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# Animal Waste Management: A Review

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**Abstract**
Livestock rearing is an important agricultural activity in developing countries. In the last two decades, due to intensification of production process, the livestock population has increased significantly, and the consumption of cereals has increased by the animals to produce more. The huge livestock population and feeding of grains have produced large quantities of livestock waste greatly affecting the surrounding environment, leading to excess greenhouse gas emissions, water and soil pollution. Poor waste management practices in developing countries have been posing a serious threat to human and animal health. Knowledge of proper disposal of livestock waste and recycling is very crucial for sustainable development of the farming system. This review is made to present researchers with the latest studies in the field of animal waste management and their impact on water, soil and land pollution. The review also briefly presents the impact of animal waste on human health, economic values of livestock waste, problems associated with proper disposal of animal waste and government policies towards waste disposal.

**Key Words:** Animal Waste, Water Pollution, Soil Contamination, Air Pollution

## 1. Introduction

Animal resources for both developing and developed countries are one of the important sources of food security. In the last two decades there has been significant growth of livestock in the developing countries to support the livelihood of poor people. In India, as per the $19^{th}$ Livestock Census, there are 512.05 million of livestock producing large volume of animal waste in the form of solid, semi-solid and liquid by-products which include animal faeces, urines, other excretions, digestive emissions, urea, bedding materials, spilled or uneaten feed, slaughterhouse waste, hatchery waste, wastewater from cleaning operations, slurry, etc. According to NITI Aayog estimate, Indian cattle produce around 3 million tonnes of cow dung per day. The cow excretes 8-12 kg dung and 4-6 liters of urine per day(Vijay, 2006). In the world scenario, 2.5 billion pigs and cattle excrete more than 80 million metric tonnes (MMT) of waste nitrogen annually whereasthe entire human population produces just over 30 MMT. Animal waste production is becoming a serious environmental problem due to continuous incorporation of nitrogen in the atmosphere from urine and faeces. The land animals is responsible for an estimated 12% to 20 % global greenhouse gas emission (FAO,2023).The continuous increase of nitrogen in the atmosphere is causing different types of respiratory diseases.In the semi urban and urban areas where livestock are reared in very congested areas, animal waste pollutes the water causing waterborne diseases (Hansen and Meres, 2002).Domestic animals such as poultry, cattle, sheep and pigs generate 85% of the world's faecal waste and their contribution is as high as $2.62x10^{13}$ Kg/ year (WHO, 2012).

To feed the growing human population in developing countries, livestock production has increased in these countries in the last decades due to the adoption of the industrial production process which benefited production efficiency but has produced major environmental issues. (Wing and Wolf, 2000). The intensification of livestock production in the densely populated areas, has resulted the large quantity accumulation of pollutants such as nitrogen, phosphorus and pathogens leading to contamination and eutrophication (García-González, 2021). The increasing demand for food products necessities efficient management of livestock farming to mitigate environmental impact.

**2. Water Pollution**

Livestock manures are applied to the crop to fertilize the soil with various forms of nitrogen. When excess quantity is applied, the crop fails to utilize the entire nitrogen content of the manure leading to the residual nitrogen content leaching through the soil to the ground water causing water pollution. One of the main pathways of nitrogen loss is through the leaching and runoff losses to the ground and surface water (Aguirre et al., 2017; Burkholder et al, 2007; Rotz, 2004). Livestock manure may harbour a wide range of viral, bacterial and parasitic pathogens. These pathogens can be mobilized from land applied manure to surface water, leach in to ground water , or contaminate vegetable crops via irrigation ( Bylund et . al. 2015; McAllister and Toppt., 2012)Contaminants from poorly constructed manure pits nearer to the water bodies can enter the water sources either through overflow of the pits and runoff due to application of manure to farm field, or atmospheric deposition followed by dry or wet fallout (Aneja, 2003). There are many contaminants present in the livestock waste like nutrients(Huddleston, 1960), pathogens (Gerba and Smit 2005; Schets*et. al.* 2005), heavy metals especially zinc and copper (Barker and Zublena, 1995 ), antibiotics (Kummerer, 2004), veterinary pharmaceuticals ( Boxall *et. al.* 2003), etc. The leachate and discharge contaminate the water, and when the water used by livestock and humans produces health related issues.

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## 3. Soil Contamination

The livestock manure generated is normally placed directly onto open land, sun dried and applied as fertiliser for agriculture production. It is widely considered as natural organic fertiliser as they improve their quality with potassium and phosphorus. They also contain many useful hormones,namely auxins, which is necessary for the development, growth and propagation of plants(Patyra*et al.,* 2023).The livestock manure also improve the water retention capacity, increase humus in the soil and helpful for multiplication of microorganism ( Voltr*et al.,* 2021). The contamination of animal manure by antibiotic residues produces multiple antibiotic resistant bacteria in the soil and ground water causing health crisis (Michael et al., 2014; Rossolini et al., 2014).

A study conducted on " Environmental risk caused by livestock and poultry farmers to the soil;: Comparison of Swine, chicken and cattle farms" in Cities such as Shenyang, Tieling, Anshan, and Benxi in PR China reported that the lack of treatment systems for pollutants in family-livestock and poultry sites results in large amount of untreated manure and urine being directly discharged to environment. In their investigation from 221 samples (feed , manure, surface soil, soil profiles, water and plant) collected from 41 livestock and poultry farms, Copper(Cu), Zinc (Zn), oxytetracycline and enrofloxacin were frequently detected in the samples. They found that the metals and veterinary antibiotics in sandy loam soils were more inclined to migrate to deep layers than those in loam soils. They observed that the Copper and Zn in the polluted soils mainly existed in available form, which facilitated their migration to deep soil layers (Zhang, 2022). The improper application of manure may lead to leaching of hazardous elements, excess fertilisation of crop land beyond the demand of crop leading to accumulation of nitrogen (N), potassium (K), and phosphorus (P) and heavy metals like copper and zinc that affects animal health directly and indirectly by crop feeding (Riaz et al., 2023; Sommer et al.,2003; Smith et al., 2001). The accumulation of heavy metals in the soil increases their availability for to plant and leaching to ground water and surface water(Moolenaar,1999; Van Riemsdijk*et al*., 1987 ).

## 4. Air Pollution

Livestock farm is not only the producer of animal waste but also a source for significant emission of pollutant to the atmosphere. The livestock farm produces organic and inorganic dust, diseases, microbes, particulates, endotoxin aerosols as well as gases including ammonia, nitrous oxide, carbon dioxide, hydrogen sulphide, methane as pollutant (Rajput, et. al., 2023; Sanchis et al., 2019; Kalkowska et al., 2018; Borlee et al., 2017; Okoli et al., 2006; Harry, 1978).These products are not only harmful to soil, water and air but also to the health of animals and humans (Donham et al. 2007). Nitrogen in the urine and faeces produces ammonia. The biological and chemical breakdown of urea, uric acid and protein in manure during decomposition and storage by urease enzymes also produces ammonia( Atia and Amrani, 2004).

Livestock activities produce 10-12 % global emissions with almost 30 % coming from cattle production system ( Ferraz, et. al., 2024, Gerber et al., 2013; Herrero et al., 2011). In Europe, dairy animals remain the main producer of $CH_4$ and $NH_3$ emission with a contribution of 79% and 51.3% respectively (Malherbe, et.al., 2022).

As per a study conducted by Pau and Buysse, 2020, the livestock farms are the major contributor to atmospheric particulate matter emissions. However, the contribution of different species of animals to ammonia emission and particulate materials is not widely studied. The emission factors of farming animal vary depending on animal characteristics, feeding pattern, management styles and manure removal system. Hristov et al. (2011) by reviewing multiple approaches and studies find emission factors from cows varying from 0.82 to 250g ammonia per day. Philippe et al. (2011) reported the same value for swine, which was between 0.38 and 27.2 g per day. As per the European Environment Agency report, pig production is responsible for 15% of $NH_3$emissions associated to livestock production globally where as in Europe, it produces nearly 25 % of the livestock emission. In China, 13.5 % of the total $NH_3$ emissions from agricultural activities are from dairy farming ( Huang et al., 2012; Wang et al., 2018) The ammoniumion is changed into ammonia gas, which easilyvolatilizes to air and raises the atmospheric $N_2$level, as the pH of cattle manure rises (Moore,1998). Odours that are bothersome are reportedto coexist with ammonia emissions from moistanimal droppings in areas with heavy livestockproduction (Chavez *et al*., 2004).

In a study in Lambardy, Italy employing a spatially and temporally indexed econometric model to investigate the specific impact of bovine and swine farming on the concentration levels of ammonia ($NH_3$) and coarse particulate matter ($PM_{10}$) found that an increase of 1000 units in livestock, equating to roughly a 1% and 0.3% rise in the average per-quadrant bovine and swine populations, respectively—triggers a corresponding daily increase in $NH_3$ and $PM_{10}$ concentrations. These increases are quantified as 0.26 [0.22; 0.33] and 0.29 [0.27; 0.41] μg/m3 for bovines (about 2% and 1% of the respective daily averages) and 0.01 [0.01; 0.05] and 0.04 [0.004; 0.16] μg/m3 for swine (Lunghi et al., 2024).

Decomposition of organic materials in the manure pits produces mal odour and low molecular weight compound containing sulphur (Merril and Haverson, 2002 ;O' Neil and Philips, 1992). Livestock farming contributes to air pollution through emissions of ammonia and other air pollutants particularly in areas with high density farming (Williams, 2024; Smith and Heederik, 2017).

## 5. Human Health Problem

The faeces of livestock species contains pathogens and present a risk to human health. The common pathogens found in livestock faeces likely to cause human risk are: E.coli, Campylobacter, Salmonella, Giardia, Cryptosporidium parvum, norovirous, etc,. The improper animal waste disposal may expose human beings to pathogens via water, sanitation and hygiene related pathways in the low-income countries where household livestock, small scale animal operation and free roaming animals are common (Priya, et al. 2020; Penakalapati et al.,2017). The movement of microbes from faecal material depends on how manure is stored and applied in the crop fields, rainfall quantity and proximity to river and water bodies. Grazing of animals in the open field allows greater movement of microbes from one place to another. With precipitation, manure is converted into slurry and moves into soil easily (US Environmental Protection Agency, 2009).

Water polluted by inadequately treated sewage and animal dung carry pathogens like bacteria, parasites and virus that pose serious threat to human health. Diarrheal diseases due to contamination of water and food claimed more than four million lives of which 80% are children under age 5(Wang et al. 2015).The International Livestock Research Institute (ILRI), Kenya and the Institute of Zoology, UK reported that most of these human infections were acquired from livestock. The study showed that 27% of livestock in developing countries like India showed signs of current or past infection with bacterial food-borne disease — a source of food contamination and widespread illness (Ravindra and Sexena, 2018). The pathogens present in the cattle faeces like.E. coli, Campylobacter, Salmonella, Cryptosporidium parvum, and norovirus are likely to be harmful to human health. The enteric pathogens present in the swine manure like Clostridium perfringens, E. coli, Salmonella, Campylobacter, Cryptosporidium, Giardia and norovirus are also important cause of risk to human health ( Guan and Holley, 2003). In one outbreak in Swaziland cattle reported about 40000 cases of waterborne diseases (Effer et al., 2001). Wilson et al, 2008 in their study concluded that 96.6% of *Campylobacter jejuni* infection in Lancashire, UK was from farm livestock.

## 6. Economic value of livestock waste

Livestock population in India are concentrated in the rural areas with ruminants and poultry. Due to the high demand of animal protein, the livestock population is increasing every year. The increased livestock population is producing an increase of animal waste which is harmful to the environment if not processed properly. Animal waste can be used as organic fertilizer or an alternative energy source, biogas. Livestock waste as an alternative source of energy has many advantages like odourless fuel and reducing soil, water and air pollutions ( Sahara, 2024).Circular economy aims at more sustainable development through increased recycling of animal waste. The nutrient recovery from animal manure has direct environmental benefits ( Rao et al.2017; Neo 2010) and may replace the synthetic fertilizers and thus reduce the costs, emissions and pollution associated with the production and use of synthetic fertilizers (Buckwell and Nadeu 2016; Yu and Wu 2018). Recycled nutrients may reduce the dependency on synthetic fertilizers which play a major role in achieving Sustainable Development Goals on food and nutrition security, clean water and sanitation, sustainable cities and life below water and on land ( Zhu et al.2017). Waste treatment and management technologies are not well established practices due to the difficulty to attribute economic value to associated social and environmental impacts of nutrient pollution. In a case study by Sampat et al.( 2021) on livestock waste management in the State of Wisconsin, USA estimated that every excess kilogram of phosphorous runoff from livestock waste results in total income losses of 74.5USD.

## 7. Problems of proper disposal of livestock waste

Over the past several decades, increased concentration of livestock farms, has spurred greater concern over the environmental implications of animal feeding operations. Manure generated as a by-product of livestock production has been linked to water and air pollution problems in many watersheds around the world. Location of confined livestock operations in close proximity to urban areas has also had impacts on nearby residential property values. Practices designed to reduce adverse environmental impacts of manure production and handling show varying degrees of promise. However, the usefulness of these practices is limited in some areas by various economic constraints such as cost to livestock operations, lack of adequate land for crop utilization of manure nutrients, and lack of incentives to promote uses of manure that are beneficial both from an environmental standpoint and from the farmer's point of view (Edward and Keith, 2008). To reduce the environmental pollution of antimicrobials and transmission and development of antimicrobial resistance(AMR), the Republic of China has banned direct application of animal waste on farmlands. The China government has adopted phasing out the non-therapeutic use of antimicrobials, developing substitutes of antimicrobials, enhancing animal welfare in farms, promoting diversification of animal farms, and developing antimicrobial removal and disinfection technologies for animal waste management in animal agriculture (Cheng and Cheng, 2024). A waste management study conducted in three towns of Tigray, Ethiopia revealed that the manure management practices were unsafe for urban inhabitants and environment. The study found that nearly 68% of respondents collected manure from animal houses once a day using and stored as heap within 10 meters distance from the farmand  6% of the households stored manure for more than three months.The manure was primarily converted into dry dung for fuel followed by fertilizer. The critical manure management constraints were lack of technical knowhow, shortage of land, distant plots, lack of transport, less market demand and labour intensiveness in their order of importance (Berihu and Ebrahim, 2024).

## 8. Government policy for waste disposal

To reduce the environmental pollution of antimicrobials and transmission and development of antimicrobial resistance (AMR), the Republic of China has banned direct application of animal waste on farmlands. The China government has adopted phasing out the non-therapeutic use of antimicrobials, developing substitutes of antimicrobials, enhancing animal welfare in farms, promoting diversification of animal farms, and developing antimicrobial removal and disinfection technologies for animal waste management in animal agriculture (Cheng and Cheng, 2024). India Government launched GOBAR-Dhan programme as a part of Swach Bharat Mission to boost rural households income using animal waste to produce organic manure and energy ( Ministry of Energy, Government of India, 2021).

## 9. Conclusion

The developing and developed nations must adopt right strategies for the proper disposal of animal waste to protect the environment and improving the quality of human and animal health in the world. Keeping in to the mind of growing human population, ensuring of food and livelihood security and changing life style of the population, a balance has to be made on how much to be produced from animal sources. The national governments should frame rules and regulations regarding the proper disposal of the animal waste and ensure the adherence to the rules with involvement of all stake holders. While enforcing the compliance, due care must be taken the livestock owners are not seriously compromised. The civil societies, research institutions, developmental agencies, world bodies and political entities must work in unison with the local governments to educate the farmers about proper disposal of animal waste and scientific recycling of waste to get economic benefits.

## 10. References:

1. Aguirre-Villegas, H. A. and Larson, R. A ( 2017). Evaluating greenhouse gas emissions from dairy manure management practices using survey data and lifecycle tools. Journal of Cleaner Production, vol.143, pp. 169–179.
2. Aneja, V. P., Nelson, D.R., Roelle, P.A., Walker,J.T.(2003). Agricultural ammonia emissions and ammonium concentrations associated with aerosols and precipitation in the southeast United States. J Geophys Res. 2003;108 (D4):ACH12-1–12-11.
3. Atia, A., Haugen-Kozyra, K. and Amrani, M. (2004). Ammonia and hydrogen sulphide emissions from livestock production. Alberta Agriculture, Food and Rural development, 229-230.
4. Atul,S R , Patra , M.K. and Jisna, K.S. (2023). Air Quality and Emission from livestock Production system: - A Review. *Trends in Agriculture*, Vol.2, Issue 3, Page: 168-172
5. Barker, J.C, Zublena, J.P. (1995). Livestock Manure Nutrient Assessment in North Carolina. Final Report. Raleigh, NC: North Carolina Agricultural Extension Service, North Carolina State University.
6. Berihu, M. and Ebrahim, A.(2024). Urban Livestock Waste Management Practices in Tigray, Northern Ethiopia, Scope, Volume 14 Number 01.
7. Boxall,A.B.A,, Kolpin, D.W,, Halling-Sorenson, B. and Tolls, J.(2003) Are veterinary medicines causing environmental risks? Environ Sci Technol. 37:286A–294A.

8. Buckwell, A., and Nadeu, E. (2016) Nutrient Recovery and Reuse (NRR) in European agriculture. A review of the issues, opportunities, and actions. RISE Foundation, Brussels
9. Burkholder, J., Libra, B., Weyer, P., Heathcote, S., Kolpin, D., Thorne, P.S., and Wichman, M. (2007) "Impacts of waste from concentrated animal feeding operations on water quality," Environmental Health Perspectives, vol. 115, no. 2, p. 308.
10. Bylund, F., Collet, E., Enfors, S., and Larsson,G.(2015. "A compilation of cost data associated with the impacts and control of nutrient pollution," tech. rep., U.S. Environmental Protection Agency,
11. Catelo, A., Moises, A. Dorado. and Elpidio, A. (2001). Living with livestock: Dealing with pig waste in the Philippines. Summary of EEPSEA Research Report 2001.
12. Chavez, C., Coufal, C.D., Lacey, R.E., Carey, J.B., Beier, R.C.*et al.*, (2004). The impact of supplemented dietary methionine source on volatiles compound concentrations in broiler excreta. Poult Sci, 83: 901- 910.
13. Cheng, G. M. and Cheng, H. (2024).Overcoming China's animal waste disposal challenge brought by elevated levels of veterinary antimicrobial residues and antimicrobial resistance, Environment International, Vol.191, September,2024,
14. Pue,D.D. and Buysse, J.(2020). Safeguarding Natura 2000 habitats from nitrogen deposition by tackling ammonia emissions from livestock facilities Environ. Sci. Pol., 111 (2020), pp. 74-82.
15. Donham, K.J., Wing, S., Osterberg, D., Flora, J.L., Hodne, C., Thu, K.M., Thorne, P.S.(2007). Community health and socioeconomic issues surrounding concentrated animal feeding operations. Environ. Health Perspect. 2007, 115, 317–320.
16. Patyra,,E., Nebot,C., Gavilán,R.E., Kwiatek,K. and Cepeda, A. (2023). Prevalence of veterinary antibiotics in natural and organic fertilizers from animal food production and assessment of their potential ecological risk.*J. Sci. Food Agric.*, 103 (7), pp. 3638-3644.
17. Edward, O. and Keith, O. K.(2008). Economic constraints to effective livestock waste management and policy implications, CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2008 3, No. 039.
18. Effler, E., Isaäcson, M., Arntzen, L., Heenan, R., Canter, P., Barrett, T., Lee, L., Mambo, C., Levine, W., Zaidi, A. and Griffin, P. M. (2001). Factors contributing to the emergence of Escherichia coli O157 in Africa. Emerg. Infect. Dis., 7(5), 812–819.
19. Elena, S., Calvet, S , Agustín del, P., Fernando, E.(2019).A meta-analysis of environmental factor effects on ammonia emissions from dairy cattle houses. Biosystems Engineering, Volume 178, February 2019, Pages 176-183
20. Borlée,F., Yzermans,J., Aalders, B., Rooijackers, J., Krop,, E. , Maassen,C.B.,andSmit ,L.A.(2017). Air pollution from livestock farms is associated with airway obstruction in neighboringresidents. Am. J. Respir. Crit. Care Med., 196, pp. 1152-1161

21. Philippe,F.-X., Cabaraux J.-F. and Nicks, .B. (2011). Ammonia emissions from pig houses: influencing factors and mitigation techniques. Agric. Ecosyst. Environ., 141, pp. 245-260
22. FAO. (2023). Pathways towards lower emissions – A global assessment of the greenhouse gas emissions and mitigation options from livestock agrifood systems (Rome: Food and Agriculture Organization of the United Nations).
23. Ferraz, P.F.P., Ferraz, G.A..S., Ferreira, J.C., Aguiar, J.V., Santana, L.S. and Norton, T. (2024). Assessment of Ammonia Emissions and Greenhouse Gases in Dairy Cattle Facilities: A Bibliometric Analysis. Animals, 14, 1721.
24. Rossolin, G.M., Arena,F., Pecile,P. and Pollini, S. (2014).Update on the antibiotic resistance crisis, *Curr. Opin. Pharmacol.*, 18 (2014), pp. 56-60
25. García-González, M. C., Masaguer, A., Moliner, A., & Navarro-Pedreño, J. (2021). Impacts of livestock farming on soil and water quality: A review. Animals, 11(1), 236
26. Gauthami, P., Jenna, S., Miranda, J., Delahoy, L. M., Breanna, W., Karen, L., and Matthew C. F.(2017). Exposure to Animal Feces and Human Health: A Systematic Reviewand Proposed Research Priorities. Environ. Sci. Technol. 2017, 51, 11537–11552.
27. Gerba, C. P., Smith, J.E., Jr.(2005). Sources of pathogenic microor-ganisms and their fate during land application of wastes. J Environ Qual.;34:42–48.
28. Guan, T.Y. and Holley, R.A. (2003). Pathogen survival in swine manure environments and transmission of human enteric illnesses-a review. J Environ Qual. 32:383-392.
29. Hristov, A.N., Hanigan M., Cole, A., Todd, R., McAllister,T.A., Ndegwa P.M. and Rotz, A. (2011). Ammonia emissions from dairy farms and beef feedlots. Can. J. Anim. Sci., 91, pp. 1-35.
30. Hansen, C. and Meres, M. (2002). Revolutionary composter proves effective in treating animal environmental products and tech corporation, Turning around impacted areas of our Environment.
31. Harry, E. G., (1978). Air pollution in farm buildings and methods of control: a review. Avian Pathology, 7:441-454.
32. Huddleston, J.H. (1996). How Soil Properties Affect Groundwater Vulnerability to Pesticides Contamination. Oregon State Extension Service. Available: wwwagcomm.ads.orst.edu .
33. Jacopo,L. , Maurizio, M. , Lara, A. R.(2024). Exploring the impact of livestock on air quality: A deep dive into Ammonia and particulate matter in Lombardy, *Environmental Impact Assessment Review,* 105, 107456.
34. Koopmans, M. (2004). World watch institute. World society for the protection of animals. The American Public Health Association (APHA), National Institute for Public Health and the Environment, The Netherlands.
35. Kalkowska, D.A. , Boender,G.J. , Smit,L.A., Baliatsas, C. , Yzermans,J., Heederi, D.J. and Hagenaars, T.J.(2018).Associations between pneumonia and residential distance to livestock farms over a five-year period in a large population-based study. PLoS One, 13.

36. Korner, I., Braukmeier, J., Herrenklage, J., Leikam, K., Ritzkowski, M.*et al.*, (2003). Investigation and optimization of composting processes-test systems and practical examples. Waste Manag, 23: 17-26.
37. Kummerer,K.(2004) Resistance in the environment. J Antimicrob Chemother.;54:311–320.
38. M. Herrero, P. Gerber, T. Vellinga, T. Garnett, A. Leip, C. *Opio, et a.l(2011).*Livestock and greenhouse gas emissions: the importance of getting the numbers right Anim. Feed Sci. Technol., 166, pp. 779-782.
39. Malherbe, L., German, R,;Couvidat, F., Zanatta, L.,Blannin, L., James, A.,Lètinois, L., Schucht, S., Berthelot, B.,and Raoult, J. (2022). Emissions of Ammonia and Methane from the Agricultural Sector. Emissions from Livestock Farming (Eionet Report—ETC HE 2022/21). European Topic Centre on Human Health and the Environment. 2022. Available online: www.eionet.europa. eu.
40. McAllister, T.A. and Toppt,E.(2012). Role of livestock in microbiological contamination of water: Commonly the blame, but not always the source, *Animal Frontiers*, Volume 2, Issue 2, Pages 17–27.
41. Michae, C.A., Dominey-Howes, I, D. and Labbate, M. (2014).The antimicrobial resistance crisis: causes, consequences, and management Front. Public Health, 2, p. 145
42. Merrill, L. and Halverson, L.J.( 2002). Seasonal variation in microbial communities and organic mal-odour indicator compound concentrations in various types of swine manure storage systems. Environmental quality. 31, 2074-2085.
43. Moolenaar, S.W. (1999). Heavy-metal balances, part II. Management of cadmium, copper, lead, and zinc in European agro-ecosystems, J. Industrial Ecol., 3, 41–53.
44. Moore,P.A.(1998). Best management practices for poultry manure utilization that enhances agricultural productivity and reduce pollution. In: Animal Waste Utilization: Effective Use of Manure as a Soil Resource. JL Hatfield and BA Stewart, (eds), Ann Arborpress, Chelsea, ML, pp 89-123
45. Neo, H. (2010) The potential of large-scale urban waste recycling: a case study of the national recycling programme in Singapore. Soc Nat Resour 23:872–887
46. Okoli, I.C., Alaehie, D.A., Okoli, C.G., Akanno, E.C., Ogundu U.E.*et al.*, (2006). Aerial pollutant gases concentrations in tropical pig pen environment in Nigeria. Nat Sci, 4: 1-5.
47. O'Neill, D.H. and Phillips, V.R. (1992). A review of the control of odour nuisance from livestock buildings. Part 3, properties of the odorous substances, which have been identified in livestock wastes or in the air around them. Journal of Agricultural Engineering Research, 53, 23 – 50.
48. Gerber ,P. , Steinfeld,H., Henderson, B., Mottet, A., Opio, C., Dijkman,, J. et al.(2013)Tackling Climate Change Through Livestock Food and Agriculture Organization of the United Nations (FAO), Rome.
49. Priya, Sahu, V., Goswami, M., Pathak, V., Swarnalata, Prachooriya. (2020). Concerns Related to Health Hazards from Livestock Waste. Journal of Animal Feed, Science and Technology. 2020;8(1):19–24.

50. Rotz, C.A.(2004). Management to reduce nitrogen losses in animal production. Journal of Animal Science, 82: E119-E137.PMid:15471791.
51. Ravindra, S. and Sexena, K L.(2018). Livestock Waste and Its Impact on Human Health, International Journal of Agricultural Sciences ISSN: 2167-0447 Vol. 6 (6), pp. 246-251.
52. Sahara, D. (2024). IOP Conf. Ser.Livestock Waste as alternative energy for rural households: A review, Earth Environ. Sci. 1292 012002
53. Sampat, M . A., Hicks, A., Ruiz-Mercado,G. J. and Zavala, V. M.( 2021). Valuing economic impact reductions of nutrient pollution from livestock waste, Resources, Conservation and Recycling, Volume 164,105199,
54. Schets, F.M., During, M., Italiaander, R., Heijnen, L., Rutjes, S.A., van der Zwaluw, W.K., et al.(2005). Escherichia coli O157:H7 in drinking water from private water supplies in the Netherlands. Water Res. 2005;39:4485–4493.
55. Serena, V. and Provvidenza Rita D'Urso , Claudia, A. and Giovanni, C.(2024). Ammonia Emissions and Building-Related Mitigation Strategies in Dairy Barns: A Review, Agriculture 2024, 14, 1148..
56. Smit, L. A. M., and Heederik, D. (2017) .Impacts of intensive livestock production on human health in densely populated regions. GeoHealth, 1. 272–277,
57. Smith, K.A., Jackson, D.R. and Pepper, T.J.( 2001). Nutrient losses by surface run-off following the application of organic manures to arable land. Nitrogen, Environ. Pollution, 112, 41–51.
58. Sommer, S.G., Génermont, S., Cellier, P., Hutchings, N.J., Olesen, J.E. and Morvan, T. (2003). Processes controlling ammonia emission from livestock slurry in the field, Europ. J. Agron., 19, 465 – 486.
59. Umair, R, Shazia, I, and Moazzam, J. (Eds.) (2023). Waste Problems and Management in Developing Countries. Apple Academic Press, Inc. Co-published with CRC Press (Taylor & Francis)
60. US Environmental Protection Agency. (2009). Review of zoonotic pathogens in ambient water. Publication EPA 822-R-09-002. U.S. Environmental Protection Agency, Washington, D.C.
61. Voltr,V. , Menšík,L. , Hlisnikovský,L., Hruška,M., Pokorný,E. and Pospíšilová., L. (2021).The soil organic matter in connection with soil properties and soil inputs. Agronomy, 11 (4) (2021), p. 779
62. Riemsdijk, Van., Lexmond,W.H., Enfield, Th.M. C.G. and Van Der Zee, S.E.A.T.M., (1987). Phosphorus and heavy metals accumulation and consequences. Animal Manure on Grassland and Fodder Crops: Fertilizer or Waste? (H.G.Van Der Meer, R.J. Unwin, T.A. Van Dijk, G.C. Ennik, Eds.), Development Plant Soil Sci., 30, 213–227, Martinus Nijhoff Publishers, Dordrecht, The Netherlands.
63. Vijay, V.K. (2006). Integrated Cycle of Cow-Project for Rural Self-Sustainable Economic Development. IIT, New Delhi, 6.
64. Wang, H.,Naghavi, M., Allen, C., Barber, R. M., Bhutta, Z. A., Carter, A., Casey, D. C., Charlson, F. J., Chen, A. Z.and Coates, M. M.( 2015). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of

death: a systematic analysis for the Global Burden of Disease Study. Lancet. 2015, 388 (10053), 1459–1544.

65. Wiliams, J. (2024).Contribution of Livestock Farming to Environmental Pollution in China, Journal of Animal Health, ISSN 2709-5517(Online)Vol.4, Issue 1,No. 5pp 43-53, 2024
66. Wilson, D. J., Gabriel, E., Leatherbarrow, A. J. H., Cheesbrough, J., Gee, S., Bolton, E., Fox, A., Hart, C. A., Diggle, P. J. and Fearnhead, P. (2008). Rapid evolution and the importance of recombination to the gastroenteric pathogen Campylobacter jejuni. Molecular Biology and Evolution, 26(2), 385–397
67. Wing, S, and Wolf, S. (2000). Intensive livestock operations, health, and quality of life among eastern North Carolina residents.Environmental Health Perspectives 2000;108:233–8.
68. WHO. (2012). Animal Waste, Water Quality and Human Health edited by A Dufour, J Bartram, R Bos and V Gannon.
69. Xiaorong, Z., Zongqiang, G., Graeme, A., Mei Xiao, X., Li, C. J. and Zijun, Ni.(2022). Environmental risks caused by livestock and poultry farms to the soils: Comparison of swine, chicken, and cattle farms. Journal of Environmental Management, Volume 317,
70. Yu, J. and Wu, J. (2018) The sustainability of agricultural development in China: the agriculture-environment Nexus. Sustainability 10:1776.
71. Zhu, Y.G., Reid, B.J., Meharg, A.A., Banwart, S.A. and Fu, B.J. (2017) Optimizing Peri-URban ecosystems (PURE) to re-couple urban-rural symbiosis. Sci Total Environ 586:1085–1090.