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Features

POULTRY LITTER INCINERATION AS A SOURCE OF ENERGY: REVIEWING THE POTENTIAL FOR IMPACTS ON ENVIRONMENTAL HEALTH AND JUSTICE

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ABSTRACT

Legislation in North Carolina has mandated obtaining renewable energy from the incineration of poultry waste, resulting in proposals for three poultry-litter-fueled power plants statewide. This article summarizes environmental health and environmental justice issues associated with incineration of poultry waste for the generation of electric power. Emissions from poultry waste incineration include particulate matter, dioxins, arsenic, bioaerosols and other toxins; various components are associated with cardiovascular disease, cancer, respiratory illness, and other diseases. Industrial farm animal production tends to be concentrated in low-income, rural communities, where residents may be more vulnerable to air pollutants due to pre-existing diseases, other exposures and stressors, and poor access to medical services. These communities lack the political clout to prevent siting of polluting facilities or to pressure industry and government to follow and enforce regulations. Policies intended to reduce reliance on fossil fuels have the potential to increase environmental injustices and threats to environmental health.

Climate change, rising energy costs, and the desire for national energy independence have contributed to interest in alternatives to fossil fuels to meet society's

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energy demands. Although biofuels are renewable, they have the capacity to increase air pollution and to negatively impact environmental health and environmental justice. Previous research has suggested that direct reduction of greenhouse gases from substituting corn-based ethanol for gasoline is offset by changes in land use, potentially resulting in a net increase in greenhouse gases [1]. Characterizing the potential for negative impacts of alternative fuels is important as they continue to be promoted by environmental groups, politicians, and commercial interests.

In 2007, the North Carolina state legislature passed Session Law 2007-397, a renewable energy bill that mandated use of wind, solar, and other forms of renewable energy including animal waste. The law required utility companies to obtain at least 900,000 megawatt-hours of electricity from poultry waste by 2014 [2]. North Carolina has a high concentration of industrial poultry operations, and as a result, a large supply of poultry litter. Poultry litter, which consists primarily of manure, bedding, feathers, and spilled feed, has been used as a fuel for a few power plants in the United Kingdom since the 1990s [3], but there were no operational facilities in the United States at the time the North Carolina bill was developed. In May of 2007, a poultry litter incineration plant in Minnesota became operational. Soon after passage of the North Carolina law, poultry litter incinerators were proposed in three North Carolina counties.

The goal of this article is to summarize the environmental health and justice issues that arise from the incineration of poultry waste to generate energy. We focus on potential impacts of poultry-waste-to-energy facilities on nearby populations. Due to a lack of research on exposures and disease among people living in proximity to poultry litter incinerators, this article describes environmental emissions of these incinerators and reviews prior research on potential health effects that have been found to be associated with those emissions. In addition, we examine environmental justice issues surrounding energy policy involving animal waste.

POULTRY LITTER AS A SOURCE OF RENEWABLE ENERGY

The first poultry litter incinerator was built in the United Kingdom in 1993 [3] to provide a disposal alternative to land application of excess poultry litter produced by industrial poultry operations. While poultry litter can be a valuable fertilizer due to its high nutrient content, poor waste management practices, including over-application, can result in nitrogen and/or phosphorus runoff and subsequent eutrophication of nearby waterways [4, 5]. Processes such as composting, gasification, and direct combustion/incineration of poultry litter provide an alternative to conventional land application and can be used to generate electricity [3, 6]. Small-scale use of poultry litter to create biocrude oil for heating poultry houses has also been discussed [7]. Large-scale incineration,

however, has been the most common commercial method of generating energy from poultry litter.

There are currently five operational poultry-litter-fueled power plants in the world: four in the United Kingdom and one in Benson, Minnesota. As a 55-megawatt (MW) power plant, the facility in Benson is the largest and most recently constructed and would be the most comparable to the plants proposed for construction in North Carolina. The next largest incinerator is a 35-MW plant located in Thetford, England, built in 1998, while the other three facilities are smaller, ranging from 9.8 to 13.5 megawatts in production [6]. A relatively inefficient form of fuel, poultry litter has approximately half the calorific value of coal, and that value can vary depending on the moisture content of the litter [8]. Currently the incinerator in Benson utilizes 500,000 tons of poultry litter supplemented with 100,000–200,000 tons of agricultural wastes to meet its energy generation goals annually [9, 10].

The processes used to generate electricity from incinerating poultry litter have been described previously [3, 6]. Briefly, workers at the incinerator coordinate with industrial poultry operations to collect the litter. Litter is loaded into trucks and transported to the incineration plant, where it is stored in a building that is kept at negative pressure to prevent odor leakage. At this point, litter may be combined with other fuels, such as agricultural waste or clean wood in order to achieve appropriate moisture levels. From storage, the litter is burned in a furnace, boiling water to power a steam turbine. The steam is condensed, and the water recycled. Byproducts of the process are a mixture of gases and particulates, as well as a highly concentrated, phosphorus-rich ash, which is permitted to be used as fertilizer [3, 6].

All the facilities use similar technologies, although processes have been modified to reflect differences in the moisture content of litter and needs for additional pollution controls. For example, two of the earlier plants use electrostatic precipitators to reduce particulate emissions, while the more recently constructed plants use a cyclone and baghouse in series to remove a greater amount of particulates [6]. The first plants also did not include controls for sulfur dioxide (SO_2) or hydrochloric acid (HCl) emissions, while later plants use lime injections to reduce these emissions [6]. In addition, there are differences in how the litter is fed into the furnace, which impacts not only efficiency of burning, but also the facilities' emissions. For example, even though most facilities utilize a conventional step-grate combustion system, there remain differences in the process depending upon whether the litter sits atop a moving grate and burns at the bottom of the furnace or is transferred to the furnace from a conveyer belt using a steam generator. The latter allows for greater oxygen involvement and greater system efficiency.

A single, smaller facility in the United Kingdom uses newer, fluidized bed technology, which utilizes air jets to move litter during combustion, causing even more effective chemical reactions and more efficient burning [6]. This

technology has the capacity to accept a wide variety of fuels with varying moisture contents, and previous research suggests that, when the proper temperature is maintained, it produces lower sulfur oxide (SO_x) and nitrogen oxide (NO_x) emissions and achieves greater efficiency [6, 11]. However, as stated above, most facilities, including those being proposed for North Carolina, use conventional grate combustion systems which, due to the low fusion temperature of poultry litter, can be impacted by fouling and slagging, two common problems related to ash deposition during burning [6]. This can further reduce the efficiency of the poultry waste incinerators if proper controls are not in place. These differences in process and the presence/absence of pollution controls can make characterizing emissions of individual facilities challenging in the absence of highly detailed facility plans and descriptions. In general, however, the majority of emissions resulting from these facilities remain fairly consistent overall, although actual monitored levels may vary across different locations, as well as over time.

ENVIRONMENTAL HEALTH

Sources of hazardous emissions from poultry litter incineration include the smokestack effluent, truck exhaust from transport of poultry litter and waste ash, runoff from washing of the trucks, and disposal of the plant's wastewater. Combustion of organic materials produces byproducts similar to those of other incinerators that use more conventional forms of fuel [12]. Each of the emissions, including particulate matter of varying sizes, carbon monoxide (CO), carbon dioxide (CO_2), dioxins, nitrogen and sulfur oxides, heavy metals, polycyclic aromatic hydrocarbons, and others, can individually and jointly impact both the environment and human health [12-14]. Exposure to these pollutants would occur mainly via inhalation of particles emitted from the facilities' smokestacks and from the exhaust of transport trucks. It is also possible for the pollutants to be deposited in the soil and local groundwater sources and thus contaminate locally grown food and drinking water [12, 15-17].

Previous studies have found associations between living near waste incinerators and adverse reproductive and cancer outcomes [18, 19], while living near fossil-fuel-powered plants has been linked with respiratory outcomes and pregnancy complications [20-22]. Previous research has also linked exposure to individual pollutants to a number of health effects. For example, exposure to particulate matter has been linked with both respiratory and cardiovascular symptoms and disease, including asthma, cough, wheezing, impaired lung development in children, decreased lung function, myocardial infarction, higher blood pressure, stroke, and increased morbidity and mortality among those with pre-existing diseases [23]. Children, the elderly, and pregnant women have been shown to be especially vulnerable [23]. In particular, diesel exhaust, which would be emitted by the many large trucks that would transport poultry litter to the

incinerators, has been linked to respiratory symptoms, cardiovascular effects, and irritation of the eyes, nose, and throat in epidemiologic and laboratory-based studies [24, 25].

Dioxins, produced by combustion of organic materials and chlorinated antibiotics in poultry feed and waste, can accumulate and persist in both the environment and the human body. Dioxins are classified as a likely carcinogen by the Environmental Protection Agency and have been shown to have health effects at low levels [26]. Developmental and behavioral problems have been observed in children born to mothers exposed to dioxins, and exposure to dioxins has been associated with cardiovascular disease and diabetes in adults [26, 27].

In a recent review paper, Florin et al. describe the greater potential for production of NO_x and SO_x from combustion of poultry litter due to the relatively high content of nitrogen and sulfur found in the litter itself [6]. These gases are produced during combustion and can combine with other substances in the air to form other compounds that can impact human health. For example, NO_x interacts with sunlight and volatile organic compounds also emitted by power plants to produce ozone, which has been linked to respiratory symptoms and asthma [28, 29]. Exposure to SO_2 has also been found to be associated with respiratory symptoms, as well as other health outcomes [30, 31]. A recent study of children living near a refinery in Canada found that increases in SO_2 exposure were associated with greater risk of asthma exacerbations [30], while research in the United Kingdom has found associations between ambient levels of SO_2 and infant mortality [31]. Additionally, both NO_x and SO_x can react to produce acid gases, which can irritate the eyes, nose, and throat as well as have detrimental effects on crops and local environments [13, 14].

As noted above, some of the emissions of concern can also result from conventional electricity-producing power plants. Therefore, it is of interest to compare the projected emissions from a plant that incinerates poultry litter to power-generating plants that use other forms of fuel. Because there is limited data on the emissions from the plant in Benson, Minnesota, the North Carolina Department of Environment and Natural Resources, Division of Air Quality, conducted an analysis using permitted emissions of plants using different forms of fuel (Table 1) [32]. The estimates for poultry-litter emissions were based on the air emissions permits for the plant in Benson, Minnesota, while the estimates for new coal and existing biomass were based on recently approved permits in North Carolina. The remaining data are from test emissions data for old coal and clean wood. This analysis was concerned only with emissions from the smokestack, and does not include the additional pollutants that may result from increased truck traffic and wastewater releases. As shown in the table, plants fueled by poultry litter are permitted to produce more carbon dioxide than other forms of fuel and more carbon monoxide than either new or existing coal plants. They are also permitted to produce more NO_x than new coal plants, and more SO_2 than plants that use new wood or existing biomass to create electricity. This analysis suggests that

Table 1. Hourly Emissions, Expressed in Pounds per Hour, from a 50-MW Boiler Using Different Types of Fuel

	Type of fuel				
Pollutant	New wood	New coal	Existing coal	Existing biomass	Poultry litter
Carbon monoxide	227.5	55.0	13.6	293.9	169.0
Particulate matter	16.3	5.5	31.4	13.1	14.0
Nitrogen oxides	130.0	31.2	185.6	150.2	113.0
Sulfur dioxide	16.3	57.9	828.8	6.5	49.5
Carbon dioxide	135,750	91,500	131,000	136,477	152,000

Source: B. M. Nicholson, "Comparison of emissions from controlled coal and biomass combustion," Committee Meeting, North Carolina Environmental Management Commission, Raleigh, NC July 9, 2008. (All values rounded to one decimal place for consistency.)

incineration of poultry litter produces more of several pollutants than some alternatives, assuming the plants perform according to expectations.

This analysis was based on permitted emissions, but information released from the Minnesota Pollution Agency in December 2009 indicates that the incinerator in Benson, Minnesota, has been exceeding permitted emissions of CO, nitrogen oxide (NO) and SO_2 since it became operational in mid-2007 [33]. As a result, the facility has been fined and has been mandated to install an additional SO_2 monitor, in order to facilitate compliance with the original air permits. It is unclear why the permitted emissions were exceeded and if any other modifications to the facility will be necessary to ensure regulatory compliance.

In addition to its potential to release more of the same pollutants emitted by other types of plants, poultry litter incineration may generate other pollutants of concern. For example, arsenic is often added to poultry feed to control intestinal parasites and promote growth [34]. Arsenic is released as a byproduct of poultry waste incineration. It is estimated that 70 percent of chickens in the United States are fed roxarsone, the most common arsenic-based additive in poultry feed [35]. For the incinerator in Minnesota, arsenic emissions were estimated to be up to 64 pounds per year [36]. At a March 2009 meeting of the Air Quality Committee of the North Carolina Emergency Management Commission, results were presented from a Department of Natural Resources Toxics Evaluation of a turkey/poultry litter combustion source [37]. The analysis used data from the Benson, Minnesota, plant as well as other sources to model the arsenic emissions of a 50-MW plant and compared the modeled emissions to the current regulations for acceptable ambient levels in North Carolina. The modeling study concluded

that emissions from the plant would cause ambient arsenic levels to exceed the current regulatory limit by a factor of three. This analysis highlights the potential for arsenic contamination of nearby communities. Additionally, because arsenic levels are often measured only at the property line itself, it is possible that regulatory requirements could be met by changing facility specifications, such as the stack height, to cause the arsenic to be dispersed farther from the plant, impacting a wider area of the surrounding community [37].

Community exposure to arsenic could occur via multiple pathways. Dermal and/or inhalation exposures can result from contact with particles dispersed in the air via the smokestack, while ingestion through contaminated drinking water and contaminated crops could occur via deposition and wastewater discharges from the facility [38]. Exposure to arsenic, a known human carcinogen, is a major health concern. In addition to being associated with multiple types of cancer [39], arsenic exposure, even at low ambient levels, has been found to be associated with cardiovascular disease, diabetes, endocrine disruption, and decreased immunity [40-42].

Arsenic contamination of soil and groundwater can also occur through land application of poultry litter, the disposal technique most often used at present [4]. However, the burning of the litter allows for a greater possibility of inhalation exposures, in addition to exposure via contaminated groundwater and soil. Further, because an incineration facility requires a large amount of fuel to operate efficiently, poultry litter must be transported to it from a large area. Waste that would have been applied to land regionally is instead concentrated at the site of the incinerator. Evaluation of human exposures and health impacts from such redistribution of waste should take account of current and future water sources in areas where waste is applied to land, as well as the dispersion of arsenic from incineration. While some communities may benefit by having reduced arsenic exposures through curtailment of land application, others may experience greater exposure, and through different, potentially more harmful routes of exposure. If land application of poultry waste as a fertilizer is reduced and the land remains under cultivation, the potential environmental and health impacts of fertilizers used to replace poultry waste, such as chemical fertilizers, other animal wastes, and treated sludge from wastewater treatment plants, should be considered. In addition, the fly ash produced during the incineration process is often marketed as a fertilizer due to its high concentration of phosphorus [43]. Because some arsenic remains in the ash, the potential contamination of the soil and water in communities where the ash-fertilizer is applied must also be considered.

OCCUPATIONAL HEALTH

In addition to the impact on local communities, there are a number of occupational exposures that arise from poultry litter incinerators. A recent study by Wultsch et al. examined both the type and amount of bioaerosols created in an operational poultry litter incineration plant [44]. Researchers sampled at multiple

locations within the plant and found that concentrations of both bacteria and fungi were greatest where the poultry litter was unloaded from arriving trucks, an area with potential for high worker exposure. Concentrations of mesophilic fungi and thermophilic actinomycetes were found to be comparable to concentrations measured in other types of waste treatment plants. However, the concentration of gram-negative bacteria was found to be much higher in the poultry litter incineration plant, when compared to previous reports from facilities dealing with composting and/or waste treatment. As a result, concentrations of endotoxins are also greater than previously observed in occupational settings. Research has found associations between both acute and chronic endotoxin exposure and respiratory disease in workers [45].

There is also the potential for infectious disease similar to the risk experienced among workers in other areas of the poultry industry, as Wultsch et al. were able to isolate *Escherichia coli* and other microorganisms at sampling locations within the poultry litter incineration plant [44, 46]. Research by Graham et al. found that, unlike composting, short-term storage of poultry litter does not cause temperatures to reach a level where bacteria such as enterococci are reduced, particularly near the surface of the piles where workers would have the greatest contact [47]. Because anti-microbials are used in poultry feed, the infectious agents found in poultry litter may be more likely to be resistant to antibiotics [48]. The risk of development of antibiotic-resistant strains may be heightened at a poultry litter incinerator due to the combination of multiple litter sources in one area. In addition, antibiotic-resistant strains of bacteria have been found to be present in flies surrounding confined poultry-feeding operations, suggesting a route of exposure that may extend beyond the workers to the surrounding communities [49].

ENVIRONMENTAL JUSTICE

By centralizing the disposal of poultry litter through incineration, the health and environmental impacts of that disposal would be transferred from wider areas of poultry production to communities and workers in the area around the waste-to-energy facility. Using 2008 population estimates from U.S. Census Bureau, we compare the demographic attributes of the state of North Carolina to the attributes of the three counties where poultry litter incinerators are proposed (Table 2) [50]. All three counties have low population density, suggesting that they are more rural than the state on average. All three counties have age distributions similar to the statewide age distribution, although Surry County had a slightly greater percentage of older residents. Montgomery and Sampson Counties have lower percentages of white, non-Latino residents than the state as a whole, although Surry County has higher percentages of these population subgroups. However, all three counties are well below the state average for educational attainment and above the state average for percentage of residents

Table 2. Demographic Profiles and Selected Hospitalization Data for North Carolina and Counties Proposed as Sites for Poultry Litter Incinerators

	North Carolina	Montgomery County	Sampson County	Surry County
Population	9,061,032	27,451	63,641	72,380
People per square mile (2000)	165.2	54.5	63.7	132.6
Percent white, non-Latino	67.2	61.7	53.1	85.2
Percent black, non-Latino	21.6	19.8	28.2	4.1
Percent younger than 18 years of age	24.3	25.0	25.5	23.3
Percent 65 years or older	12.4	13.9	13.2	16.5
Percent aged 25 years or older with 4-year college degree	22.5	10.0	11.1	12.0
Percent living below poverty line	14.3	16.9	20.6	17.5
Asthma hospitalization rate (per 100,000 people)	115	65	125	103
Diabetes hospitalization rate (per 100,000 people)	180	220	190	190
Cardiovascular disease hospitalization rate (per 100,000 people)	1740	2220	2370	2580

Source: U.S. Census Bureau, "State and County Quick Facts: North Carolina Population Estimates by County," http://quickfacts.census.gov/qfd/states/37000.html (accessed May 26, 2010) and North Carolina State Center for Health Statistics, *North Carolina 2010 County Health Data Book*, http://www.schs.state.nc.us/SCHS/data/databook/ (accessed May 26, 2010).

living in poverty. A more detailed analysis of the plant location in Sampson County found that 50 percent of residents in the immediate area surrounding the facility were Medicaid-eligible [51].

Table 2 also includes 2008 hospitalization data, compiled from the Hospital Inpatient Discharge Dataset from the North Carolina State Center for Health Statistics, for conditions that would make a population especially vulnerable to the emissions of a large-scale incinerator [52]. All three counties have greater hospitalization rates for diabetes and cardiovascular disease than the state average, and Sampson County has a greater asthma hospitalization rate as well. Impacts of pollutants from the proposed incinerators could be increased by the underlying vulnerabilities of the affected populations.

Residents of these communities already experience a disproportionate burden of industrial animal operations located in their neighborhoods, and this burden is not limited to poultry operations. For example, Sampson County has the second-highest density of hogs in the state of North Carolina, following only its immediate neighbor, Duplin County [51]. Previous research in North Carolina has found associations between living in proximity to industrial animal operations and wheezing in children, stress, negative mood, limiting of social activities, and other health-related outcomes [53-55], and a national study found associations between increases in livestock production and infant mortality [56]. These findings suggest that the rural communities expected to host poultry-waste-to-energy incinerators are already experiencing a disproportionate burden of the negative effects related to the industrial animal operations which produce that litter.

DISCUSSION

Poultry litter incinerators are proposed for North Carolina communities that also experience exposures stemming from the industrial animal operations themselves, as well as from other industrial facilities in these communities. Cumulative impacts from multiple facilities and multiple pollutants are not generally considered in decisions about how much a facility is permitted to emit. Although it is unclear how the multiple sources of emissions will interact, they represent a potential threat to environmental health in communities that are already vulnerable. Previous research suggests that diesel exposure can lead to greater reaction to ozone exposure among previously healthy adults [57]. As the facility in Benson, Minnesota, continues to operate, there is a need for increased monitoring and health-effects research to determine how emissions from these facilities individually and jointly impact the health and quality of life of community residents.

The simultaneous construction and operation of three large incinerators within North Carolina, with capacities ranging from 40 MW to 55 MW, would demand very large inputs of poultry litter. Based on utilization at the Benson,

Minnesota, facility, it is estimated that the plants would require between 1 and 1.5 million tons of poultry litter annually in addition to other fuels. As of 2004, it was estimated that the state could only support three 35-MW incinerators due to competition with farmers for purchase of poultry litter [58]. The additional fuel could come from out-of-state poultry operations, other agricultural waste, or increased poultry production in North Carolina.

Incineration of poultry litter has been framed as the solution to the issue of excess waste stemming from industrial poultry operations. However, the construction of these incinerators would do nothing to reduce the amount of waste produced and, as discussed in this paper, would present its own set of environmental and health-related concerns, which could be worse than those presented by land application. The existence of three large-scale incinerators that demand large amounts of poultry litter to efficiently supply electricity could spur growth of industrial poultry operations as there would be demand not only for the poultry but also for the waste. In this case, conversion to more sustainable farms that do not use arsenic, hormones, or subtherapeutic administration of antibiotics, and that can recycle all their waste, would become more difficult. Large-scale capital investment in waste-to-energy incinerators that require poultry litter would further entrench industrial poultry operations within the Southeast. There are other problems related to industrial animal operations, besides disposal of waste, which incineration would not address, including negative impacts on health and quality of life of community residents, emergence of antibiotic-resistant bacteria related to use of feed containing anti-microbials [55], and potential for amplification of novel influenza strains [59]. In addition, most industrial poultry operations are operated under contract to large corporations that funnel profits from production out of poor, rural communities to faraway corporate headquarters and shareholders, reducing the potential for healthier local economic development.

Some of the side effects of generating electricity from poultry waste are shared by other provisions of Session Law 2007-397, the renewable energy bill. The bill promotes capture of methane from swine waste lagoons to produce electricity, a practice that would reduce emissions of a potent greenhouse gas. However, swine production in North Carolina is densely concentrated in the eastern coastal plain, an area with high water tables that is subjected to periodic flooding [60]. Investments in the lagoon and sprayfield technology will help prolong use of facilities that pollute ground and surface water and release air pollutants that are associated with asthma, other respiratory diseases, stress, and reduced quality of life. Even more than the poultry-waste-to-energy plan, methane capture promotes industrial animal production in low-income communities of color. Without consideration of impacts on host communities, renewable energy programs have the capacity to magnify and perpetuate environmental injustices.

CONCLUSION

There are many unresolved issues and potential negative environmental health impacts of incinerating poultry litter for the purpose of energy generation. Preliminary analyses suggest that emissions from this type of power plant can be greater than from plants using some other forms of fuel, and many of the emissions have well established associations with a variety of diseases and functional impairments. North Carolina's experiment with animal-waste-to-energy may be relevant to other regions where construction of incinerators that burn poultry litter and/or other biofuels have been proposed. Large-scale capital investments in technologies that depend upon animal wastes further entrench industrial animal operations in impacted communities without resolving many of the negative environmental and health effects associated with this form of animal production. Policy debates over energy policy may create conflicts between urban environmental groups that promote biofuels and poor rural communities that host animal production facilities. As new technologies develop and are advocated by commercial interests, the processes and emissions related to alternative energies require detailed scrutiny to prevent sacrificing the health and environment of low-income rural communities for the promise of renewable energy that would be used primarily by wealthier urban areas.

Postscript

On May 17, 2010, Surry County's Board of Commissioners unanimously voted to end negotiations with the company proposing the construction of the poultry litter incinerator. The commissioners cited the widespread community opposition to the incinerator as a factor in their decision. In June 2010, discussions to build a poultry litter incinerator in Hart County, GA, became public. However, on August 5, 2010, the Hart County government announced that plans for poultry litter incinerators in the state of Georgia were no longer being pursued due to an inability by the company to negotiate purchase agreements with the state power companies. Local officials speculated that community opposition to the plant also played a role in the company's withdrawal. As this article goes to press, the plans to construct poultry litter incinerators in Montgomery and Sampson Counties in North Carolina remained in place.

NOTES

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