MANURE MANAGEMENT IN LIVESTOCK SYSTEMS: ASSESSING ONE HEALTH IMPACTS ON ENVIRONMENTAL CONTAMINATION AND HUMAN EXPOSURE

Cosmin ȘONEA[1], Dana TĂPĂLOAGĂ [1], Ștefan LAZĂR[2], Ovidiu JERCA[1], Raluca-Aniela GHEORGHE-IRIMIA [1#], Alexandra-Mădălina PÎTIU[1], Paul-Rodian TĂPĂLOAGĂ[1]

[1] University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania
[2] University of Medicine and Pharmacy "Carol Davila" Bucharest, 37 Dionisie Lupu Street, Distric 2, Bucharest, Romania

REVIEW

Abstract
This review investigates the multifaceted environmental and human health implications of manure management, emphasizing the critical challenges presented by nutrient overload, greenhouse gas emissions, and the distribution of antimicrobial resistance (AMR) and pathogens. Although the application of manure in agricultural systems is useful for soil fertility, it can result in substantial water contamination due to nutrient discharge, which contributes to eutrophication and the leaching of nitrates and phosphates into nearby groundwater. Furthermore, the review examines the role of inadequately managed manure in the production of greenhouse gas emissions, particularly methane and nitrous oxide, which contribute to the acceleration of climate change. Additionally, the review assesses the public health consequences of manure management, such as the occupational risks for farmers and labourers who are exposed to zoonotic pathogens and toxic gases, as well as the community's exposure to contaminated drinking water and food sources. The study also investigates the correlation between the application of manure and the development of foodborne illnesses, with a particular emphasis on the use of improperly treated manure as fertilizer and crops that are irrigated with an untreated effluent. In conclusion, this paper emphasizes the pressing necessity of sustainable manure management that is prioritized in integrated strategies that safeguard public health and environmental quality.

Keywords: Manure Management, One Health, Environmental Contamination

[#]Corresponding author: raluca.irimia@fmv.usamv.ro

INTRODUCTION

Livestock systems are critical in agriculture because they contribute significantly to food security and overall ecosystem health. Livestock are a significant source of protein and other necessary nutrients, and they support the livelihoods of millions of people worldwide, particularly in developing countries (Șonea, 2023a; Șonea 2023b; Gheorghe-Irimia, 2023; Tudor, 2023). Livestock integration into agricultural systems improves food production and resistance to climatic variability because livestock can use resources that are not suited for crop production, such as marginal lands and crop byproducts (Godfray et al., 2010). Furthermore, livestock systems improve soil fertility by applying manure, a natural fertilizer, and hence promote sustainable farming practices (Godfray et al., 2010; Liu, 2012). In addition to their direct benefits to food security, livestock systems benefit a variety of socioeconomic elements. They generate revenue and employment opportunities, particularly for rural areas, which improves economic stability and reduces poverty (Kahn, 2011). The interconnection of livestock and crop production systems promotes a diverse agricultural landscape, which is critical for climate resilience and food security (Godfray et al., 2010; Hertel et al., 2021, Kahn, 2011). However, managing waste from livestock systems offers both benefits and challenges.

Manure is a rich resource that can be used as organic fertilizer, improving soil health while reducing the requirement for synthetic fertilizers (Godfray et al., 2010; Liu, 2012). Manure can improve soil structure, boost nutrient availability, and promote microbial diversity, all of which are necessary for sustainable agricultural operations (Godfray et al., 2010; Liu, 2012). On the other hand, inappropriate manure management can contaminate the environment, endangering water quality and public health. For example, runoff from manure application can transfer pathogens and nutrients into water bodies, causing eutrophication and the development of waterborne diseases (Godfray et al., 2010; Liu, 2012). The concept of One Health is especially applicable in manure management since it emphasizes the interdependence of human, animal, and environmental health. One Health supports a collaborative approach to addressing health difficulties caused by interconnections between these domains (Pettan-Brewer et al., 2022). Effective manure management strategies must take into account the possible effects on public health, including antimicrobial resistance (AMR) and zoonotic diseases (Kalpana et al., 2023; Collignon and McEwen, 2019, Pettan-Brewer et al., 2022).

The importance of One Health goes beyond manure management to include the entire agricultural ecosystem. Recognizing the links between agriculture, health, and the environment allows stakeholders to collaborate to address complex concerns such as food security, climate change, and disease outbreaks (Pettan-Brewer et al., 2022). This comprehensive approach is critical for establishing sustainable agriculture methods that meet the nutritional needs of a growing global population while also maintaining environment and community health (Pettan-Brewer et al., 2022).

In this direction, the aim of this paper is to evaluate the One Health impacts of manure management practices in livestock systems, focusing on their role in environmental contamination and human exposure.

ENVIRONMENTAL IMPACTS OF MANURE MANAGEMENT

Nutrient overload and water contamination

The use of manure in agricultural activities can cause nutrient overload and subsequent water contamination. One of the main concerns is runoff from manure application, which contributes significantly to eutrophication in aquatic bodies. Eutrophication is defined as excessive nutrient enrichment, notably phosphorus and nitrogen, which causes algal blooms that decrease oxygen levels in aquatic environments and destroy aquatic life (Jahanzad et al., 2019; Wang et al., 2019). Studies have shown that when manure is spread to fields, particularly before rains, the nutrients can be washed away into neighbouring streams and lakes, worsening the problem of nutrient pollution (Wang et al., 2019; Johnson et al., 2011). For example, studies show that phosphorus loss from manured soils can be significant, especially if the manure is not properly mixed into the soil (Kumaragamage et al., 2012; Johnson et al., 2011). Another important concern with manure management is the leaching of nitrates and phosphate into groundwater. When manure is applied excessively or under inappropriate conditions, such as when the ground is frozen or saturated, nutrients can permeate through the soil and contaminate groundwater supplies (Haack et al., 2015; Varel et al., 2010). This leaching endangers not just water quality but also human health, as nitrates in drinking water can cause major health problems, including methemoglobinemia, also known as "blue baby syndrome" (Hilaire et al., 2022). Furthermore, the presence of phosphorus in groundwater might contribute to long-term impairment of surface water quality since it can be released into surface waters via groundwater discharge (Stocker et al., 2018). Case studies from diverse regions demonstrate the effects of manure mismanagement on water quality. For example, in California, concentrated animal feeding operations (CAFOs) have been connected to considerable water contamination caused by runoff from badly managed manure (Baek & Smith, 2019). Similarly, studies in the Midwest United States have demonstrated that improperly timed manure applications can cause high phosphorus levels in surface runoff, directly contributing to eutrophication in the Great Lakes (Johnson et al., 2011). These instances demonstrate the critical need for better manure management procedures to reduce water pollution hazards.

Greenhouse Gas Emissions & Climate Change

Manure management's environmental implications go beyond water contamination and include major contributions to greenhouse gas emissions. Methane (CH_4) and nitrous oxide (N_2O) are two potent greenhouse gases generated from stored manure, especially in anaerobic conditions typical of manure storage facilities (Jokela et al., 2012; Song et al., 2010). Methane is created during the anaerobic breakdown of organic matter in manure, whereas nitrous oxide emissions are predominantly caused by the application of nitrogen-rich manure to soils (Thiel et al., 2020). These gases have a substantially larger global warming potential than carbon dioxide, thus their management is crucial in terms of climate change mitigation (Guardian & Aga, 2019). Poorly managed manure systems increase the issue of global warming. For example, studies have found that methane and nitrous oxide emissions can be much greater when manure is not adequately stored or handled (Fahrenfeld et al., 2014). This emphasises the significance of using appropriate manure management strategies to limit these emissions. Anaerobic digestion can convert manure into biogas, collecting methane for energy consumption while limiting its escape into the atmosphere (Ghaly & Hattab, 2012). Furthermore, precise timing and methods of manure application can reduce nitrous oxide emissions by ensuring that crops use nitrogen efficiently (Vadas et al., 2017). Manure management plays an increasingly important role in reducing emissions, according to climate action plans. Farmers can cut greenhouse gas emissions greatly by using optimal management techniques, such as integrating manure into the soil rather than spreading it on the surface (Frentrup et al., 2021). Furthermore, incorporating manure management into crop production systems can improve nitrogen cycling, lowering the requirement for synthetic fertilisers and associated emissions (Hall et al., 2020). Overall, good manure management is critical for not just improving water quality but also mitigating climate change.

Antimicrobial Resistance (AMR) and Pathogen Spread

The presence of antimicrobial residues and resistant genes in manure poses a substantial risk to public health and the environment. Manure from livestock frequently contains antibiotic residues from animal husbandry, which can lead to the establishment and spread of antimicrobial resistance (AMR) (Cavalcante et al., 2019; Kim et al., 2010). When manure is sprayed to fields, residues can enter soil and water systems, promoting the growth of resistant bacterial strains that can harm both human and animal health (Bojarski et al., 2020). Research has shown that antibiotic resistance genes (ARGs) can survive in the environment for long periods of time, creating persistent contamination threats (Hall et al., 2020; Hilaire et al., 2022). Pathogen contamination is another major worry with manure management. Manure can include a variety of diseases, including bacteria, viruses, and parasites, which can spread through soil, water, and air (Shrestha et al., 2019). For example, studies have shown that pathogens such as Escherichia coli and Salmonella can live in manure and be transmitted to water bodies via runoff, posing considerable public health hazards (Cardoso et al., 2012; Park et al., 2020). Such pathogens can spread not just through direct runoff, but also through the leaching of contaminated groundwater, affecting drinking water supplies (Song et al., 2010). The consequences of disease spread are severe, particularly in areas where agricultural activities are inextricably tied to water sources. For example, in the Kathmandu Valley, inappropriate sewage and agricultural runoff management has been related to enteropathogen pollution of water bodies, providing a public health risk (Shrestha et al., 2017). Effective manure management measures, such as vegetated filter strips and optimal application timing, can help lower the risk of disease transmission and pollution in nearby water bodies (Bai et al., 2016; Lin et al., 2011).

HUMAN HEALTH CONSEQUENCES

Occupational Hazards

The hazards associated with manure management are extensive and diverse, especially for farmers and personnel who have direct contact with manure. Handling manure exposes people to a variety of zoonotic pathogens, including Salmonella, E. coli, and Campylobacter, which can cause major health problems (Givens et al., 2016; McDaniel et al., 2014). These pathogens can be found in large quantities in animal waste, and direct exposure can occur during manure application, cleaning of animal housing, or even contact with infected equipment (Dungan, 2012). Furthermore, harmful gases such as ammonia and hydrogen sulphide, which are generated during manure decomposition, increase the risk of infection (Ko et al., 2010). According to

Śledź et al. (2017), ammonia can irritate the respiratory system and worsen pre-existing lung problems, whereas hydrogen sulphide, even at low quantities, can induce respiratory failure and death. Bioaerosols produced during manure management activities provide an additional occupational health risk. Land application of manure, composting, and even animal movement can aerosolise pathogens and particulate debris, which workers can then inhale (Dungan 2012). According to studies, workers who work close to livestock activities are more likely to get respiratory infections and other health problems as a result of inhaling these bioaerosols (Jahne et al., 2015). Endotoxins in the air, which are generated by manure, can also contribute to respiratory ailments and other health problems among agricultural workers (Ko et al. 2010). As a result of the occupational dangers linked with manure management, persons working in these areas must take protective measures and undergo health monitoring.

Community Exposure

Community exposure to manure-related health issues is a developing concern, particularly in terms of contaminating drinking water supplies and the food chain. Manure application on agricultural areas can cause pathogen and nutrient leaching into groundwater, contaminating drinking water sources (Zhang et al., 2020; Pandey et al., 2014). This contamination poses a serious public health risk since bacteria like E. coli and Salmonella can persist in groundwater for long periods of time, causing epidemics of gastrointestinal ailments in communities that rely on these water supplies (Samarajeewa et al., 2012). Furthermore, runoff from manure-treated fields can transport pathogens into surface water bodies, compounding water quality and safety concerns (Samarajeewa et al., 2012). In addition to water contamination, airborne particles and pathogens emitted during manure management can have a negative impact on respiratory health in surrounding areas. According to research, people who live near livestock operations have a higher rate of respiratory problems, such as asthma and chronic bronchitis, which are most likely caused by exposure to bioaerosols containing pathogens and particulate matter (Baghdadi, 2023; Jahne et al., 2015). Inhaling these airborne pathogens can have both acute and chronic health effects, especially in vulnerable populations like children and the elderly (Baghdadi, 2023). As a result, the consequences of manure management go beyond occupational health issues to address broader community health concerns.

Link to Foodborne Illnesses

The contamination of crops by manure, particularly those irrigated with untreated wastewater or fertilised with poorly processed manure, is a serious public health concern. Manure can act as a reservoir for numerous diseases, which can then be transported to crops during irrigation or fertilisation processes (Givens et al., 2016; Jahne et al., 2016). For example, applying untreated or improperly treated manure to agricultural fields has been related to outbreaks of foodborne illnesses, as bacteria can remain in the soil and infect edible crops (Jahne et al., 2016; Seltenrich, 2017). This risk is especially high in areas where agricultural activities do not follow proper safety regulations for manure application (Seltenrich, 2017). Human pathogen exposure through the ingestion of contaminated produce can cause severe gastrointestinal ailments, putting a load on healthcare systems and affecting public health (Givens et al., 2016; Jahne et al., 2016). The Centres for Disease Control and Prevention (CDC) has recorded multiple outbreaks associated with the consumption of fruits and vegetables contaminated with pathogens from manure (Jahne et al., 2016; Seltenrich, 2017). Furthermore, the increasing incidence of antibiotic-resistant bacteria in manure raises additional concerns, as these resistance strains can be transmitted to people via the food chain, complicating illness treatment choices (Baghdadi, 2023; Garder et al., 2014). As a result, the links between manure management techniques and foodborne illnesses underline the importance of strict rules and best practices for ensuring food safety and protecting public health.

CONCLUSIONS

In summary, the health implications of manure management are substantial and intricate, covering occupational hazards for workers, community exposure to contaminated water and air, and associations with infectious diseases. This requires a comprehensive approach that includes public health education, regulatory supervision, and enhanced manure management methods to mitigate the potential health risks associated with manure application and processing.

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