

Agriculture's Impact on Water Quality in Rural Communities

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Introduction

In a developed country such as the United States, it is often taken for granted that the water we have access to is both safe and clean. However, human activities have threatened the clean water supply putting health in jeopardy. In particular, agricultural activities are among the top contributors to the impairment of the nation's lakes, ponds, and reservoirs as well as being the single greatest contributor to the impairment of rivers and streams (U.S. EPA, 2009). The changing face of the American agricultural system has contributed to this problem. Traditional family farms of the past are being replaced with larger, more specialized operations. In terms of livestock production, this shift has been toward concentrated animal feeding operations (CAFO). The United States Environmental Protection Agency (EPA) has defined large CAFOs as operations having 1,000 animal units* or more, and as such are a point source for pollutants (US EPA 2008). Facilities of this size concentrate animals and animal waste in relatively small areas; this can pose a threat to local water sources if the waste and manure produced are inappropriately managed. Improper waste management introduces excess nutrients and microbial pathogens into the local water supply. Residents in rural communities near CAFOs face health risks from the presence of these contaminants in both their private well water supply and in recreational bodies of water like lakes and streams. This paper specifically examines the distal and proximal causes of water contamination by large CAFOs, with an emphasis on the impacts caused by large dairy CAFOs in Wisconsin. Consequences of CAFO pollution will also be identified and shown to add to the health disparities faced by the residents of these rural agricultural communities.

Theoretical Framework

This paper employs a theoretical framework to guide and identify the causes and consequences of water contamination in rural agricultural communities. The model set forth is

*1,000 animal units is equivalent to 700 mature dairy cattle, 1000 mature beef cattle, 2,500 mature hogs and 10,000 sheep.

adapted from a conceptual framework for urban health developed by Galea et al (2005). Their model asserts that urban health is determined by urban living conditions, municipal level factors, and major global and national trends. Their model establishes a comprehensive structure to identify the upstream and proximal causes of health issues; thus, it can be used to direct interventions and research to minimize the risk factors and improve community health. Although the Galea model focuses on determinants of urban health, it can be adapted to study rural health issues.

To develop an understanding of the causes and consequences of poor water quality in rural agricultural communities, this paper will follow the theoretical framework shown in Figure 1 from left to right. In this manner, the causes of rural water pollution will be examined from an upstream approach toward more proximate causes followed by an examination of the outcomes. The analysis of municipal level determinants will focus on changes in agriculture market trends and government regulations. Further downstream, assessment of rural living conditions will establish pollution in the physical environment as a determinant of health. Ultimately, this paper will identify the health and non-health outcomes caused by water pollution in rural agricultural communities.

Causes – The Rise of CAFOs and its Impacts on Rural Water Pollution

Before public health interventions can be established to remedy the health inequalities in rural communities near CAFOs, it is important to examine the elements fueling the disparities. This investigation will begin with an upstream assessment of municipal level determinants followed by a critical look at proximal causes in rural living conditions.

Municipal Level Determinants – Market Factors and Government Policies

Over the past century, the American agricultural system has changed significantly, causing far reaching outcomes including negative impacts on water quality. This change has been attributed to increased farm size, innovations in production technology, increased specialization, and improved organization between the phases of production (MacDonald and McBride, 2009). The small family farms of the past, responsible for producing several crops and livestock, are being increasingly replaced with large, consolidated operations, such as CAFOs. By specializing at one level of agricultural production, farmers are best able to maximize the resources and technology available. Due to this efficiency, productivity can be increased and the cost of production decreased. This economic factor has acted as huge driving force in the establishment of CAFOs in the United States agricultural system. The shift in Wisconsin's dairy industry reflects these national trends. According to the Wisconsin Department of Natural Resources, the number of dairy CAFOs has increased from 2 in 1990 to 179 in 2010 (2012). As the name suggests, CAFOs concentrate large numbers of animals into relatively small areas. These operations generate immense amounts of manure which are typically applied to fields as fertilizer; however, improper waste management can contaminate water sources. As such, the impacts of the increasing number and size of CAFOs have profound effects on the environment and communities in which they are found.

Government policies have attempted to combat the threat to water safety posed by CAFOs, but there is still much progress to be made. The United States EPA has identified improper manure management practices by CAFOs as a source of water pollution; thus, under the CAFO Rule in the Clean Water Act, CAFOs that discharge or propose to discharge pollutants must apply for National Pollutant Discharge Elimination System (NPDES) permits (U.S. EPA, 2008).

Additionally, the CAFO Rule requires CAFOs to submit Nutrient Management Plans (NMPs) when applying for NPDES permits. NMPs outline the terms and conditions under which operators will use fertilizer and manure to provide the correct concentrations of crop nutrients to area fields. NMPs are designed to protect the environment from adverse effects from over-application and oversaturation of manure and fertilizer. The proposed NMP is to be reviewed by permitting authorities and the public and then incorporated into the terms of the NPDES permits (U.S. EPA 2008). Despite these regulations attempting to protect the water quality in agricultural communities, much of America's water remains impaired and many rural residents are vulnerable to the negative outcomes caused by water contamination.

Poor compliance and enforcement of the terms established in NPDES permits are contributing factors to rural water contamination from CAFO generated pollutants. According to estimates made by the U.S. EPA Office of Enforcement and Compliance Assurance in 2008, only 47% of the CAFOs requiring NPDES permits had them (2009). Poor compliance is initiated by high costs and the laborious process of building and maintaining facilities capable of earning a NPDES permit. Some operators choose to risk paying a noncompliance penalty rather than obtaining a permit (Centner 2011). Additionally, operators of unpermitted CAFOs may underestimate their pollution potential and may mistakenly believe that their operation does not fall under the jurisdiction of the CAFO Rule (U.S. EPA, OECA, 2009). Enforcement is hindered by difficulties encountered identifying violators and often requires lawsuits from environmental groups to act as catalysts to the enforcement of the CAFO Rule. Summarily, regulations have been instituted to protect water quality from CAFO pollutants, but poor compliance and enforcement of these regulations have contributed to the impairment of rural water sources, putting health at risk.

Lack of private well regulation further exacerbates the negative health disparities in rural communities caused by poor water quality. According to the Wisconsin DNR, Wisconsin is home to over 900,000 private wells which serve over two thirds of the residents (2011). Although the EPA and Wisconsin DNR have established enforceable standards to ensure the quality and safety of municipal water sources, private wells are not subject to such regulation. Instead, the responsibility to maintain and test the well for contaminants falls primarily on the owner. Many residents do not take these measures, however, putting their health at risk. This behavior has been credited to owner complacency, perceived inconvenience, and the lack of a perceived threat to water safety and human health that residential well owners have developed (Imgrund, Kreutzwiser, and Loe 2011).

Rural Living Conditions – Pollution and the Physical Environment

The introduction of contaminants by CAFOs into the water system of rural agricultural communities is a determinant of health at the level of rural living conditions. Pathogens and excess nutrients may be introduced into water sources as a result of agriculture practices. These pollutants threaten the water quality and safety of communities being served by private wells.

CAFOs generate enormous amounts of manure on relatively small areas of land. When more manure is generated than farm operators are capable of safely managing, human health is put at risk. On large commercial farms, manure is typically held in huge tanks, called “lagoons;” lagoons are capable of storing millions of gallons manure. Typically, this waste is processed and then applied to fields as a nutrient rich fertilizer. However, there are several routes of water contamination in this scheme. Lagoon leakage and overflow can directly contaminate water sources. Additionally, improper application or over-application of liquid manure to fields can

initiate runoff or oversaturation of soil which contributes to the pollution groundwater and surface waters.

Improper manure management introduces excess nutrients and pathogens into the water supply, putting human health and safety at risk. Applying manure produced on CAFOs to fields as fertilizer serves the dual purpose of disposing of animal waste as well as improving nutrient quality. However, over-application of manure can contribute to excess nutrients, such as nitrate-nitrogen, contaminating surface runoff water and ground water (Hill, Owens, and Tchounwou, 2005).

High levels of nitrates in drinking water have been linked to the negative health outcomes of pregnant women and infants. Improper manure management can also introduce parasitic, bacterial, and viral pathogens into water supplies through runoff or percolation through the soil. Improperly treated and applied cattle manure can contaminate water sources with *Giardia lamblia*, *Escherichia coli*, *Campylobacter spp.*, and enteric viruses among others (Gerba and Smith 2005). Contamination of water sources by these pathogens, coupled with limited water testing of residential wells, places many members of rural agricultural communities at risk of negative health outcomes from poor water quality.

Outcomes of Impaired Water Quality in Rural Agricultural Communities

CAFOs contributions to water pollution are significant because of their potential to impact entire communities. Contamination of a groundwater aquifer affects every member of the community that relies upon water from private wells tapped into that aquifer. Rivers, streams, lakes and other surface waters contaminated by CAFO generated runoff, negatively affect members of the community trying to use these natural resources as well. The environmental impact made by CAFOs is felt by the surrounding rural communities and leads to negative

outcomes. As shown in Figure 1, the consequences of water pollution by CAFOs are classified based on their ability to impact community health as well as the capacity to impact non-health issues.

Health Outcomes

Maternal and child health are negatively affected by water contaminated with high levels of nitrate. Agricultural communities frequently have nitrate contaminated water due to crop fertilization and improper field application of manure. Contaminated water has long been known to negatively affect the health of infants. Infants who drink formula prepared with nitrate contaminated water are at risk for developing methemoglobinemia (Knobeloch et al 2000). Infants with this condition may appear blue-gray and, thus, methemoglobinemia is more commonly known as blue baby syndrome. Blue baby syndrome is characterized by high levels of methemoglobin, the oxidized form of hemoglobin, in an infant's blood. Methemoglobin is incapable of transporting oxygen; as such, it is a serious medical condition. If left untreated, blue baby syndrome can rapidly progress to coma and death (Knobeloch et al 2000). Consumption of nitrate contaminated water has also been associated with a number of maternal health issues. Nitrates have been implicated as contributing to pregnancy complications such as anemia and threatened abortion/premature labor (Tabacova, Balabaeva, and Little 1997). 14.1% of private wells in Wisconsin have nitrate levels greater than 10 $\mu\text{g/l}$, which is the level established by the federal government as unsafe for infants (Wisconsin DATCP 2002). In heavily farmed communities, the proportion of wells with unsafe nitrate levels can be much higher.

Besides adverse health effects caused by high concentrations of nitrates, rural community members are also at risk from water contaminated by microbial pathogens. An estimated 23% of private wells in Wisconsin tested positive for total coliforms, indicating the presence of bacterial

contamination (Wisconsin DNR 2010). Many of the pathogenic microorganisms originating from improperly handled animal manure can lead to gastrointestinal illness; however, water contamination by *E. Coli O157:H7* and *Campylobacter spp.* can cause illnesses as serious as Hemolytic Uremic Syndrome, which can cause acute kidney failure and death, and paralysis inducing Guillain-Barre Syndrome, respectively (Peterson 2001). The number of disease outbreaks caused by water contamination from CAFO pollution is likely underestimated because people experiencing mild gastrointestinal illness often do not seek medical attention.

Non-health Outcomes

Residents in rural communities polluted by CAFOs are also burdened with the financial costs of treating contaminated water or finding a different source. In a 2008 study, Lewandowski et al quantified the costs incurred by private well owners due to contamination. This study found that purchasing bottle water costs \$190 per year, treatment systems, such as nitrate removal systems, cost \$800 with additional maintenance costs of \$100 per year, and the average cost of well replacement was \$7200. This financial burden contributes to inequities that exist in rural communities near CAFOs, particularly in low income areas.

Conclusion

Poor waste management practices by concentrated animal feeding operations contaminate surface and groundwater in rural agricultural communities, leading to increased inequities endured by the residents. The transformation of the livestock production industry has contributed to the increase of CAFOs in the United States. Although government regulation has attempted to protect the environment from CAFO induced pollution, it has fallen short and the residents of these agricultural communities continue to pay the price of water contamination. Poor manure management practices have introduced excess nutrients and microbial pathogens into the

aquifers tapped by private wells, rendering the health of thousands of people at risk. Rural residents are faced with the tough decision whether to pay large amounts of money to treat their water or forego treatment and risk illness. Water treatment or replacement is an expensive endeavor and may not be financially feasible in low income areas, thus contributing to the health disparities existing in agricultural communities near CAFOs. These communities experience more disparate health and financial burdens than rural communities free from CAFO establishment. By examining the upstream and proximal causes of poor health caused by impaired water quality in rural agricultural communities, as outlined in this paper, further research and interventions can be designed to address this growing problem.

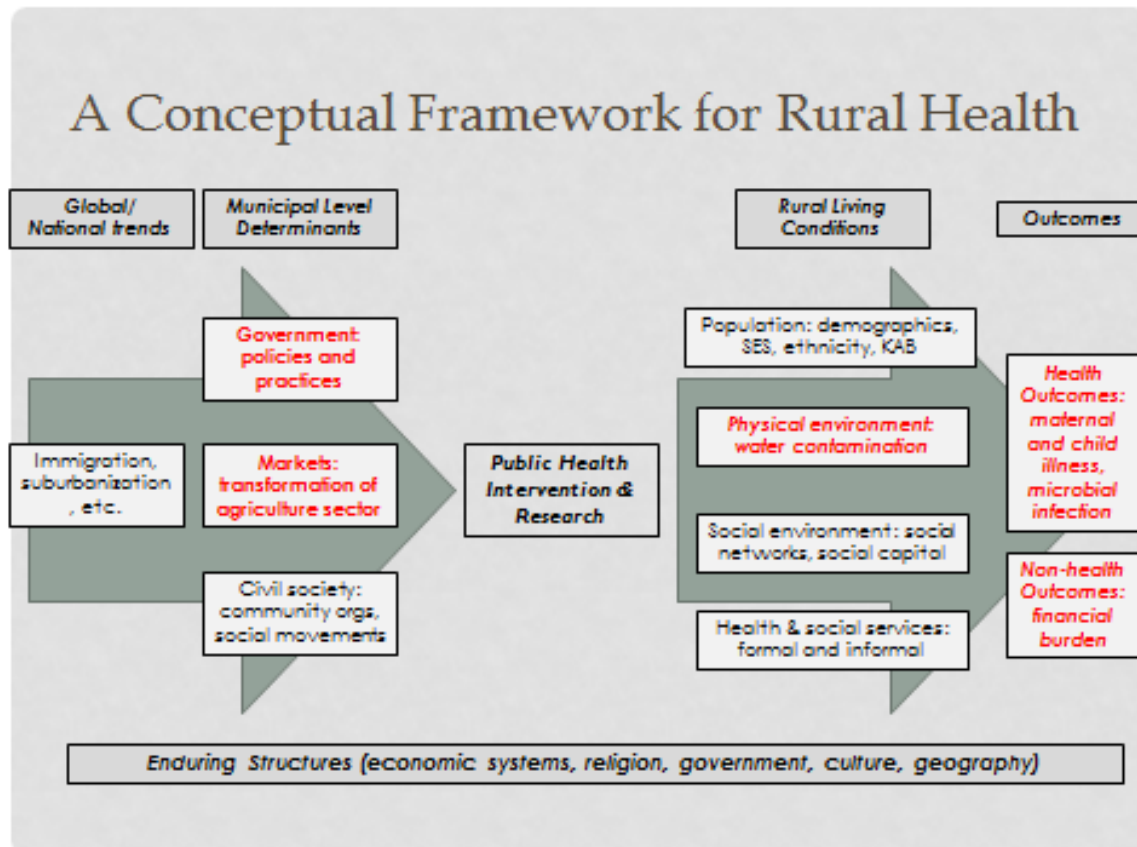


Figure 1 Adapted from Galea et al's urban model, this framework conceptualizes the elements contributing to rural health. This paper follows the model from left to right, identifying the upstream determinants of health and moving to more proximal causes contributing to the outcomes of rural health. The elements of this theoretical framework emphasized in this paper are labeled in red.

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