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The Mitigation of Pollution Induced by Concentrated Animal Feeding Operations (CAFOs)

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ABSTRACT

Through hazardous agricultural practices and waste mismanagement, America's Concentrated Animal Feeding Operations (CAFOs) emit a significant amount of water and air pollution that causes a myriad of environmental and human health problems. This is an issue that can be largely mitigated through the implementation of technical, legislative, and holistic solutions. The following technical solutions will be discussed: editing pollutant diets, deploying air cleansing within CAFO structures, sprinkling vegetable oil on CAFO grounds, converting methane to energy, binding waste lagoons with geosynthetic clay liners, and installing riparian buffers. Furthermore, legislative solutions entail revising and enforcing existing regulations, imposing reflexive law, mandating nutrient management plans, offering federal credits, and revisiting the Farm System Reform Act. Finally, holistic alternatives regard hog hoop barns, free-range grazing, and changing consumer preferences.
This paper will examine the issue of CAFOs and the specifics of the pollution they emit and will primarily focus on practical solutions to it. The methods used to contextualize the problem and discover possible solutions will be content and meta analysis research. Ultimately, the final take away was that combining technical and legal solutions–forcing physical change through legislative mandates–will cause the most significant reduction of CAFO pollution.

Introduction

Background of CAFOs

Concentrated Animal Feeding Operations (CAFOs) are industrial sized, intensive livestock operations that mass slaughter animals such as cows, hogs, and chickens for meat and dairy products (Sierra Club, 2022). There are currently 450,000 animal feeding operations in the US, producing about 90% of America's meat and eggs (CDC, 2022). Eighteen thousand of these are CAFOs. CAFOs are so expansive that the largest farms house millions of animals, who are typically confined in boxes or stalls within massive, windowless structures. In addition, these animals produce mass amounts of waste. Even the smallest CAFO in America contains enough waste to equal the amount of urine and feces produced by 16,000 humans (Sierra Club, 2022).

This bacteria infested, pollutant waste manure is typically untreated and released into the environment by ineffective and environmentally destructive forms of waste disposal (DiPalma, 2021). For instance, the waste is sprayed onto land in fertilization attempts or dumped into lagoons, emitting greenhouse gas emissions and polluting ground water sources (Wendee, 2013). As award winning science writer Nicole Wendee articulates, CAFO waste not only contains pathogens, heavy metals, and antibiotic-resistant bacteria, but can reach nearby homes and drinking water sources. Waste emissions can cause mucosal irritation and respiratory ailments (Wendee, 2013).

Unfortunately, these detrimental environmental and health effects most affect impoverished minority groups. This is because in major CAFO states like Wisconsin and North Carolina, CAFOs are concentrated in

impoverished, underprivileged Black and Hispanic communities (Duke, 2016). In fact, CAFOs are seven times more common in high-poverty areas and are roughly five times more likely to be found in majority-nonwhite communities (Wing, et. al.). They are located in these areas because lower income communities of color have less resources and political influence to prevent CAFOs from moving into their area (MCE, 2020).

Holistically, CAFOs mass produce bacteria infested manure that is destructive to both the environment and human health, polluting America's most marginalized communities. Thus, it becomes imperative to raise the question: *How can the existing practices of American CAFOs be reformed to mitigate pollution through technical and legislative solutions?*

History of CAFOs

Historically, the Industrial Revolution and Green Revolution led to the growth of mass food production and animal feeding operations in the mid twentieth century. CAFOs were originally pioneered by the 1950s poultry industry, then gained larger traction with swine and cattle (Montefiore et. al, 2022). Strong financial pressures caused the rapid industrialization of these operations, as it was recognized that larger farms meant "lower costs and higher returns, while coordination among firms at different processing stages can reduce financial risk" (Hribar, 2022). When it became evident that vertically integrated industrial farms were most cost efficient, CAFO numbers expanded significantly.

Moving forward, CAFOs were first recognized and regulated as point sources of pollutants by the EPA in the early 1970s. They were defined as animal feeding operations (AFOs) when over 1000 animal units were confined for over 45 days a year. Additionally, farms that released manure or wastewater into waterways were deemed AFOs by the Environmental Protection Agency (USDA). In 1976, CAFO regulations began to establish the Clean Water Act and its NPDES permit system to determine which operations could be deemed as CAFOs.

The Role of Politics and Lobbying

Furthermore, agricultural pro-CAFO lobbying groups have pushed back on small towns and environmental activists that have tried to regulate CAFOs and their pollutant emissions, preventing CAFO restrictive legislation from becoming fruitful. In 2021, the Center for Food Safety filed a petition to the EPA that advocated for the use of the Clean Air Act to control CAFO methane emissions–a move that was lobbied against by the National Cattlemen's Beef Association and thus never went into full effect (Heavican, 2021). In Wisconsin, the Wisconsin Dairy Alliance lobbied on behalf of the nation's largest CAFOs, claiming that CAFOs are unfairly blamed for pollution. Wisconsin lobbiers had sent threatening letters to the county, causing activists to back down on their CAFO moratoriums, deeming such action as an unlawful felony. Multiple senate bills, such as Senate Bill 133, 391, and 951, have been directed towards putting more control in favor of CAFO friendly law enforcement and politicians, taking that control away from rural advocates. Senate Bill 951 in particular "lists the state and federal agencies which can inspect the grounds or facilities in Missouri used to produce eggs, milk or other dairy products, livestock, or facilities where dogs or other animals are raised - and the only county official in the list is the sheriff" (Haldiman, 2020). It becomes clear that regulating CAFO emissions and urging them to change their pollutant ways has been largely restricted by local politics, the circumventing of legislation, and ultimately, influential lobbyists.

Technical Solutions

Air Pollution

Although fully combating the challenges presented by CAFOs must be achieved through legislation–inciting systematic change–improvements begin with basic technical solutions. Moreover, the primarily physical changes start with air pollution mitigation methods.

CAFOs contribute to air pollution primarily through livestock manure and digestive processes. The decomposition and land application of animal manure within CAFOS is the main source of air pollution, releasing methane, ammonia, hydrogen sulfide, methane, and particulate matter (Hribar, 2022). As manure is compiled and begins to ferment, these gasses are released and spread as the manure is applied to land as fertilizer. Due to the pollutant contaminated air, CAFO workers and local residents are more susceptible to lung disease and health issues like chemical burns on respiratory tracts, lung inflammation, and chronic bronchitis (Hribar, 2022). Researchers in North Carolina found that the closer children live to a CAFO, the greater the risk of asthma symptoms–which can be attributed to the dust and particulate matter that CAFOs emit (Pfikunk, 2019).

CAFO livestock also emit methane through their digestive processes. As the grass, vegetation, and feed they consume ferments in their rumen, they produce methane–a pollutant greenhouse gas– which they release through belching. Cattle are the largest agricultural contributor to greenhouse gasses (Quinton, 2019). Thus, the question remains: *How can CAFO air pollution be reduced?*

Editing Pollutant Diets

To limit air pollution and methane emissions of CAFOs, CAFOs should first utilize diet manipulation to lessen manure induced greenhouse gas emissions. As confirmed by Austen Depalma, Action for Climate Emergency Director, CAFOs produce air pollutant greenhouse gas emissions that contribute to climate change and global warming through the livestock's degrading manure and digestive processes (Depalma, 2021). Primarily, cattle in feedlots are currently fed a diet meant for rapid weight gain with a high methane producing capacity via manure. This diet is highly unnatural and is made up of high protein feed like corn and soybeans. These protein rich soy products and grains make their waste emit more pollutants like nitrogen and methane (Malomo, 2018).

However, environmental health expert authors Malomo et. al explain that animals fed low protein diets produced less manure with lower nitrogen intensity, compared to those on higher protein diets (2018). Amino acid supplementation, enzyme supplementation, and various alum related manure treatments resulted in less nitrogen excretion in chickens as well (Malomo, 2018). Additionally, a more natural, low-energy diet composed of more grass and vegetation results in manure with about half of the potential to generate methane (EPA, 2020). Plant-based bolus is another helpful addition, working to reduce excessive fermentation and "regulate the metabolic activity of rumen bacteria to reduce methane emissions from both the animals and their manure" (Koneswaran et. al, 2008).

Finally, increasing fiber in the cattle's diets and implementing 1% seaweed in their food can reduce methane by up to 60%, as concentrated fiber and plant based content improves digestion, leading to less gas (Nelson, 2021). In fact, it's quantified that doses of about 3 ounces of seaweed in cattle's diets reduces methane by up to 82% (Nelson, 2021). By switching CAFO animals to more plant based fibrous diets and increasing seaweed content, amino acids, and enzymes in their meals, it becomes clear that diet manipulation can reduce the greenhouse gasses found in animal manure, thus lessening air pollution. However, since high protein diets speed up animal growth and cause them to be bulky and have more body mass, this switch may be less desirable for CAFOs–but it is a necessary one for the significant lessening of nitrogen and pollutant contents in manure.

Air Cleansing Methods

Another method CAFOs can use to reduce air pollution is capturing and treating polluted air as it leaves the building through the use of biofilters, which ventilate the air. In addition, they can wet or dry scrub the air as it passes through evaporative pads before release (CRS, 2022). CAFOs should also be regularly cleaned and maintained of dust and pollutants, and exhaust fans should be used to disperse pollutants. Windows in CAFOs should be structured and opened regularly to make the air clean and breathable for human workers and animals. Ensuring that CAFO facilities are well ventilated and set with biofilters, windows, and fans is a major solution to the odorous air pollution that livestock production emits.

Vegetable Oil Sprinkling in Swine Buildings: Research has shown that sprinkling vegetable oil, especially soybean oil, on the floor and other pen surfaces in swine barns can significantly reduce airborne particulate matter concentrations. The soybean oil may be dispersed manually or through automated technology. Moreover, vegetable oil sprinkling is effective when it is spread on the floor of CAFO facilities at the right temperature, thus preventing rising clouds and settling particles from moving and floating around, polluting the atmosphere.

As the NCBI quantifies, “a five percent oil-water emulsion automatically applied at the rate of three and five g/pig/day achieved a 23% to 34% reduction in total dust” (Nonnenmann, 2004). Additionally, in a northern Missouri study, the daily dispersal of soybean oil in a swine finishing barn exponentially decreased dust and particulate matter less than 10 microns in diameter (PM10), and “at an overall operational cost of about $1 per pig space (about $0.40 per finishing pig) for the basic oil sprinkling system” (Schmidt, 2018). Clearly, vegetable oil sprinkling is a valid, cost effective method for curbing CAFO air pollution, especially dust and particulate emissions.

Methane to Energy: A well researched, and thoroughly controversial "solution" is the use of anaerobic methane digesters. There are now a total of 185 digesters servicing 194 dairies across all of California, which includes those that are functioning and in construction (Dairy Cares, 2021). They operate by first storing the manure from CAFO waste lagoons and capturing its methane emissions–either burning it for renewable energy or injecting it into natural gas pipelines. This is in effort to use it for electricity or vehicle fuel (UC Davis, 2020). The USDA and EPA have historically attempted to encourage the subsidized use of these digesters on CAFOs, aimed at reducing greenhouse gas emissions. The initiatives claim that captured methane from digestion could be used as alternative biofuel sources. Current President Joe Biden has even encouraged their use. Unfortunately, this method has been rebuked, criticized, and often dismissed by environmental agencies as ineffective at making any real impact in reducing the polluting nature of CAFOs. The reduction in greenhouse gasses is negligible; and in fact, the valorization of methane can create a slew of new environmental issues. For these reasons, methane digestion and capture was discussed but is not recommended as a technical solution or source of potential legislative control for CAFO air and water pollution control.

Water Pollution

The contaminants that CAFOs emit extend beyond just air, to water pollution. The waste from CAFOs dirties large bodies of water and pollutes ground and drinking water sources.

One primary way that CAFOs treat manure is by dumping the waste into massive lagoons or pits where the manure breaks down anaerobically, increasing methane production. In these areas, the wastewater naturally seeps into groundwater due to faulty lagoon liners and storm inflicted overflows, thus causing water pollution (Sierra Club, 2022). As confirmed by a CDC research study, surface discharges of water pollutants can be caused by heavy storms or floods that cause storage lagoons to overfill, running off into nearby bodies of water (2010). Additionally, environmental journalist Adam Skolnick highlights how waste from lagoons can also be sprayed onto nearby fields of undeveloped land, but how such fertilization processes end up saturating the soil with toxic particles that leak into nearby aquifers and streams (Skolnick, 2017). Regardless of whether it’s a waste overflow, seepage, or faulty sprayage, CAFO lagoons are a major problematic factor in contributing to water pollution.

CAFOs also treat manure by applying it as fertilizer to fields. As CAFO waste applied in farm fields begins to seep into groundwater and runoff due to overflow or rain, nearby bodies of water are polluted and left with the fecal coliforms, pathogens, and excessive amount of nutrients like nitrogen and phosphorous that the waste contains (Sierra Club, 2022). Algal blooms from a nutrient overload occur, decreasing the dissolved oxygen in the water and killing off wildlife. The field application of manure as fertilizer can also be detrimental,

as the manure often contains too many nutrients for the farmland to handle. Overall, CAFOs are a leading contributor of pollutants to lakes, rivers, and receivers, as areas where CAFOs are highly concentrated suffer from roughly thirty serious water quality issues annually (Hribar, 2010). Therefore, it becomes imperative to ask: *How can CAFO water pollution be addressed?*

Installing Geosynthetic Clay Liners Around Lagoons

Pollutant CAFO lagoons are an issue that can be fixed by instituting thick geosynthetic clay liners around the lagoons, so that waste doesn't seep into ground and water sources. In their geosynthetic clay liner study regarding animal waste, academic journalists Brown and Shackelford found that geotextile woven bentonite clay liners should be paired with a sacrificial layer of topsoil to prevent waste leakage (2022). The clay liner would essentially be structured with "a layer of bentonite sandwiched between woven and non-woven geotextiles" with a thickness of at least 10 mm to prove effective (Brown, 2022). However, dairy science and agricultural expert Karen Lee counters the efficacy of these liners, claiming they are prone to ripping and tearing, and are weak and erodible (Lee, 2015). This concern is actually solved with the material in which these clay liners are built: these clay liners, placed on the sides of the lagoons, would include geotextiles that contain the bentonite and frictionally resist sliding along the geotextiles, thus preventing ripping and tearing (Brown, 2022). The topsoil would additionally prevent overflow by having the manure be soaked into the soil. Overall, geotextile woven bentonite liners are a viable solution because these clay liners successfully prevent the water pollution from lagoon manure leakage, and are easy to install and cost efficient as well.

Riparian Buffers

Although the solution of strong, geosynthetic clay liners would greatly prevent manure leakage from lagoons, riparian buffers would holistically stop additional manure from entering water sources for both lagoon and farm field pollution. Riparian buffers are streamside vegetation consisting of trees, shrubs, and grasses that intercept pollutants like sediment and pesticides from an adjacent farm field (EPA, 2010). They decrease eroded soil sediment and nonpoint source pollutants like pesticides, herbicides, and surplus nutrients; in fact, a properly installed buffer can "effectively trap 90 percent of sediment and nitrate moving from a farm field" (EPA, 2010). Riparian buffers also prevent soil erosion and cut off the flow of parasites and fecal bacteria to water sources (PSU, 2021). Overall, it becomes clear that planting trees and shrubs around pollutant operations such as CAFOs would intercept harmful pollutants, thus greatly decreasing water pollution.

Existing CAFO Regulations

Currently, the U.S. EPA's sole method of regulating CAFOs is the Clean Water Act (CWA), first established in 1976. The CWA essentially defines farms containing more than 1000 animal units as CAFO point sources of pollution and thus subjects them to National Pollution Discharge Elimination System (NPDES) permit regulations (EPA, 2014). NPDES permits regulate pollutant discharge into waters of the U.S. and dictate how and where waste should be treated. However, a major historical loophole within the CWA is that these operations are not defined as CAFOs if they discharge only during a 25-year, 24 hour storm, or "a precipitation event of 24-hour duration with a four percent probability of occurring in any given year" (EPA, 2014 and Law Insider). Therefore, only about 2500 of the 12,000 qualifying CAFOs in the U.S. are subject to NPDES regulations, since the majority of CAFOs utilize this loophole (EPA, 2022). Additionally, the CWA fails to address the pollutant, nonpoint agricultural runoff and leakage from large CAFO waste lagoons and manure application, as it only focuses on point source pollution. As a result of the Clean Water Act's loopholes and lack of clear regulatory enforcement, CAFOs remain largely pollutant. In fact, "half of the country's rivers, streams, lakes, and ponds are classified as "impaired," and farm pollution is the primary cause" (Held, 2022).

Next, CAFOs do not face regulations and emission reporting requirements from the Clean Air Act. This is because in the late 1990's, the EPA recognized there wasn't enough data to conclude which CAFOs had to report emissions or obtain Clean Air Act permits–after farm groups came under legal fire due to this lack of data, they struck a deal with the EPA that ensured legal immunity for data (Wertz, 2020). Under this 2005 deal, farmers "paid small fines to fund a new study of air emissions at dairy, egg, hog and poultry operations" and in exchange, "got immunity from enforcement actions over past violations of federal air pollution laws," all while negotiating a ban on EPA lawsuits (Wertz, 2020). Currently, emission models are incomplete and farms are protected legally by the EPA, remaining insulated from any air pollutant regulations.

Finally, CAFOs are also exempt from EPCRA and CERCLA reporting requirements. Both acts require reports of air emissions from animal waste, and CERCLA can even work to clean waste from manure dumping operations under their superfund program. However, CAFOs are not covered in either acts and have escaped regulations for the past decades (EPA, 2022).

Recommended Legislative Solutions

Revising and Enforcing Existing Legislation

After completing extensive legislative research, it is evident that to control and cease water pollution, an organized county specific permit system must be enacted in order for new CAFOs to begin operations. Permits must determine whether a potential CAFO can operate or not, and should only be given to farms that have clear and convincing evidence that their operation will abide by the health and safety of neighboring communities. A prime example of this is in Bayfield County, Wisconsin, in which CAFOs can only obtain a permit if they protect the environment, prevent pollution, preserve quality of life, and protect local livestock agricultural operations (Kottwitz, 2022). Additionally, the Bayfield County also "requires CAFO operators to post a bond to ensure that if they shut down, there are funds to repair damages to the land, and protect the surrounding community," and outlines steps for waste disposal in regards to pollution (Kottwitz, 2022). Another example of an environmentally protective, organized permit system is in Gooding County, Idaho in which a permit application requires "a detailed site plan, description of the waste management system, and a strategy to mitigate odor, dust, and pests" (Kottwitz, 2022). Existing CAFOs should be made subject to mandated permit regulations as well, and fix their practices to abide by them. Technical solutions can be applied to ensure CAFOs reduce pollutant emissions.

Measuring and controlling toxic air emissions is crucial to protect the health of those living around CAFOs. The EPA must additionally enforce the Clean Air Act by establishing county specific ambient air quality standards for each CAFO and requiring emission reports that monitor and collect data on air pollution in CAFO areas. Specifically, levels of ammonia, nitrous oxides, sulfur dioxide, volatile compounds, and particulate matter should be observed and mitigated, as these air pollutants are linked to 17,900 US agricultural-linked deaths a year, causing health issues like pneumonia and respiratory disease (Regan, 2022). Twelve thousand-four hundred of those deaths are linked to ammonia, which is a major CAFO pollutant (Regan, 2022). CAFOs should be made subject to EPCRA and CERCLA reporting requirements to ensure transparency regarding air pollution emissions, and CERCLA's superfund can thus be applied to properly dispose of CAFO waste. Adequate emission models must be completed, and technical solutions must be administered to actually cease air pollution.

Reflexive Law

Furthermore, one way to powerfully address CAFO pollution through legislation is the implementation of reflexive law. As the NYU law review states: "reflexive law policies mandate the public disclosure of information, whether in the form of raw data, hazard warnings, or environmental labels," which can influentially shame

polluters and allow consumers, shareholders, and business partners to "exercise their displeasure with polluting industries and their support for more environmentally responsible companies" (Braunig, 2005). Additionally, reflexive law is fast and cheap to implement, and it is a less politically radical approach than other CAFO restrictive laws. Reflexive law enforces legal self-restraint causing polluting CAFO corporations to adopt new methods and correct their environmentally hazardous ways (Teubner, 2006). Overall, reflexive law is a dynamic solution, effective in sparking change and ensuring transparency within CAFOs.

Implementing Nutrient Management Plans

One way to regulate and check on CAFO water pollution is the installation of nutrient management plans (NMPs). These plans eliminate these faulty waste disposal methods by setting and enforcing rates of CAFO nutrient standards to maintain environmental cleanliness within CAFOs.

Authors Bradford et al. in their esteemed NCBI research article explain that an NMP is a design document that "sets rates for waste application to meet the water and nutrient requirements of the selected crops and soil types," regulating water quality and ensuring that CAFOs don't pollute water to an unhealthy extent (NCBI, 2008). Clearly, nutrient management plans are important for regulating CAFO water pollution, especially when manure is haphazardly sprayed as fertilizer and leaks into water sources. A California Waterboards report details the specifics of an NMP, stating that an NMP would entail the identification of "protocols for testing manure, litter, and process wastewater for nitrogen and phosphorus annually" and force CAFOs to undergo the evaluation of soil quality at least every five years. This would keep CAFO environments constantly checked for pollutants and ensure that CAFO wastewater and fertilizer is fully treated before release (Waterboards, 2014).

Nutrient management plans solve the issue of pollutant CAFO manure-to-fertilizer application. Although the nutrient rich manure produced in CAFOs can be used to fertilize cropland, there are many environmental problems that result from the application of it. Nutrients applied above what the crops require for growth can "accumulate in the soil (especially P), denitrify (in the case of N), or wash off fields and then contaminate surface water" (Long et. al, 2018). This mainly occurs because there may not be enough cropland that actually needs the manure as fertilizer, which is why a nutrient overload may ensue.

It's evident that CAFO manure is extremely valuable for soil fertilization as it contains essential nitrogen and phosphorus–it simply needs to be applied correctly. In order to correctly use fertilizer from CAFOs, more land in need of fertilization would have to be available and edged by riparian buffers, which NMP's would ensure. Notably, NMP's would require CAFOs to assess and apply manure at the appropriate rate as well as properly use or dispose of excess nutrients.

In the status quo, there is rarely any CAFO evaluation on soil and water qualities, especially in regards to the wastewater they release into the environment. The implementation of an NMP would enforce such action. Nutrient Management Plans are evidently the most effective way to keep CAFO nutrient and water quality in check, and should be implemented and enforced in each individual county CAFO by the EPA.

Government Credits: The US government can financially incentivize CAFO corporations to decrease pollution. Subsidies such as favorable tax treatment, low-interest loans, and grants can be given to CAFO polluters in exchange for them lowering emission rates. They can also take another angle by making it expensive to pollute–using charges, fees, and increased taxes, or a per unit monetary charge on waste and emissions (EPA, 2021). Pollution taxes, water user fees, wastewater discharge fees, and solid waste disposal fees are more specific examples (EPA, 2021).

Additionally, with emission reduction credits, polluters can't exceed a specified rate of emissions and can even earn monetary credits for reducing pollution below the rate (EPA, 2021). Thus, CAFOs are legally pressured and economically incentivized to keep their pollution at low rates.

Capped allowance systems are another financial incentive to mitigate pollution. These systems give a certain number of pollutant cap allowances to polluters who must then purchase more allowances from firms that have already emitted below cap rates (EPA, 2021). Therefore, the amount of large pollutant CAFOs are balanced out and decreased, as it is costly to continue purchasing allowances.

Overall, from incentives and credits, the government must certainly play a role in mitigating the pollution CAFOs produce through financial methods.

Farm System Reform Act: New Jersey Senator Cory Booker reintroduced the Farm System Reform Act in 2021 in an attempt to regulate and limit the influence of the largest CAFOs after the initial act gained little traction in 2019 and 2020. The act places a moratorium on new and expanding large CAFOs and phases out the largest CAFOs by 2040 (Booker, 2021). It holds "corporate integrators responsible for pollution and other harm caused by CAFOs, provides a voluntary buyout for farmers who want to transition out of operating a CAFO" and also restores accurate and transparent meat label requirements (Booker, 2021). Although just a proposal, legislation like the Farm System Reform Act has the potential to change communities for the greener by holding CAFOs to stricter environmental standards, limiting their expansion, and implementing transparency. It's clear that more must be done, but this act is a major step towards true and meaningful change.

Holistic CAFO Alternatives

Instead of expanding existing CAFOs or creating new ones, holistic CAFO alternatives reap significant environmental and economic benefits. One such alternative is hog hoop barns, which are naturally ventilated hog shelters that come at an incredibly low starter cost. These structures should be used for smaller-scale swine operations, as they accommodate natural animal behavior. Hog hoop barns stretch sun reflective tarps over a steel truss system, creating a tent-like structure that is flexible for use in all weather conditions (Leopold, 2022). These barns are not only healthier and provide more space for animals, but they produce comparable and earn higher profits than CAFOs per unit despite being smaller (Anderson, 2016). Because of the ventilation, "94 percent of hogs raised in hoop barns exhibited normal lung function, compared with 70 percent of the hogs reared in confinement" (Sare, 2003). With low tax and insurance rates, rapid and easy construction, and lower energy costs, it's clear that hog hoop barns are a viable alternative to swine CAFOs economically. They also output lower levels of manure gasses, thus decreasing air pollution (Osborne, 2020). Manure leakage and waste runoff is avoided with hog hoop barns, which contain the manure within the storage structure (Leopold, 2022). Clearly, since hog hoop barns emit significantly less water and air pollution than swine CAFOs and are also more economically profitable, they are a valid alternative to CAFOs.

The second major alternative to CAFOs is free range grazing. Free range grazing works to decrease carbon in the atmosphere due to the carbon sequestering that occurs when livestock graze on grass (Kiesel, 2009). One example of this is in Georgia's free range White Oak Pastures. The 3,200-acre farm "stored enough carbon in its grasses to offset not only all of the methane emissions from its grass-fed cattle, but also much of the farm's total emissions" (Matsumoto, 2019). Additionally, with the free range method and feedlot system, there are less greenhouse gas emissions as grass-fed cows gain weight more slowly therefore emit less methane; moreover, there is also a higher energy feed and less land footprint (Matsumoto, 2019). Free range grazing is commonly thought to contribute to ecosystem regeneration, and is a viable eco-friendly alternative to CAFOs. To take it a step further, meat producers should implement intensive rotational grazing methods, which would ease pressure on land by moving livestock to different portions of the pasture, thus maximizing forage regrowth (NRCS, 2022).

Finally, consumers can play a role in mitigating CAFO pollution through their dietary choices. Of course, they can buy pasture grazed and free range produce; but choosing meat alternatives and plant based products is another powerful step towards a greener future. Not only does plant based meat emit 30-90% less

greenhouse gas than conventional meat, but it also uses 72-99% less water and causes 51-91% less aquatic nutrient pollution (GFI, 2022). For example, brands like *Impossible and Beyond* meat–which produce soy-based burgers–sell products that use roughly 80-90% less water, land, and emissions than CAFO meat (Hayek, 2021).

Overall, there are various alternatives to environmentally hazardous CAFOs–from hog hoop barns and free range grazing to different dietary choices.

Conclusion

The hazardous pollution and environmentally destructive effects that result from CAFOs can certainly be reduced and resolved through the implementation of the previously discussed solutions. This may occur with the power of EPA mandates, the cooperation of CAFO directives in specific counties, and/or state governments. Primarily, these entities must work together to produce meaningful change.

Furthermore, from editing pollutant diets, deploying atmospheric cleansing techniques, sprinkling vegetable oil, and converting methane to energy, air pollution can be mitigated through technical solutions. Diet editing and vegetable oil sprinkling are the most practical solutions to efficiently reduce CAFO air pollution without political upheaval. Similarly, lining CAFOs with geosynthetic clay liners and implementing riparian buffers can decrease CAFO runoff and water pollution.

Finally, physical solutions must all coexist and be enforced with legislative change. Reflexive law, nutrient management plan guidelines, and revising the faults of existing legislation, as well as closing legal loopholes, can work to deploy technical solutions and further mitigate CAFO pollution. CAFOs cannot change their polluting ways unless they are guided and checked by a legal entity. Holistic alternatives like turning towards hog hoop barns, free-range grazing, and changing consumer preferences creates a more sustainable world that is not dependent on large, environmentally harmful animal feeding operations.

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