the TKN, TAN, and UN concentrations, dry matter, and pH of feces, urine, and fresh manure from pigs and cattle were determined (Table 1). All the TKN values were higher for the pig samples than for the corresponding cattle samples. Thus, the highest TKN concentration was found in pig feces with a value of 578.8±1.2 mmol/kg and that of cattle feces was only 337.8±33.0 mmol/kg ($p<0.05$). The TKN values for pig and cattle urine were 350.2±2.1 mM and 261.3±0.9 mM, respectively. In addition, the TAN measurements for pig feces (39.6±4.6 mmol/kg) and urine (23.6±1.0 mM) were significantly higher than the values for cattle feces (21.2±0.4 mmol/kg) and urine (15.9±1.0 mM), respectively. In addition, the urea concentrations in the urine samples were evaluated by finding the UN values. The urea concentration of pig urine (99.2±2.5 mM) was significantly higher than it was in cattle urine (76.4±0.5 mM). The dry matter of pig feces (15.32±0.09%) was approximately 4% higher than it was for cattle feces (11.44±0.22%), and the pH values of both pig feces (pH 6.89±0.01) and urine (pH 7.69±0.03) were lower than the corresponding values for cattle (pH 7.02±0.02 and 8.55±0.02, respectively) ($p<0.05$). With the exception of the TAN concentration in pig manure, all the values measured in fresh manure samples (combined feces and urine samples) were consistent with the expected values based on those determined for the separate feces and urine samples and their ratios in the combined feces and urine samples. The relatively high TAN concentration in pig manure (87.2±1.6 mM; Table 1) is most likely caused by the significantly faster formation of NH_3 in manure from pigs than from cattle when feces and urine are mixed (Figure 3). Therefore, the initial TAN concentrations used to determine the TAN formed in the manure reactions (Figures 1, 3, 4, and Figures S2 and S3) were calculated by adding the proportions of TAN originating from pure feces and urine (or urea stock solution) (Table 1).

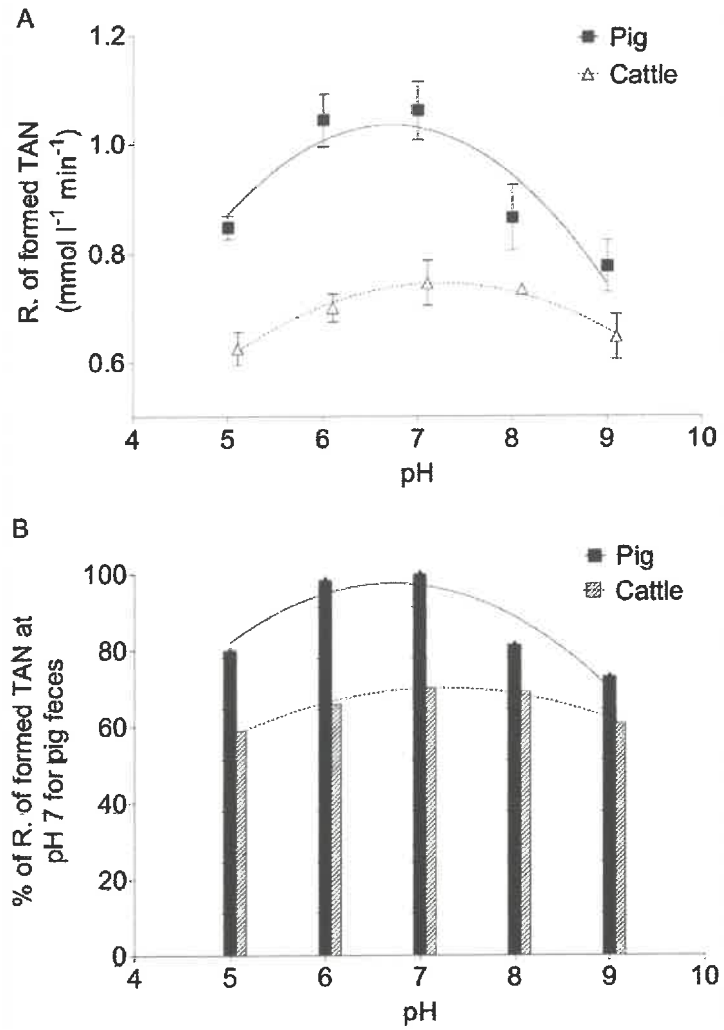

Figure 4

The effect of the pH on fecal urease activity.

Urease activity at different pH values are presented as the rate of TAN formation (R. of formed TAN; panels A) and the relative R. of formed TAN compared with that of pig feces at pH 7 (panel B). The optimal pH for urea hydrolysis catalyzed by fecal urease is approximately pH 7 for pig feces and between pH 7 and 8 for cattle feces.

Urease Activity in Feces from Pigs and Cattle

The kinetics of urea hydrolysis as catalyzed by fresh feces from pigs and cattle were investigated by first determining the rates of TAN formation in reaction mixtures containing feces and different urea concentrations (Figure 1). To obtain accurate enzymatic reaction velocities for the fecal samples, the rates of NH_3 formation at different urea concentrations should be determined during the initial phase of the reactions and at a time when the levels of TAN formation are sufficient to achieve significant and reliable TAN measurements by Kjeldahl method. Therefore, to identify the optimal reaction time for the initial rate measurements, the levels of TAN formed at different reaction times (5 min, 11 min, and 20 min) were determined in mixtures of pig feces and 100 mM urea and the relation between the calculated rate of TAN formation and corresponding reaction time was investigated (Figure S2). The results clearly show that the calculated rate of TAN formation decreases significantly when the reaction time increases. Thus, the reaction rate calculated from the TAN formed at 5 min (0.45 mM/min) was significantly higher than the rates calculated at 11 min (0.31 mM/min) and 20 min (0.22 mM/min). Therefore, the initial rates of TAN formation were calculated from the TAN formed during the first 5 min of the reaction (Figures 1A and 1B). The maximum rates determined for TAN formation in reactions with pig feces and cattle feces using regression analyses were 1.03±0.04 mM/min (R^2=0.84) and 0.99±0.05 mM/min (R^2=0.82), respectively (Figures 1A and 1B). In addition, a comparison of the rates of TAN formation at different urea concentrations for the two feces samples reveals that the maximum rate of TAN formation is reached at a lower concentration for the cattle feces than for the pig feces (Figures 1A and 1B). This finding indicates that pig feces require higher concentrations of urea to reach the maximum reaction rate of TAN formation for the 5 min incubation. For comparison, the specific rates of TAN formation, that is, the reaction rates per wet weight of fresh feces, were calculated for all the urea concentrations (Figures 1C and 1D). The results show that pig feces are a much better catalyst for TAN formation than cattle feces (Figures 1C and 1D). Thus, the maximum specific rates of TAN formation for pig feces and cattle feces according to regression analyses were 4.11±0.17 mmol/kg/min (R^2=0.84) and 1.61±0.07 mmol/kg/min (R^2=0.82), respectively (Figures 1C and 1D). Based on the assumption that the hydrolysis of each urea molecule generates two molecules of NH_3, the specific rates of TAN formation (mmol/kg/min) were converted into specific reaction velocities of hydrolyzed urea (V_0; mmol urea/kg/min) and presented in Michaelis-Menten curves (Figures 2A and 2B) and Lineweaver-Burk plots (Figures 2C and 2D). From the Michaelis-Menten curves, the specific V_{max} and K'_m values of the urease activity in fresh feces from pigs and cattle were determined. The V_{max} was 2.06±0.08 mmol urea/kg/min and 0.80±0.04 mmol urea/kg/min for pig feces and cattle feces, respectively (Table 2). The K'_m was 32.59±5.65 mmol urea/l and 15.43±2.94 mmol urea/l for pig feces and cattle feces, respectively (Table 2). For comparison, the V_{max} and K'_m values were also determined from the Lineweaver-Burk plots (Figures 2C and 2D). Both the V_{max} (1.94 mmol urea/kg/min for pig feces and 0.75 mmol urea/kg/min for cattle feces) and K'_m (26.58 mmol urea/l for pig feces and 12.31 mmol urea/l for cattle feces) from the Lineweaver-Burk plots were consistent with those determined from the Michaelis-Menten curves. The urease activities in thawed pig and cattle feces pools that had been saved at −80°C were also evaluated by Michaelis-Menten kinetics (Figures S3 and S4), and their corresponding V_{max} and K'_m values were calculated from the Michaelis-Menten curves (Table S1). The V_{max} was 1.63±0.12 mmol urea/kg/min and 0.51±0.01 mmol urea/kg/min for the thawed pig feces and cattle feces, respectively. The K'_m was 12.84±3.03 mmol urea/l and 2.58±0.34 mmol urea/l for the thawed pig feces and cattle feces, respectively (Table S1). The V_{max} and K'_m values determined from Lineweaver-Burk plots (Figures S4C and S4D) were 1.43 mmol urea/kg/min and 9.86 mmol urea/l for the thawed pig feces, respectively, and those for thawed cattle feces were 0.53 mmol urea/kg/min and 3.08 mmol urea/l, respectively.

Urease Activity in Fresh Manure from Pigs and Cattle

To investigate and compare the urease activity in fresh manure from pigs and cattle, fresh feces and urine were mixed in (w:v)-ratios of 1.0:3.0 and 3.0:2.0 for pigs and cattle, respectively (Figure 3). The concentration of formed TAN and the pH increased rapidly in both types of manure. However, the rate of TAN formation in pig manure is significantly faster than it is in cattle manure. Thus, the initial velocities of TAN formation based on measurements taken at 5 min after mixing are 1.53 mM/min and 0.33 mM/min for pig and cattle manure, respectively. After approximately 30 hours, the formed TAN concentration for pig manure reaches a plateau of ~0.2 M (0.20±0.003 M; K=0.16, R^2=0.980) and that of cattle manure reaches a plateau of ~0.14 M (0.14±0.001 M; K=0.12, R^2= 0.998) (Figure 3) as determined by regression analyses through one-phase exponential association. For both manures, the pH change was fitted with a one phase association (Figure 3; R^2=0.99 for both pig and cattle, n=30). The pH in cattle manure reaches a maximum of 8.91 after 6–8 hours, and a maximum of pH 8.70 for pig manure is obtained after reacting for 8–10 hours. This finding indicates that the pH of cattle manure changes by a total of 1.04 pH units from the initial pH of 7.87 (Table 1). For the pig manure, the pH changes by a total of 1.65 pH units from the initial pH of 7.05 (Table 1). After reaching the plateau, the pH values for both manure preparations decrease through one phase decay (Figure 3; R^2=0.64 for pigs (n=12), and R^2=0.87 for cattle (n=18)). The pH of pig manure decreases, with 0.41 units for the 12–96 hour time period, and the pH of cattle manure decreases 0.76 units in the 8–92 hour time period (Figure 3).

The pH Effect on Urease Activity in Feces from Pigs and Cattle

For a direct comparison of the urease activity in pig and cattle feces at different pH values, all reactions in this experiment contained the same amount of feces. Therefore, the rate of urea hydrolysis was lower for cattle feces than for pig feces (Figure 4). The initial rates of TAN formation were within ranges of 0.78–1.06 mM/min and 0.63–0.75 mM/min for pig feces and cattle feces, respectively. For both species, the fecal urease activity varied significantly with the pH but the cattle feces is less affected by changes in pH (Figure 4). By comparison, the relative rates of TAN formation were calculated with reference to that catalyzed by pig feces at pH 7.0 (100%, Figure 4A). The relative reaction rates of TAN formation for the pig feces were 80%, 98%, 81%, and 73% at pH values of 5.0, 6.0, 8.0, and 9.0, respectively (Figure 4B). The relative rates of TAN formation for cattle feces compared with that for pig feces at pH 7.0 were 59%, 66%, 70%, 69%, and 61% at pH values of 5.0, 6.0, 7.0, 8.0, and 9.0, respectively (Figure 4B). Thus, the results suggest that the optimal pH for urea hydrolysis as catalyzed by fecal urease is approximately pH 7 for pig feces and between pH 7 and 8 for cattle feces.

Discussion

To understand the process of NH_3 formation in animal manure, we have determined the chemical and physical properties of feces, urine, and fresh manure and characterized the urease activity in fresh feces and manure from pigs and cattle.

Pig Samples Contain Higher Levels of Nitrogen Compounds

The measured concentrations of TKN and TAN, and the pH values for feces, urine, and manure from pigs (Table 1) were consistent with previous results [20], [22], [26]. With regards to the urinary urea concentration and dry matter of feces and urine from pigs, our results were lower than those reported by Canh et al. [20]. The observed concentrations of TKN and TAN in urine and manure from cattle (Table 1) were consistent with nitrogen excretion values reported in some other studies

[27]–[29]. In addition, the pH of the fresh manure is consistent with the values reported by those studies [28], [29]. However, the amount of urea in urine and the dry matter in manure from cattle in the present study are lower than those observed by Bristow et al. [27] and Burgos et al. [29]. The differences in dry matter levels compared with other studies are likely caused by variations in water consumption between animal facilities. Furthermore, several factors including the dietary protein content, feed composition, and volume of urine produced are known to affect the composition of nitrogen compounds and their concentrations in urine and feces and lead to large variations in TKN, TAN, and urea concentrations. The fact that all TKN, TAN, and urea measurements are higher for the pig samples than for the cattle samples (Table 1) most likely reflects that the pigs are given feedstuff with higher protein contents, which affects the nitrogen composition of urine and feces [30]. In particular, the TKN and TAN values in pig feces are 71% and 87% higher than the values for cattle feces, respectively. The higher TAN concentrations in pig feces and urine could be caused by a more ready conversion of organic nitrogen into ammoniacal nitrogen in the pig samples than in the cattle excreta. In addition, the dry matter of the pig manure is significantly lower than it is for cattle manure, which has also been reported in other studies [29], [30]. Our results also show that the pH values of feces, urine, and fresh manure from pigs are all lower than the values for cattle (Table 1).

Pig Feces Have a Higher Specific Urease Activity than Cattle Feces

By using Michaelis-Menten kinetic analyses, we have determined the specific urease activity of fresh feces from pigs and cattle at 25°C. We first determined and compared the activities in feces-urea mixtures with feces:liquid ratios equaling those in authentic manure from pigs and cattle (Figure 1A and 1B). The maximum rates of TAN formation in the reaction mixtures are approximately 1 mM/min for both mixtures, and the urea concentration at half-maximum reaction rates of TAN formation are very different for the reactions. Thus, to further elucidate the results and make a thorough kinetic comparison of the pig and cattle fecal urease activities, the kinetic data were converted into specific reaction velocities of hydrolyzed urea (mmol urea hydrolyzed per kg wet feces per min, Figure 2). The kinetic analyses showed that the maximum specific urease activity and the K'_m value are more than 2-fold higher for pig feces than for cattle feces. In kinetic analyses employing pure enzyme preparations, the Michaelis constant is an inverse measure of the affinity between the substrate and enzyme. Thus, the smaller the K_m value, the higher the affinity [24], [25]. However, with a complex biological material such as feces, the Michaelis constant of the urease activity is actually a measure of the "overall affinity" between urea and the microbial community in feces and depends on factors such as diffusion, membrane-spanning urea transporter characteristics, the urease enzyme, and other components of the urease system [4], [31]–[33]. Most microbial ureases are intracellular and, therefore, the urea must first reach the cells in feces and then be transported across the cytoplasmic membrane before it is degraded by urease. Thus, the fact that the K'_m value for pig feces (32.59±5.65 mM) is approximately two times higher than it is for cattle feces (15.43±2.94 mM) suggests that the "overall affinity" of urea is lower for pig feces than for cattle feces. This finding signifies that a lower urea concentration is required to saturate the urea hydrolysis capacity of cattle feces than that of pig feces. The differences between the fecal urease kinetic parameters of pigs and cattle may indicate that their feces are dominated by different ureolytic bacteria species.

Muck R.E. [19] previously determined the V_{max} (1.17±0.19 mg urea-N/g wet feces/h) and K_m (0.48±0.04 mg urea-N/g mixture) for bovine feces at 24°C. When converted into molar concentrations, these values roughly equal V_{max} and K_m values of 0.7±0.1 mmol urea/kg/min and 17.1±1.4 mmol urea/l, respectively. Thus, the kinetic parameters for cattle in our study are slightly different from those determined by Muck R.E. In contrast to the findings of Muck R.E., who used a 1 h incubation time in the urease kinetic experiments, we used a much shorter reaction time (5 min), which should give more correct initial reaction velocity measurements according to enzyme kinetic theory, and thus better V_{max} and K_m determinations. In addition, other researchers have previously used a value of 2 mM (2 μmol/g) for the Michaelis constant in studies of both pig and dairy-cow houses [15], [34], [35].

Faster NH_3 Production in Pig Manure than in Cattle Manure

The difference in the enzymatic reaction velocity of urea hydrolysis between pig and cattle feces was even more significant in authentic fresh manure when the ammoniacal nitrogen production was recorded (Figure 3). Thus, the initial velocity of TAN formation was more than 4-fold higher in fresh pig manure (1.53 mM/min) than in cattle manure (0.33 mM/min) despite the higher feces-to-urine ratio in cattle manure. That observation may be explained by factors affecting the urease activity including the different chemical composition, pH, dry matter (Table 1), and texture of pig and cattle manure and the higher concentration of urea in pig manure. According to the measured concentrations of urea in urine (Table 1) and the ratios of feces and urine in the manures, the initial urea concentrations in manure from pigs and cattle are approximately 75 mM and 30 mM, respectively. The lower rate of pH change in pig manure than in cattle manure after reaching the maximum pH (Figure 3) suggests that less NH_3 vaporizes from the pig manure or/and that pig manure has a stronger buffer capacity than cattle manure close to the maximum pH.

The Effects of the pH on the Fecal Urease Activity Suggest There Are Different Bacterial Communities in Feces from Pigs and Cattle

Our measurements of urea hydrolysis activity at different pH values show that the maximum urease activity for pig feces is observed at approximately pH 7, and that of cattle feces is closer to pH 8 (Figure 4). It is noteworthy that fresh pig manure has an initial pH of 7.05 and that of cattle manure is 7.87 (Table 1), which suggests that the bacterial communities in the feces from the two animal species have urease enzymes that are most efficient at the initial pH of the manure. Thus, these results indicate that the predominant ureolytic bacterial species responsible for the urea hydrolysis activity in feces are different between pigs and cattle and are adapted to species-specific conditions in the animal manures.

Implications for NH_3 Production and Volatilization from Manure

Our results show that TAN production is both significantly faster and higher in pig manure than in cattle manure, which is important in relation to the volatilization of NH_3 from the two manure types. The rate of NH_3 volatilization from manure is related to different factors including, for example, the urease enzyme activity, the equilibrium between NH_3 and ammonium, the pH, the temperature, and the air velocity at the manure surface. Consequently, reducing the urea hydrolysis activity in manure by adding urease inhibitors, for example, will lead to a reduction in the NH_3 production and volatilization levels as reported by Varel V.H. and colleagues [12], [36]. In Denmark, acidifying manure to pH <6 is an approved and established technology to reduce the volatilization of NH_3 from animal production [14]. Our observations show that the acidification of both pig and cattle manure to pH 5–6 slightly reduces the urease activity (at a reduction of up to 10–20%) compared with the maximum activity observed at the optimal pH values (Figure 4). A previous study showed that the microbial activity as expressed by oxygen consumption, methanogenesis, and sulfate reduction in a slurry acidified to pH 5.5 was greatly reduced relative to that of untreated slurry [37]. Together, these observations show that some metabolic processes including NH_3 formation from urea hydrolysis are almost unaffected and others are dramatically reduced or absent in acidified manure relative to normal manure.

The kinetic parameters of urease activity in feces and manure have been incorporated into the calculations and process modeling of NH_3 concentration and volatilization from manure stores and animal houses in many studies [15], [19], [34], [35], [38]. We believe that the kinetic measurement and characterization of fecal urease activity for both pigs and cattle as presented in the current study will be useful in future studies to make more accurate and animal-specific prediction models for urea hydrolysis rates and NH_3 concentrations in pig and cattle manures and thus, for NH_3 volatilization rates from animal production.

Supporting Information

Figure S1

Determining the urea nitrogen concentration [UN] in urine. Jack bean urease was added to the urine samples for urea hydrolysis. The TAN concentration was measured at different time points and the corresponding level of formed TAN was calculated by subtracting the initial TAN ($TAN_{i,urine}$) concentration from the measured TAN ($TAN_{m,urine}$) concentration. The final constant TAN reached at the completion of the reaction was defined as $TAN_{f,urine}$. The final concentration of formed TAN ($TAN_{f,urine}$- $TAN_{i,urine}$) reached at the completion of the reaction equals [UN] and was used to calculate the initial urea concentration in urine.

(TIF)

Click here for additional data file. (121K, tif)

Figure S2

The relation between the reaction time and the rate of formed TAN. Formed TAN (filled triangles) and the corresponding rate of formed TAN (R. of formed TAN; open squares) after different reaction times. The levels of formed TAN after 5 min, 11 min, and 20 min of reaction time were measured in mixtures containing pig feces and 100 mM urea. The highest R. of formed TAN is observed at a reaction time of 5 min.

(TIF)

Click here for additional data file.(129K, tif)

Figure S3

Rates of formed TAN as catalyzed by thawed pig and cattle feces. The rate of TAN formation (R. of formed TAN; panels A and B) and the specific rate of TAN formation (S.R. of formed TAN; panels C and D) as catalyzed by thawed pig feces (panels A and C) and thawed cattle feces (panels B and D).

(TIF)

Click here for additional data file.(153K, tif)

Figure S4

The Michaelis-Menten kinetics of urease activity in thawed pig and cattle feces. Michaelis-Menten curves (panels A and B) and Lineweaver-Burk plots (panels C and D) for the specific reaction velocities of hydrolyzed urea (V_0) as catalyzed by thawed pig feces (panels A and C) and thawed cattle feces (panels B and D). The curves are generated from Figure S3 data. The goodness of fit values (R^2) were 0.89 (panel A) and 0.86 (panel C) for the pig feces and 0.90 (panel B) and 0.93 (panel D) for cattle feces.

(TIF)

Click here for additional data file.(157K, tif)

Table S1

Kinetic parameters of the urease activity in thawed feces. V_{max} and K'_m values of the urease activity of thawed feces from pig and cattle were determined by Michaelis-Menten kinetic analysis (Mean±S.E.).

(DOCX)

Click here for additional data file. (15K, docx)

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Data Availability

The authors confirm that all data underlying the findings are fully available without restriction. All relevant data are within the paper and its Supporting Information files.

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Environmental impact of pig farming

The **environmental impact of pig farming** is mainly driven by the spread of feces and waste to surrounding neighborhoods, polluting air and water with toxic waste particles.[1] Waste from pig farms can carry pathogens, bacteria (often antibiotic resistant), and heavy metals that can be toxic when ingested.[1] Pig waste also contributes to groundwater pollution in the forms of groundwater seepage and waste spray into neighboring areas with sprinklers. The contents in the spray and waste drift have been shown to cause mucosal irritation,[2] respiratory ailment,[3] increased stress,[4] decreased quality of life,[5] and higher blood pressure.[6] This form of waste disposal is an attempt for factory farms to be cost efficient. The environmental degradation resulting from pig farming presents an environmental injustice problem, since the communities do not receive any benefit from the operations, and instead, suffer negative externalities, such as pollution and health problems.[7] The United States Agriculture and Consumer Health Department has stated that the "main direct environmental impact of pig production is related to the manure produced.[8]

Farms often pump their animal waste directly into a large lagoon, which has environmental consequences.

Pigs in intensive farming

Around the world

Australia

Australia is home to one of the largest pork industries in the world with farms across Australia collectively containing over 300,000 pigs but there are high levels of water pollution. [9]

China

Pork is the most popular meat in China. Intensive pig farming leads to smog and water pollution in some Chinese regions. According to the Chinese Ministry of Agriculture, livestock farming is the leading cause of water pollution in the country.[10]

France

Swine farm manure leads to toxic algal blooms in the French region of Brittany.[11]

Netherlands

The Netherlands has one of the densest livestock sectors in the world. In 2019, a Dutch court halted the expansion of pig and other farms to prevent nitrogen pollution, which had led to algal blooms, smog, and soil acidification.[12]

United States

The United States Environmental Protection Agency (EPA) calls intensive farms above a certain threshold concentrated animal feeding operations (CAFOs).

In the 1970s, a series of laws, known as "Murphy's Laws", were passed in North Carolina to eliminate the sales tax on hog farm equipment and to prevent authorities from using authority to prevent and address odor issues.[13] After the passage of Murphy's Laws and other similar bills, there was a rapid increase in industry in North Carolina, where the population of swine was estimated around 9-10 million.[14] Each of those hogs produces eight times the feces as a human, causing a crucial need for regulation and maintenance for that waste.[15]

Regulation and laws could not keep up with the rapid explosion of the hog farming and spread of CAFOs in the early 2000s, which has caused severe harm and health impacts over time. Furthermore, agencies with jurisdiction over CAFOs are typically environmental or natural resource state-run agencies, as opposed to local health departments. This is an advantage for addressing environmental impacts but a disadvantage for human health concerns, as the majority of local health issues get overlooked by state-run agencies.[16] Additionally, although there are laws and regulations in place, such as the Swine Farm Environmental Performance Standards Act, which prohibits new waste lagoons and mandates that new CAFOs must use technology that will prevent discharge of waste, these regulations do not mandate for existing CAFOs to clean up or regulate the pollutants within their lagoons.[17] These regulations also make it more costly to clean up these wastes and prevent other consequential harms, without actually assisting farms in shouldering these costs, making it difficult for them to actually act on these regulations.

Ag-gag laws have made it even more difficult for farms to be held accountable for their actions, and for communities to have a transparent view of farm operations. These laws forbid the undercover video-taping or documenting of farms without the consent of the farm's owner. These laws are targeted at keeping animal rights and environmental activists away from the most damaging farm operations.[18] These laws emerged in the 90's and are now in effect in North Carolina, Utah, Missouri, Idaho, and Iowa, and is being considered in at least five states. These bills have the potential to exacerbate animal abuse on these large scale farms and CAFOs, as well as threaten community health, social justice, and consumer health by restricting organizations and individuals from sharing pertinent information about the food supply.[19]

The EPA does require that operations with qualified number of pigs must demonstrate that there is no runoff from their farm, in order for them to acquire a permit. But, this regulation varies from state to state and most of the time, enforcement only happens in response to citizen complaints, rather than active monitoring.[20] Further, locally developed policies often have inefficient resources and abilities to enforce regulation, and often don't address transboundary issues that arise with pig operations that exist across multiple states. And with Federal laws such as the Clean Water and Clean Air act, regulation is delegated to state agencies, but these agencies don't usually take on active regulation until the damage has been done. Further, many operations are exempt because they have been grandfathered in, meaning they have been in operation for so long that they are not subject to the new laws.[20]

North Carolina

In 2014, National Geographic wrote a piece on the extent of the contamination in North Carolina. Swine sales in the state (second largest pork producer in the nation) were nearly $3 billion in 2012, and the state received attention in 1999 when Hurricane Floyd caused waste pods on the swine ponds to overflow, polluting the water supply. National Geographic suggested that despite the execution of a $17 million research project on waste in the area, no one in the state seemed to know what to do with the pig waste, which was a huge issue considering that there are nearly as many pigs as people.[21] Nearly two decades later when Hurricane Florence hit the coast of North Carolina in 2018, hog waste remained a major concern. According to the NC Pork Council, 98% of hog lagoons experienced minimal impact.[22] The NC Department of Environmental Quality identified six hog farms with anaerobic lagoons that suffered structural damage and 28 farms that had lagoons overflow due to the floodwater.[22]

Effects on water quality


A typical waste lagoon in North Carolina.

Many intensive pig farms store the swine waste in vats often referred to as lagoons. These lagoons often contain pathogens such as salmonella, pharmaceuticals like antibiotics and antimicrobials, as well as nitrogen and phosphorus. This can lead to widespread pollution within the watershed the farm is located within, if the water from these lagoons leaches out into the soil and trickles down into the water table beneath.[23] Unlike human sewage, which is always treated with chemical and mechanical filtration, the waste from these lagoons is untreated when it is released back to the environment. Spills are the most common contributor to pollution, but regardless of spills, toxic nutrients like nitrates and ammonia can seep into the water table located just below the surface, infecting the groundwater that nearby communities drink.[24] It has been estimated that 35,000 miles of river across over 20 states has been contaminated by manure leakage.[25] Some of the causes for the environmental problems are inadequate sewage treatment and lack of developing technologies. Many farms lack adequate wastewater treatment systems, which release untreated wastewater to release into the environment in the form of contamination.[26]

Some spills and leakage of contaminated waste are not accidental. In 2014, Mark Devries used spy drones to expose pig farms in North Carolina that were spraying untreated fecal waste into the surrounding areas, allowing the waste to dissipate into far-off communities.[27] Smithfield Foods, the company responsible for one such factory, claimed this was a tactic used to fertilize its fields. It is true that historically hog feces have been used as fertilizer and can be done safely and without runoff, but the magnitude was described by Dan Whittle, a former senior policy associate at the North Carolina Department of Environment and Natural Resources, as a "mass imbalance", with far too great a magnitude of fecal matter being sprayed for the crops being generated to not have significant spill off into neighboring plots of land.[27] Many residents of the surrounding areas of such farms complain that the industrially concentrated fecal matter creates an unbearable odor of a different magnitude than typical farm manure. Charlotte Savage, a resident who lives on a property separated from the Smithfield farm by an 80-foot path of forest, reported seeing her husband Julian faint at one point due to the smell, and that their house was also once surrounded by a three foot deep puddle of fecal matter. This was described as a common occurrence in this community and many others.[28]

Effects on air quality

Communities located near factory pig farms experience negative health and environmental effects due to several factors associated with industrial pig farming. One main issue that arises out of intensive animal agriculture is the waste that the huge number of animals produce. Pig waste is similar to human waste; filled with bacteria and high amounts of ammonia. At most intensive pig farms, hog waste is kept in large open-air pits called lagoons where waste is broken down by anaerobic bacteria and then sprayed onto crops as fertilizer. This is called the lagoon and sprayfield system and remains legal in the United States, including in states like North Carolina[29] where there have been on-going efforts in the NC legislature to ban open-air lagoon and sprayfield system practices in the state and replace these with more environmentally sound waste management practices.[30][31]

The waste then reaches neighboring towns, resulting in civilians not being able to even leave their house in order to avoid pig waste filled air. People living in nearby towns have suffered a variety of adverse health effects including respiratory diseases, infections, increased risk of cancer, and other health risks.[32]

The nitrogen from pig waste can also contribute to acid rain in the local areas; team of scientists from the US Agricultural Research Service and the US Department of the Environment has examined and noted that within wastewater lagoons in North and South Carolina, there are a host of genes involved in the process of turning ammonia into nitrogen.[33]

One case study, conducted by Environmental Health Perspectives, sought to prove that malodor and pollutant concentrations from swine operations are associated with stress, altered mood, and increased blood pressure. For two weeks, adult volunteers living near swine operations in North Carolina sat outside for ten minutes twice a day. They reported levels of hog odor, and recorded their blood pressure. The study found that like noise and other similar environmental stressors, the malodors from the swine operations were likely associated with an increase in blood pressure, which could contribute to an increase in chronic hypertension.[32]

Disease spread

There are many documented incidences of disease outbreaks occurring due to the presence of pig farms in a given community, particularly industrial pig farms. MRSA (Methicillin-resistant Staphylococcus aureus, a type of anti-biotic resistant bacteria) outbreaks have been correlated to an individual working in a pig farm, likely attributed to the strong antibiotics often used in industrialized pig farms.[34] Other diseases can also spread in pig farms such as Salmonella, Toxoplasma, and Campylobacter.[35] Many of these diseases are preventable given proper safety precautions such as washing hands and clothes, wearing face masks, and covering any open wounds when coming into contact with pigs. Improvements in farmer education about diseases are often cited as the reason for the lack of increase in disease outbreaks in North Carolina despite an increase in pig population by a factor of four in the years leading up to 1998.[36]

In popular culture

In *The Simpsons Movie,* Homer Simpson dumps a silo of pig manure into a lake near the town of Springfield, provoking an environmental catastrophe that leads the US Environmental Protection Agency (EPA) to quarantine Springfield with a giant glass dome.[37]

See also

- Cultured meat
- Environmental impact of meat production
- Environmental impact of fishing

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	Strata Depth (ft.)	Water Type
Water Quality:	395 - 400	FRESH

Chemical Analysis Made: **No**

Did the driller knowingly penetrate any strata which contained injurious constituents?: **No**

Certification Data: The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the report(s) being returned for completion and resubmittal.

Company Information: **Finch Water Well**

FM 524
Sweeny, TX 77480

Driller Name: **JOHN F FINCH** License Number: **2405**

Comments: **No Data**

Lithology:
DESCRIPTION & COLOR OF FORMATION MATERIAL

Top (ft.)	Bottom (ft.)	Description
0	60	CLAY
60	190	SAND
190	395	CLAY
395	400	SAND
400	465	CLAY

Casing:
BLANK PIPE & WELL SCREEN DATA

Dia (in.)	Type	Material	Sch./Gage	Top (ft.)	Bottom (ft.)
4	Blank	New Plastic (PVC)	40	-3	430
4	Screen	New Plastic (PVC)	40 0.006	430	440
4	Blank	New Plastic (PVC)	40	440	465

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking Number on your written request.

Texas Department of Licensing and Regulation
P.O. Box 12157
Austin, TX 78711
(512) 334-5540

STATE OF TEXAS WELL REPORT for Tracking #648786

Owner:	KIM BROWN	Owner Well #:	No Data
Address:	5112 FM 2668 BAY CITY, TX 77414	Grid #:	81-01-5
Well Location:	5112 FM 2668 BAY CITY, TX 77414	Latitude:	28° 56' 52" N
		Longitude:	095° 57' 28" W
Well County:	Matagorda	Elevation:	No Data
Type of Work:	New Well	Proposed Use:	Domestic

Drilling Start Date: **7/17/2023** Drilling End Date: **7/18/2023**

	Diameter (in.)	Top Depth (ft.)	Bottom Depth (ft.)
Borehole:	7.75	0	465

Drilling Method: **Mud (Hydraulic) Rotary**

Borehole Completion: **Straight Wall**

	Top Depth (ft.)	Bottom Depth (ft.)	Description (number of sacks & material)
Annular Seal Data:	-3	100	Cement 22 Bags/Sacks

Seal Method: **Tremie**

Sealed By: **Driller**

Distance to Property Line (ft.): **30**

Distance to Septic Field or other concentrated contamination (ft.): **200**

Distance to Septic Tank (ft.): **80**

Method of Verification: **TAPE**

Surface Completion: **Surface Sleeve Installed** **Surface Completion by Driller**

Water Level: **75 ft.** below land surface on **2023-07-18**

Packers: **Rubber at 395 ft.**

Type of Pump: **Submersible** Pump Depth (ft.): **160**

Well Tests: **Jetted** **Yield: 60 GPM**

FEATURES

Animal Operations and Residential Property Values

by John A. Kilpatrick, PhD, MAI

Animal feeding and processing operations have grown more concentrated, with each facility handling much larger numbers of animals than traditional farms. The larger concentration of animals impacts the quality of surrounding air and water. In addition, the facilities impact the economic conditions of the communities where they are located. All of these factors can potentially affect the value of nearby houses. This article summarizes the current literature on how animal operations may affect the value of residential properties located near such facilities; this information will be useful to practicing appraisers faced with valuing houses in these communities.

Animal operations (AOs) may be broadly defined as facilities in which animals are raised or brought for slaughter. The common denominator is a large perpetual inventory and density of animals.[1]

Although livestock and poultry production has more than doubled in the United States since the 1950s, the number of animal operations has decreased by 80%.[2] Food animal production in the United States has shifted to concentrated facilities where animals usually are raised in confinement. This concentration of animals brings environmental concerns related to air and water quality as well as animal and human health. As a result, animal operations are subject to regulation by the US Environmental Protection Agency (EPA), the US Department of Agriculture (USDA), and a variety of state entities. Laws and government regulations related to animal operations include specific definitions based on the function and size of the operations. For example, the EPA defines *animal feeding operations* (AFOs) as

> agricultural enterprises where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or on rangeland.[3]

To qualify as an AFO, an animal operation must confine animals for at least 45 days in a twelve-month period.[4] According to the EPA, there are approximately 450,000 AFOs in the United States.[5] The EPA also designates certain AFOs as *concentrated animal feeding operations* (CAFOs) based on the confinement of large numbers of animals and the pollutant discharge. At CAFOs, there is a higher concentration of waste that increases the potential impact on air, water, and land quality.[6] CAFOs are regulated by the EPA under the Clean Water Act,

1. Quite a few documents were reviewed to develop this discussion; see subsequent footnotes and Drew L. Kershen and Chuck Barlow, "Concentrated Animal Feeding Operations and Water, Air, Land, and Welfare," report on the American Bar Association (ABA) Special Committee on Agricultural Management Roundtable II on Environmental Challenges in Animal Feeding Operations (September 23, 1999).
2. EPA, *Literature Review of Contaminants in Livestock and Poultry Manure and Implications for Water Quality* (EPA 820-R-13-002, July 2013), 3; http://water.epa.gov/scitech/cec/upload/Literature-Review-of-Contaminants-in-Livestock-and-Poultry-Manure-and-Implications-for-Water-Quality.pdf.
3. EPA, "What is a CAFO?", http://www.epa.gov/region07/water/cafo/.
4. Ibid.
5. EPA, "Animal Operations," http://www.epa.gov/agriculture/anafoidx.html.
6. http://www.epa.gov/region07/water/cafo/cafo_impact_environment.htm.

as environmental concerns arise when waste runoff is discharged onto adjacent landscapes and waterways.[7]

As the structure of the livestock industry has trended toward concentration of more animals in fewer operations, state and local governments also have acknowledged the problems associated with large operations by enacting legislation imposing stricter regulations on CAFOs and increasing separation distances.[8] For example, in North Carolina the following mandatory setbacks are imposed on new or expanded farms with 250 or more hogs: 1,500 feet from occupied residences, 500 feet from any residential property boundary to swine houses and lagoons, and 75 feet from any residential property boundary to sprayfield boundaries.

Overall, the empirical evidence indicates that residences near AOs are significantly affected, and data seems to suggest a valuation impact of up to 26% for nearby properties, depending on distance, wind direction, and other factors. Further, there has been some suggestion that properties immediately abutting an AO can be diminished as much as 88%. One study estimates the total negative impact to property values in the United States at $26 billion.[9] Mitigation makes a marginal impact. Not only are residences affected, but nearby small farms can be impacted by such factors as water degradation and insects.

Environmental Impacts and Regulation of Animal Operations

AOs are generally recognized to affect the surrounding environment in several key ways: air quality and odors (ammonia, hydrogen sulfide, methane, and particulate matter), greenhouse gas and climate change, insect vectors (often carrying resistant strains of pathogens), groundwater and surface water contamination, and a variety of pathogens.[10]

Data from the USDA and the EPA estimate that livestock in the United States produce 130 times the total amount of manure as the entire human population of the country. For example, one hog excretes nearly three gallons of waste per day or 2.5 times the average human's daily total. A 3,000-sow AO will produce about 25 tons of manure a day.[11] A similar number of chickens will produce about 700 pounds of manure per day (plus or minus 30%), containing about 9 pounds of nitrogen gas, 7.5 pounds of phosphorus pentoxide (a powerful irritant and corrosive) and over 4 pounds of potassium oxide, a highly reactive deliquescent that reacts violently with water to produce potassium hydroxide.[12] Manure from livestock production can contain bacteria (salmonella, E. Coli 0157:H7), parasites, viruses, and antimicorbials (antibiotics and vaccines).[13] Excessive levels of phosphorus in land and water have been correlated with livestock density; and manure has caused eutrophication and degradation of US waterways.[14]

AOs are regarded as potential sources for contamination because of the large amounts of manure that they produce, and because the proximity in which the animals are confined allows for disease to be easily transferred.[15] A 2006 outbreak of E. coli 0157:H7 was associated with the consumption of fresh spinach that had been in contact with water contaminated with animal feces.[16] One of the

7. The USDA and EPA first regulated animal operations under the 1999 "Unified National Strategy for Animal Feeding Operations," see http://water.epa.gov/polwaste/npdes/afo/Animal-Feeding-Operations-Regulations.cfm. The USDA Economic Research Service presents a discussion of regulatory issues related to animal waste at http://www.ers.usda.gov/topics/animal-products/animal-production-marketing-issues/policy-regulatory-issues.aspx#regulatory. Up-to-date information on the Clean Water Act is available at http://www2.epa.gov/laws-regulations.
8. Joseph Herriges, Silvia Secchi, and Bruce A. Babcock, "Living with Hogs in Iowa: The Impact of Livestock Facilities on Rural Residential Property Values" (Iowa State University Center for Agricultural and Rural Development working paper, August 2003).
9. Doug Gurian-Sherman, *CAFOs Uncovered: The Untold Cost of Confined Animal Feeding Operations* (Cambridge, MA: Union of Concerned Scientists, 2008).
10. Carrie Hribar, *Understanding Concentrated Animal Feeding Operations and Their Impact on Communities* (National Association of Local Boards of Health, 2010), available at http://www.cdc.gov/nceh/ehs/docs/understanding_cafos_nalboh.pdf.
11. Don Hopey, "Study Finds Large Hog Farms Lower Property Values," *Post-Gazette* (June 7, 2003).
12. Jing Tao and Karen Mancel, "Estimating Manure Production, Storage Size, and Land Application Area," Ohio State University, 2008 Agricultural Fact Sheet. According to a study by the University of Wisconsin-Madison, the average chicken farm has 14,500 birds, with farm sizes ranging up to 50,000 birds; see UW-Madison College of Agricultural and Life Sciences, Center for Integrated Agricultural Systems, Research Brief 63, January 2003.
13. EPA, *Literature Review of Contaminants in Livestock and Poultry Manure*.
14. Stephen Jann, "Recent Developments in Water Pollution Control Strategies and Regulations," presentation at ABA Special Committee on Agricultural Management Roundtable II on Environmental Challenges in Animal Feeding Operations, Minneapolis, MN (May 12, 1999).
15. "National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitation Guidelines and Standards for Concentrated Animal Feeding Operations (CAFOs); Final Rule" *Federal Resister* 68 (February 12, 2003). Note that portions of this were subsequently overturned in *Waterkeeper Alliance v. EPA*, 399 F.3d 486.
16. "FDA Finalizes Report on 2006 Spinach Outbreak," FDA (March 24, 2007), http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/2007/ucm108873.htm.

leading causes of food and waterborne illness in the United States is this E. coli 0157:H7 organism, which is a specific strain of the Escherichia coli bacteria commonly found in the intestines of healthy cattle. One means of transfer of E. coli to humans occurs when untreated manure is able to enter water sources or used for fertilization.[17] The EPA acting under the Clean Water Act has designated AFOs as point sources of pollution and requires that they have zero discharge or apply for a permit that requires an extensive waste management plan. Despite regulatory efforts to segregate manure-related contaminants from the water supply, contaminants still may enter the supply because of flooding, leeching into the soil, or through disregard of regulations.

In addition to water quality issues related to manure and waste run-off, animal operations facilities attract flies and other insects and parasites.[18]

As noted in Kilpatrick, state entities began regulating AFOs in the late 1990s.[19] In 2000–2001, the EPA began levying fines against concentrated beef production facilities in the Northwestern United States that met two criteria: the facility confined animals for at least 45 non-consecutive days per year and the confinement area was devoid of vegetation. The rules generally applied to any operation with 300 head of cattle or more. At the time of the regulations, the EPA estimated that this would affect between 26,000 and 39,000 AFOs in the United States.[20]

On December 11, 2002, the EPA issued its final revised regulations.[21] The regulations affirmed the prior definitions of AFOs and CAFOs, provided for an explicit duty to apply for a permit, established required performance standards and best management practices, and explicitly required nutrient management plans.[22]

Overview of AO Impacts on Property Values

An AO can affect the value of proximate properties in two ways. First, AOs have a substantial indirect negative economic impact on surrounding communities, including property values in those communities, via shifts in sources of purchases and other inputs in the factors of production. An early study by Chism and Levins reports that smaller farms make nearly 95% of their expenditures locally, while larger operations spend less than 20% locally.[23] Gomez and Zhang study 1,106 rural communities and conclude that economic growth rates in communities with conventional farming are 55% higher than in those with AOs.[24] They document the negative impact of AOs on the economy of the surrounding community, as revealed by sales tax receipts and reduced local purchases. They note that conventional farmers buy most or all of their supplies locally, thus stimulating the local community and, by extension, stimulating the local real estate market. On the other hand, AOs bypass local retailers and import the factors of production. Gomez and Zhang state that AOs exacerbate the economic negative impact by "importing" large quantities of pollution and the attendant costs; they also find AOs cause "disruption of local social and economic systems, pollution problems resulting from intensive agriculture, and negative impacts on the quality of life in rural communities." This finding replicates those of an earlier study by Abeles-Allison and Connor, which showed AOs have the effect of crowding out more traditional farmers and decreasing purchases in local stores.[25]

Hence, local communities suffer the negative economic byproducts without the attendant economic benefits.

17. "Disease Listing, Escherichia Coli 0157:H7, Gen Info," Centers for Disease Control and Prevention, http://www.cdc.gov/ecoli/.
18. Stuart A. Smith, "Concentrated Animal Feeding Operations—Resources for Environmental Responsibility" (working paper prepared by Smith-Comeskey Ground Water Sciences, April 1, 2000); for additional information see http://www.groundwaterscience.com/resources/tech-article-library/100-concentrated-animal-feeding-facilitiesresources-for-environmental-responsibility-.html.
19. John A. Kilpatrick, "Concentrated Animal Feeding Operations and Proximate Property Values," *The Appraisal Journal* (July 2001): 301–306.
20. Peggy Steward, "Cattlemen Find CAFO Rules Confusing," *Capital Press Agricultural Weekly* (March 9, 2001): 9.
21. Claudia Copeland, "Animal Waste and Water Quality: EPA Regulation of Concentrated Animal Feeding Operations (CAFOs)," Congressional Research Service Report for Congress No 7-5700, February 16, 2010. The regulations were published in the *Federal Register* on February 12, 2003 and went into effect on April 14, 2003.
22. http://water.epa.gov/polwaste/npdes/afo/. Permitting is under the EPA's National Pollutant Discharge Elimination System (NPDES) program, which regulates the discharge of pollutants from point sources; CAFOs are defined as point sources by the Clean Water Act.
23. John W. Chism and Richard A. Levins, "Farm Spending and Local Selling: How Do They Match Up?" *Minnesota Agricultural Economist* 676 (1994): 1–4.
24. Miguel Gomez and Liying Zhang, "Impacts of Concentration in Hog Production on Economic Growth in Rural Illinois" (Illinois State U. working paper presented at annual meeting of American Agricultural Economics Association, July 30–August 2, 2000).
25. M. Abeles-Allison and L. Connor, *An Analysis of Local Benefits and Costs of Michigan Hog Operations Experiencing Environmental Conflicts* (Agricultural Economic Report 536, Department of Agricultural Economics, Michigan State University monograph, 1990).

Second, AOs impact values at the individual residential value level. Property values are impacted as market participants view the AO as a negative externality. As an externality, it is not typically considered economically curable under generally accepted appraisal theory and practice. Hence, the value diminution attributable to proximate location of an AO can be attributed to stigma. The next section discusses case studies regarding the effects of AOs.

Proximity Case Studies

Kilpatrick presented a series of case studies from the 1990s that document the impacts of AOs.[26] For example, a Minnesota homeowner lived near two swine AOs when her family reportedly became ill and testing found that the level of hydrogen sulfide was well above the danger levels.[27] An early study in North Carolina by Schiffman et al. reports emotional impacts (tension, depression, anger, reduced vigor, fatigue, and confusion) linked to airborne contamination emanating from an AO.[28] A later North Carolina study by Wing and Wolf reports increased incidences of headache, runny nose, sore throat, excessive coughing, diarrhea, burning eyes, and "reduced quality of life."[29] An early study in Iowa by Thu et al. finds increases in eye and upper-respiratory problems among those living within 2 miles of an AO.[30] A later Iowa study[31] finds extensive literature documenting acute and chronic respiratory disease and dysfunction among CAFO workers from exposures to complex mixtures of particulates, gases, and vapors; it concludes that CAFO air emissions may constitute a public health hazard.

Ables-Allison and Connor were among the first to examine property value impacts resulting from airborne contamination and odors.[32] Examining 288 sales between 1986 and 1989, they find that for every thousand animals added within a 5-mile area, there is an average sale price drop of $430 per property, with the most significant losses within 1.6 miles. Notably, they find that during the first half of 1989 an AO with greater than 500 animals was 50 times more likely to have an odor complaint lodged with the state than one with fewer than 500 animals.[33]

Taff, Tiffany, and Weisberg perform a hedonic price analysis on 292 rural residences in Minnesota and find a statistically significant pricing impact related both to the existence of an AO as well as the distance to the AO.[34] A 1996 study by Padgett and Johnson finds that homes within 0.5 mile of a CAFO decrease in value by 40%, and homes within 1.0 mile decrease in value by 30%, within 1.5 miles by 20%, and within 2.0 miles by 10%.[35] Palmquist, Roka, and Vukina quantitatively determine that AOs depress nearby home values. They develop a model to measure the spatial impacts of AOs and, like Padgett and Johnson, find differential value impacts at 0.5, 1.0, and 2.0 miles.[36]

Hamed, Johnson, and Miller, quantify both the average value impact of an AO as well as the impact by distance with a study of 99 rural, non-family real estate transactions of more than one acre near an AO. Thirty-nine of the properties in the study included a residence. An average residential parcel within 3 miles of an AO experienced a loss of about 6.6%. However, if that parcel was located within 0.10 mile of the AO (the minimum unit of measure in the study), then the loss in value was estimated at about 88.3%.[37]

26. Kilpatrick, "Concentrated Animal Feeding Operations."
27. Presentation at ABA Special Committee on Agricultural Management Roundtable II.
28. Susan S. Schiffman, Elizabeth A. Miller, Mark S. Suggs, and Brevick G. Graham, "The Effect of Environmental Odors Emanating from Commercial Swine Operations on the Mood of Nearby Residents," *Brain Research Bulletin* 37, no. 4 (1995): 369–375.
29. S. Wing and S. Wolf, "Intensive Livestock Operations, Health, and Quality of Life Among North Carolina Residents," *Environmental Health Perspectives* 108, no. 3 (March 2000): 233–238.
30. K. Thu, K. Donham, R. Ziegenhorn, S. Reynolds, P. Thorne, P. Subramanian, P. Whitten, and J. Stookesberry, "A Control Study of the Physical and Mental Health of Residents Living Near a Large-Scale Swine Operation," *Journal of Agricultural Safety and Health* 3, no. 1 (1997): 13–26.
31. *Iowa Concentrated Animal Feeding Operations Air Quality Study—Final Report*[End Ital], Iowa State University and the University of Iowa Study Group (February 2002), http://www.public-health.uiowa.edu/ehsrc/CAFOstudy/CAFO_final2-14.pdf.
32. Abeles-Allison and Connor, *Analysis of Local Benefits and Costs of Michigan Hog Operations.*
33. As previously discussed, this study also reports that AOs affect the economics of local communities.
34. Steven J. Taff, Douglas G. Tiffany, and Sanford Weisberg, "Measured Effects of Feedlots on Residential Property Values in Minnesota: A Report to the Legislature" (U. Minnesota Staff Paper Series, July 1996), http://ageconsearch.umn.edu/bitstream/14121/1/p96-12.pdf.
35. Reported in William J. Weida, "The CAFO: Implications for Rural Economies in the US" (Colorado College working paper, February 24, 2004), http://www.columbus.in.gov/planning/staff-reports/gellius-materials-part-1/.
36. R. Palmquist, F. Roka, and T. Vukina, "Hog Operations, Environmental Impacts, and Residential Property Values," *Land Economics* 73, no. 1 (1997): 114–124.
37. Mubarek Hamed, Thomas Johnson, and Kathleen Miller, "The Impacts of Animal Feeding Operations on Rural Land Values," University of Missouri-Columbia, Community Policy Analysis Center Report R-99-02 (May 1999).

Additional empirical studies have supplemented these findings. Kim and Goldsmith analyze property values of 2,155 homes located within 3 miles of an AO in North Carolina. The principle focus of their study is spatial hedonics, and within a 3-mile area they find the average impact to be negative 18%. At 1 mile, they find the impact is negative 23.5%.[38]

Weida studies the economic and financial impact of CAFOs. While this study principally focuses on the diminished economic growth rates in communities surrounding CAFOs, it also notes the substantial decreases in property values in those areas, as evidenced by property tax reductions.[39]

Kuethe and Keeney find that the negative impacts of AOs are comparable to those generated by industrial waste, solid waste, and septic waste facilities.[40] They focus on airborne-related problems and note that odor is a particular source of nuisance, and higher-valued residences are more severely impacted.

The odor and airborne particulate issues also have been explored in a more recent study by Isakson and Ecker. They examine the impact of swine CAFOs on sale prices of 5,822 houses in Iowa. The study shows large adverse impacts for houses located within 3 miles and directly downwind from a CAFO—a loss of value of as much as 44.1%. Value loss diminished to 16.6% for houses not directly downwind, and loss in value decreased to 9.9% for houses directly downwind but 3 miles away. Isakson and Ecker also find a correlation between CAFO size and value loss; a 10% increase in CAFO size resulted in a 0.67 % decrease in house price as far as 7 miles from the nearest CAFO.[41]

Studies Using GIS

Increasingly, AO studies have relied on geographic information systems (GIS) technology and other spatial methods to investigate property value impacts.

Worley Rupert, and Risse use GIS to examine the efficacy of buffers to mitigate AO impacts.[42] They find that adding buffers to animal operations reduces the amount of land available within an area for such operations.

Cajka, Deerhake, and Yao present a study technique using GIS and modeling software to investigate the dispersion of air pollution emanating from CAFOs. The advantage of this approach is it looks at cumulative emissions from multiple sources.[43]

Milla, Thomas, and Ansine, study homes in Craven County, North Carolina, use a GIS-based hedonic pricing model to evaluate the impacts of CAFOs, particularly hog operations, on residential property values. Their results indicate a negative and significant impact on property value from hog operations and a relationship between distance to hog farms and property sale prices. They determine that a farm with 5,000 animals has a statistically significant impact on values of homes 1 mile away, with an impact on the average home of 3.1%.[44]

Based on the results of the case studies, it is quite apparent that significant externalities are associated with animal feeding operations, that the relationship between externalities, farm characteristics, and community attributes can be quite complex, and that negative impacts of animal facilities, as reflected in lowered property values, can extend beyond established setbacks. The GIS-based studies suggest the externalities associated with AOs are a function of distance and that the GIS-based hedonic price modeling is a promising method for assessing property value damages associated with animal operations, for evaluating potential impacts when siting new operations, and for developing setback guidelines.

38. Jungik Kim and Peter Goldsmith, "A Spatial Hedonic Approach to Assess the Impact of Swine Production on Residential Property Values," *Environmental and Resource Economics* 42, no. 4 (April 2009): 509–534.
39. William J. Weida, "Potential Regional Economic Effects of CAFOs" (Colorado College working paper, August 24, 2001), available at http://sraproject ~~.org/wp-content/uploads/2007/12/commentsonthepotentialregionaleconeffectsoffeedlots.pdf~~.
40. Todd H. Kuethe and Roman Keeney, "Environmental Externalities and Residential Property Values: Externalized Costs Along the House Price Distribution," *Land Economics* 88, no. 2 (2002): 241–250, available at http://naldc.nal.usda.gov/naldc/download.xhtml?id=54130&content=PDF.
41. Hans R. Isakson and Mark D. Ecker, "An Analysis of the Impact of Swine CAFOs on the Value of Nearby Houses," *Agricultural Economics* 39, no. 3 ~~(November 2008): 365–372~~.
42. J. W. Worley, C. Rupert, and L. M. Risse, "Use of GIS to Determine the Effect of Property Line and Water Buffers on Land Availability," *Applied Engineering in Agriculture* 17, no. 1 (September 2000): 49–54; available at https://www.itos.uga.edu/library/buffers.pdf.
43. Jamie Cajka, Marion Deerhake, and Chengwei Yao, "Modeling Ammonia Dispersion from Multiple CAFOs Using GIS," *Proceedings of the 24th ESRI Users* ~~*Conference*, August 9–13, 2004, available at http://proceedings.esri.com/library/userconf/proc04/docs/pap1381.pdf~~.
44. Katherine Milla, Michael H. Thomas, and Winsbert Ansine, "Evaluating the Effect of Proximity to Hog Farms on Residential Property Values: A GIS-Based Hedonic Price Model Approach," *URISA Journal* 17, no. 1 (2005): 27–32.

Legal and Regulatory Actions

Legal and regulatory actions also can reveal the impacts of AOs on nearby properties. For example, in 2000, Central Industries operated a large-scale poultry rendering plant near Central, Mississippi. As part of the process, large quantities of poultry processing byproducts were brought to this facility for further processing. The plant had been subject to a number of flooding events, spreading bacteria-laced poultry byproducts into nearby creeks and downstream rivers. Poultry byproducts were discovered up to 50 miles away from the rendering plant. For violations of the Clean Water Act, company officers were fined varying amounts up to $300,000 each, and the company was fined $14 million.[45] Researchers found property value diminution of up to 60% for farms closest to the plant, and transaction prices impacted as far as 11 miles away.

In numerous counties across the country tax assessors have granted property value reductions as a result of proximity to AOs. For example, Beasley reports that Clark County, Illinois, established a property tax abatement for fifty homes around a swine AO. Homes within 0.5 mile were determined to have values diminished by 30%, ranging down to a 10% reduction in value for homes at 1.5 miles.[46]

Aiken reports that the Nebraska Court of Appeals ruled that county board of equalization erred in not considering a rural residence's proximity to a swine facility in determining the residence's valuation. The owner of the facility also built a house 0.75 mile away and obtained an easement to spray the hog manure on the cropland across the road from the house. The court ordered the county to ignore the fact that the swine were also the property of the owner. The court cited Nebraska livestock nuisance decisions that show that hog odors would influence the home's value. Upon the ruling, the county accepted a determination by a local, independent appraiser that the value was diminished 30%.[47]

Spears reports that in the summer of 2003, health officials declared about 40 kilometers of beaches on Lake Huron permanently unsafe because of E. coli bacteria emanating from nearby AOs. This became the first new pollution hot spot on Canada's side of the Great Lakes in almost twenty years. Lab tests demonstrated that the E. coli levels in the streams feeding Lake Huron, and draining off nearby AOs, exceeded water quality standards by as much as 41,000 percent.[48]

Ready and Abdalla expand upon the hedonic analyses of others and reviewed the amenity and disamenity impacts of agriculture in Berks County, Pennsylvania, including different types of open space (publicly owned, eased, vacant, pasture/crops), landfills, airports, mushroom production, and AOs. The study determines that "only landfills have a worse effect on adjacent property values,"[49] and further states, "a sewage treatment plant has less depressing effects on nearby housing prices

Table 1 Property Tax Reductions in Areas Around AOs

Area	Amount of Reduction	Property Type
Grundy Co, MO	30%	
Mecosta Co, MI initially:	35%	Dwellings only
later changed to:	20%	Land and structures
Midland Co, MI	20%	
DeWitt Co, IL	30%	
McLean Co, IL	35%	
DeKalb Co, AL	Base reassessment, variable rates	
Renville Co, MN	Base reassessment, variable rates	Dwellings only
Humbolt Co, IA	20%-40%	Dwellings only
Frederick Co, MD	10%	
Muhlenberg Co, KY	18%	Dwellings only

45. US Department of Justice Press Release, November 2, 2000.

46. Lee Beasley, "Cumberland Hog Facility May Affect Clark County Homeowners Property Values," *Guardian Publishing* (2001).

47. J. David Aiken, "Property Valuation May Be Reduced by Proximity of Livestock Operation" Cornhusker Economics, Department of Agricultural Economics, University of Nebraska–Lincoln (May 2002).

48. Tom Spears, "Ontario's West Coast Permanently Polluted," *The Ottawa Citizen* (November 15, 2003); also R. E. Dines, Deborah Henderson, and Louise Rock, "The Case Against Intensive Hog Operations" (working paper, February 2004).

49. Richard C. Ready and Charles W. Abdalla, "The Amenity and Disamenity Impacts of Agriculture: Estimates from a Hedonic Pricing Model," *American Journal of Agricultural Economics* 87, no. 2 (May 2005): 314–326.

than a factory farm operation." The study also finds that the clustering of AOs within a certain area is the controlling factor, not the location of the nearest operation when considering proximity. The study reports a value impact of -4.1% from AOs within 800 meters, and at least -6.4% from within 500 meters, both of which were half the impact of a landfill at comparable distances. The study did not find any statistically significant difference in the effects based on AO size or species.

Herriges, Secchi, and Babock expand upon previous work on AO price effects by using variables to quantify the effects in a hedonic analysis of proximity, size, and direction of nearest facility. Direction from site was included to determine the effect of being downwind, and the odor and pest issues associated with AOs. Results from this study indicate that a moderate-size facility has a value impact up to -6% within 1.5 miles and -26% within a 0.25 mile.[50]

Finally, Keske documents ten lawsuits over AO nuisance in which the plaintiff prevailed, with jury awards ranging up to $50 million (Table 2). The size of these awards suggests that preventive measures, even if expensive, might be cost effective.[51]

Summary of AO Empirical Findings

The establishment of an AO results in value diminution to nearby properties, both through a negative externality as well as through indirect economic impacts. The amount of the value loss is an inverse function of distance (closer properties diminish more), a function of property type (newer, nicer residences lose more), and a function of property use (farms will lose value due to diminished productivity and comparative marketability to farm lands further away; residential use will no longer be a highest-and-best use). The empirical studies and case studies results indicate diminished marketability, loss of use and enjoyment, and loss of exclusivity that can range up to nearly 90% of otherwise unimpaired value for homes that are adjacent to the facility. Negative impacts are noted at distances exceeding 3 miles, and in the case of a flood or other weather event, waste from the facility can be spread over far greater areas, extending the area of negative impact (Table 3).

Mitigation of Impacts

There is surprisingly little empirical evidence of attempts to mitigate either the physical impacts or the perception of negative externality of AOs given the fairly consistent evidence of negative impacts on surrounding property values. The most significant and transcendent impacts are to surrounding community values and economics and to air quality. However, neither of these is well suited to mitigation efforts. Generally, mitigation fall into three categories: waste management plans, tree windbreaks, and anaerobic

Table 2 Damage Awards Related to AOs

Year/State	Jury Award	Case/Remarks
1991/NE	$375,600	*Kopecky v. National Farms*, swine operation
1996/KS	$12,100	Swine settlement – parties undisclosed in news article
1998/KS	> $15,000	*Twietmeyer v. Blocker*, beef operations
1999/MO	$5,200,000	*Hanes v. Continental Grain*, swine operation
2001/OH	$19,182,483	*Seelke v. Buckey Egg Farm*, poultry
2002/IA	$33,065,000	*Blass v. Iowa Select Farms*, swine operation
2004/OH	$50,000,000	*Bear v. Buckey Egg Farm*, poultry
2006/AL	$100,000	*Sierra Club v. Whitaker*, swine
2006/MO	$4,500,000	*Turner v. Premium Standard Farms*, swine
2007/IL	$27,000	State of Illinois (respondent unreported), swine

Source: Catherine M. H. Keske, "Determining the Economic Feasibility of Anaerobic Digestion in Colorado: Guidelines for Animal Farm Producers," CSU Extension Fact Sheet 1.229 (2012).

50. Herriges, Secchi, and Babcock, "Living with Hogs in Iowa."

51. Catherine M. H. Keske, "Determining the Economic Feasibility of Anaerobic Digestion in Colorado: Guidelines for Animal Farm Producers," CSU Extension Fact Sheet 1.229 (2012), http://www.ext.colostate.edu/pubs/livestk/01229.pdf.

Table 3 Summary of Studies of AO Value Impacts

Case Study	Value Loss	Remarks
Ables-Allison and Connor (1990)	$430 within 5 miles	Greatest impact within 1.6 miles
Taff, Tiffany, and Weisberg (1996)	N/A	AO sited near older, less-expensive homes
Palmquist, Roka, and Vukina (1997)	9%	Average up to 2 miles
Hamed Johnson, and Miller (1999)	6.6%–88%	Largest loss if within 0.10 mile
ABA Presentation (1999)	N/A	Confirmed respiratory problems
Central Industries (2000)	60% for farms closest to plant	USDOJ cases, values by appraisal
Beasley (2001)	Up to 30%	Impacts 10% at 1.5 miles
Aiken (2002)	30% @ 0.75 mile	Confirmed by court and local appraiser
Spears (2003)	N/A	40 km of beaches closed due to AO emissions
Herriges, Secchi, and Babcock (2003)	26% at 0.25 mile	Moderate-size AO, 6% at 1.5 miles
Weida (2004)	40% at 0.50 mile	10% at 2 miles
Ready and Abdalla (2005)	Residence at 0.25 mile > 6.4% Residence at 0.50 mile 4.1%	Roughly half the impact of a landfill
Kim and Goldsmith (2008)	23.5% at 1 mile	18% average within 3-mile radius
Isakson and Ecker (2008)	44%	Directly downwind and within 2 miles

Source: Catherine M. H. Keske, "Determining the Economic Feasibility of Anaerobic Digestion in Colorado: Guidelines for Animal Farm Producers," CSU Extension Fact Sheet 1.229 (2012).

digestion. Nonetheless, such mitigation does not appear to have an economically material impact on nearby property values.

Waste Management Plan

Laws or regulations typically require wastewater runoff treatment. However, some facilities go beyond that with actual waste management plans. There is some evidence that such plans will have marginal impact, as noted in the Ready and Abdalla study, which found a residential value differential of 4.2% versus 1.1%. Notably though, some of the most severe impacts have occurred near facilities with mandated waste management plans, particularly when and after those plans failed. For example, in one four-month period, the Central Industries facility studied by Ready and Abdalla committed approximately 1,114 permit violations, exceeding the pollutant limitations set forth in the company's permit by hundreds of percentage points and exceeding its permitted flow rate by millions of gallons. Hence, the efficacy of a waste management plan must be taken in the light of potential impacts of violations.[52]

Planting Trees

The University of Delaware, College of Agriculture and Natural Resources, studied the planting of windbreaks around poultry houses to reduce odor, dust, feathers, and noises, and suggests that this approach can also ameliorate nitrogen in the groundwater.[53] However, several aspects regarding this mitigation study should be noted:

1. The study focus is on protecting the poultry houses themselves, not adjacent or nearby neighbors.
2. Establishment of an effective windbreak takes quite a few years and quite a few trees.
3. A windbreak may partially ameliorate view problems but does not seem to address the major issues of odor and other airborne contaminations (particles, insects, etc.).

Anaerobic Digestion Facility

The purpose of Keske's study was to provide guidance on the financial feasibility of a biogas-fueled cogeneration facility.[54] The study recognizes the significant production of flammable biogas by AOs and notes the feasibility of biogas-fueled cogeneration

52. Ready and Abdalla, "The Amenity and Disamenity Impacts of Agriculture."
53. George W. Malone, "Environmental and Production Benefits of Trees for Poultry Farms," U. Delaware Cooperative Extension Service (2001).
54. Keske, "Determining the Economic Feasibility of Anaerobic Digestion."

is limited by a number of factors. First, the up-front costs can be prohibitive—typically $1.2 million, and up to $5 million depending on the technology used. Also, annual operating costs are significant, and while these technologies are sold with the promise of offsetting electric bills, Keske notes that in the study area (Colorado) electricity rates are already lower than other parts of the United States. Hence, AO operators should be "particularly wary of relying on anaerobic digestion to generate revenues by selling electricity to the utility." Finally, Keske notes that for a biogeneration facility to be feasible, at least two of the following criteria must be met:

1. The AO meets the definition of a confined AFO.
2. The waste stream can be combined with the waste stream of another operation or business (e.g., food manufacturing, municipal waste).
3. The AFO already receives frequent odor complaints.
4. The AFO produces swine or chickens (the two most egregious sources of biogas).
5. The AFO incurs more than $5,000/month in average electricity or heating charges.

Keske notes that given the high threshold of cost of this mitigation approach, the approach is feasible only if it outweighs costs associated with not implementing a mitigation plan. As previously mentioned, to support this Keske documents ten lawsuits in which claimants were awarded as much as $50 million for agricultural nuisance (Table 2). Notably, the two largest awards cited ($50 million and $19 million) were for poultry operations.[55]

Summary and Conclusions

Since *The Appraisal Journal*'s previous review of AO effects on proximate property values,[56] new study approaches have been identified. First, there has been an increased use of GIS by local governments, which has given researchers the ability to conduct more thorough investigations. GIS provides researchers with more data—in abundance and in detail—and allows researchers to better locate which factors, and to what degree, have an effect on value.

Second, in conjunction with more data and use of GIS, there are substantial improvements in the hedonic analyses performed. Keske noted that early studies (such as the Taff, Tiffany and Weisberg study and the Palmquist, Roka, and Vukina study) were conducted on fewer than 300 sales transactions each, while the later study by Ready and Abdalla reviewed 8,090 sales, and the Herriges, Secchi, and Babcock study examined 1,145 sales transactions.

Third, because of the increased use of GIS and the results from the hedonic analysis in newer case studies, it has been shown that an AO's basic impact is related to proximity and size, but there are also other factors, such as the operations' waste management practices, that can reduce or exacerbate that impact. Overall, the new studies confirm the valuation impacts reported in earlier studies, as they range from 3.1% to 26% loss depending on multiple factors, and that properties immediately abutting an AO can be diminished as much as 88%. More importantly, however, is the discussion of the impact of other site-specific factors that were considered as part the hedonic analyses.

With respect to mitigation efforts, the Ready and Abdalla study of Berks County (Pennsylvania) shows that at 800 meters an operation with a waste management plan diminishes a house's value 1.1%, while an operation without such a plan would diminish the value 4.2%. Also related to this is the effect of operation size on property values. Both the Ready and Abdalla study and the Herriges, Secchi, and Babcock study show that a larger facility in close proximity would not necessarily decrease the value of a nearby property more than a smaller facility. Both of the studies concluded that this effect could be attributed to unmodeled characteristics such as waste management practices and other site-specific attributes.

55. Ibid.

56. Kilpatrick, "Concentrated Animal Feeding Operations."

John A. Kilpatrick, PhD, MAI, is the managing director of Greenfield Advisors and is a visiting scholar in real estate finance at the Zicklin School of Business, Baruch College. He is the author or a contributing author to eight books, including *Private Real Estate Markets and Investments*. His research has been published in *The Appraisal Journal, Journal of Real Estate Research, Journal of Housing Research, Real Estate Issues, Journal of Property Investment and Finance, Journal of Wealth Management*, and *Journal of Real Estate Literature*. His work in real estate appraisal has been featured in *The Wall Street Journal, The New York Times*, and *The Boston Globe*, among others. **Contact: john@greenfieldadvisors.com**

Web Connections

Internet resources suggested by the Y. T. and Louise Lee Lum Library

eXtension Land-Grant University Cooperative Research Information
—Geospatial Technology
http://www.extension.org/geospatial_technology

–Animal Manure Management
http://www.extension.org/animal_manure_management

Food & Water Watch—Factory Farms
http://www.foodandwaterwatch.org/food/factoryfarms/

Texas A&M University, Texas Animal Management Issues Clearinghouse
http://tammi.tamu.edu/index.html

US Department of Agriculture, National Agricultural Library
http://www.nal.usda.gov/topics

US Environmental Protection Agency
—Agriculture Center
http://www.epa.gov/agriculture

—Drinking Water Regulations
http://water.epa.gov/lawsregs/rulesregs/sdwa/currentregulations.cfm

—Animal Feeding Operations Overview
http://water.epa.gov/polwaste/npdes/afo/index.cfm

Pig Farms May Soil Ground Water with Bacteria

SHARE THIS

May 31, 2002

Reuters | May 22, 2002 | Anne Harding |

SALT LAKE CITY (Reuters Health) - Methods now used by many swine farmers to dispose of pig manure may contaminate nearby groundwater with multiple-drug-resistant bacteria, North Carolina researchers report.

And while it is not known if this contamination is finding its way into drinking water, one of the researchers told Reuters Health, the E. coli contamination itself--let alone contamination with drug-resistant forms of this and other bacteria--would indeed be a public health concern.

Pigs raised for meat are treated with a number of antibiotics to boost growth and fight disease, notes Maren Anderson, a PhD candidate at the University of North Carolina at Chapel Hill and the study's lead author. The animals are known to shed bacteria--often resistant to antibiotics--in their feces.

To investigate whether swine manure disposal practices could be contaminating groundwater, Anderson and her colleagues tested groundwater near four farms. Two of the farms raised swine and dumped pig manure into lagoons or spread it over nearby land, and another did not raise swine but did apply swine manure to land as fertilizer. For comparison, the researchers looked at a fourth farm that raised only crops and used no swine manure.

The researchers tested water in 48 monitoring wells near the farms. One quarter of the wells tested positive for enterococci, and 17% contained E. coli. The enterococci the investigators found was associated with fecal contamination and capable of making people sick. And many of the bacteria they found were resistant to several drugs.

The most heavily contaminated water was found near the two farms that raised pigs and disposed of pig manure via lagoons and land application. Antibiotic resistance also was more prevalent at these sites.

Anderson told Reuters Health in an interview that lagoons and land application are the primary manure disposal methods used in North Carolina, and that a considerable amount of money is being spent on research to investigate less-polluting waste management techniques. She noted that older lagoons are probably leakier than newer ones, which use special liners to prevent contaminated water from seeping out.

Anderson presented her findings here Wednesday at the American Society for Microbiology's annual meeting.**Reuters:** (http://story.news.yahoo.com/news?tmpl=story&u=/nm/20020522/hl_nm/pigs_groundwater_1)

(https://www.iatp.org/mil-palabras-milpas-and-trade-and-food-justice)

TRADE

Mil-palabras for milpas and trade and food justice (/mil-palabras-milpas-and-trade-and-food-justice)

Nov 20, 2023

(https://www.iatp.org/setting-course-global-climate-action-cop28)

CLIMATE CHANGE

Setting the course for global climate action at COP28 (/setting-course-global-climate-action-cop28)

Nov 1, 2023

AND-
INTERNSHIPS)

Minneapolis | Washington, D.C. | Berlin

IATP Minneapolis Office Address

1700 Second Street NE, Suite 200
Minneapolis, MN 55413

Sec. 14-13. - Keeping horses and similar animals.

All horses, mules, jacks, jennets, or similar animals shall be kept in a stable, shed, pen or other enclosure. Such stable, shed, pen or other shall be at least 100 feet from every adjoining lot and at least 50 feet from every building or structure used for sleeping, dining, or living. This section shall not apply to such animals trailered into the city on a temporary basis not to exceed eight hours, nor shall it apply to such animals entered in a special event (rodeo, circus, etc.) for the period during which such event is held.

(Ord. No. 1573, § 2(Exh. A), 4-14-2016)

Sec. 114-71. - Wellhead protection.

(a) The following requirements have been adopted to prevent pollution of water pumped from the wellheads of city-owned wells, as set out below:

(1) It shall be unlawful for any person to construct a tile or concrete sanitary sewer, sewer appurtenance, septic tank, storm sewer, or cemetery within 50 feet of a city water well. With respect to sanitary or storm sewers, it is an affirmative defense to prosecution under this subsection (1) that the sanitary or storm sewer is located ten feet or more from the city water well, is constructed of ductile iron or PVC pipe that meets American Water Works Association standards, has a minimum working pressure of 150 psi or greater, and is equipped with pressure type joints.

(2) It shall be unlawful for any person to allow livestock in pastures within 50 feet of a city water well.

(3) It shall be unlawful for any person to construct an on-site sewage facility tank perforated drain field, tank absorption bed, or tank evapotranspiration bed, or to construct a petroleum or chemical storage tank or liquid transmission pipeline within 150 feet of a city water well.

(4) It shall be unlawful for any person to irrigate an area within 150 feet of a city water well with spray from an on-site sewage facility.

(5) It shall be unlawful for any person to construct a water well within 150 feet of a city water well unless the well complies with all applicable state regulations.

(6) It shall be unlawful for any person to construct a sewage wet well or sewage pumping station within 300 feet of a city water well.

(7) It shall be unlawful for any person to construct a drainage ditch for industrial waste or sewage treatment waste within 300 feet of a city water well.

(8) It shall be unlawful for any person to construct a sewage treatment plant, animal feed lot, or solid waste disposal site within 500 feet of a city water well.

(9) It shall be unlawful for any person to apply sludge or effluent from a septic tank or sewage treatment plant on land with 500 feet of a city water well.

(10) It shall be unlawful for any person to drill an oil or gas well, including an injection well for recovery of oil or gas within 500 feet of a city water well.

(b) It is a defense to prosecution under subsection (a) of this section that the actor has obtained a variance in writing from the utility official. The utility official shall grant a variance upon a showing by the applicant that:

(1) The facility or activity will not contaminate the groundwater; and

(2) The facility or activity is not prohibited under any other provision of this Code.

(c)

The department shall investigate existing facilities whether located within or without the distance requirements of subsection (a) and determine if those facilities are a pollution hazard to city well water. The department shall recommend acquisition of such facilities in the event the department determines that the facilities are a pollution hazard to city well water and the owner refuses to take action necessary to abate the pollution hazard.

(d) Any person who violates any provision of this section shall be guilty of an offense and upon conviction thereof shall be subject to a fine as set forth in appendix B of the Code of Ordinances. Each day in which a violation occurs shall constitute a separate offense. In addition to criminal prosecution, the legal department may seek appropriate judicial remedies to protect city ground water from contamination.

(Ord. No. 1659, § 1(Exh. A), 12-1-2020)

CITY OF BAY CITY

October 19, 2022

Kimberly Brown
5112 FM 2668
Bay City, Texas 77414

RE: Water and Wastewater Service Availability to 5112 FM 2668, Bay City, Texas
Matagorda County Property ID# 10158

Dear Mrs. Brown:

The above described property is **not** located within the service area of the City of Bay City. Water and wastewater service for this property cannot be provided in accordance with all applicable policies, ordinances and regulatory requirements. Please refer to the City of Bay City Code of Ordinances (https://library.municode.com/tx/bay_city/codes/code_of_ordinances).

The property owner and/or developer of this property is responsible for design and construction of water and wastewater infrastructure required to accommodate proposed development of this property. Service Extension Requests may be required for future development. However, at this time, the City has no plans to provide these services to the above referenced location. Actual service delivery will be contingent upon available system capacity at the time an application for Tap and/or Service Extension Request is made and will be subject to all fees, charges, ordinances and policies in effect at that time.

If we can provide additional information, please call me at (979) 245-7236 or email me at bcalhoun@cityofbaycity.org.

Sincerely,

Barry Calhoun

Barry Calhoun
Director of Public Works
City of Bay City

1901 FIFTH STREET • BAY CITY, TEXAS 77414 • (979) 245-2137 • FAX (979) 323-1626
www.cityofbaycity.org

City of Bay City

Sewer Tap Request

1217 Avenue J
Bay City, Tx 77414
(979) 323-1659

Name	Kimberly Brown
Address	3216 13th st, Bay City TX 77414
Phone Number	979-323-4802
Address of requested tap	5112 FM 2668, Bay City TX 77414 ☐ Commercial ☒ Residential
Reason for requested tap	Building Home on Property for Homestead- Would ~~Like to have septic & waterwell approved~~
Signature	Authentisign Kimberly Brown — Date 10/19/2022

*Please note that all tap requests are good for **30 days** after the quote has been given*

For Office Use Only					
Date Surveyed			Amount		Date Quoted
Tap Size		Surcharge		Receipt Number	
Location of tap	☐ FRONT	☐ REAR		Employee	

NOTES City does not have a water or sewer main in this area. City will be unable to provide services to this address

Approval of Tap Request/Fees: ____________________

UTILITIES FOREMAN

UTILITIES SUPERINTENDENT

PUBLIC WORKS ASST DIRECTOR/DIRECTOR

Authentisign ID: 0439309A-D0CD-4D74-9810-649B320842E6

City of Bay City

Water Tap Request

1217 Avenue J
Bay City, Tx 77414
(979) 323-1659

Name	Kimberly Brown
Address	3216 13th St. Bay City, TX 77414
Phone Number	979-323-4802
Address of requested tap	5112 FM 2668, Bay City TX 77414 ☐ Commercial ☐ Residential ☐ Irrigation
Reason for requested tap	X
Signature	Authentisign Kimberly Brown 10/19/2022 2:35:28 PM GMT
Date	10/19/2022

*Please note that all tap requests are good for **30 days** after the quote has been given*

For Office Use Only					
Date Surveyed		Amount		Date Quoted	
Tap Size		Water Tap Service Agreement Completed		Receipt Number	Employee
Backflow Prevention Device Required	☐ YES ☐ NO			Location of tap	☐ FRONT ☐ REAR

NOTES City does not have a water or sewer main in this area to provide services at this address

Approval of Tap Request/Fees: ______________________

UTILITIES FOREMAN

UTILITIES SUPERINTENDENT

PUBLIC WORKS ASST DIRECTOR/DIRECTOR

Greg Baker
Texas A+M
Extension Agent
on Right To FARM
Act when I asked him
to check on Bens
claim

Gregory

Active 17 minutes ago

Kin From our Ag Law Attorney

Hey Greg—Good to hear from you. I can't give specific legal advice here—but happy to give some general info.

Okay—so there are a couple of nuances here.

First, regardless of whether Proposition 1 passes or not, the protections of the right to farm statute are in place. So the date that the Prop 1 election happens is not of any consequence as far as the statutory defense goes.

The operation would need to be in its location substantially unchanged for a year before it gets the statutory protection. So if it moves from Location A to Location B, the clock would start over. The only real exception I can think of is if there was someone else previously at Location B that was doing the same type of operation—I think in that situation you could at least argue you should be able to count their time. I'm not sure if that wins or not...but there's at least an argument there.

So—short answer: if an operation moves from one location to another, the clock for the 1 year in operation substantially unchanged requirement begins over.

Message