# A review of the effects of intensive poultry production on the environment and human health

**Himu H.A.[1]; Raihan A.[2*]**

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## Abstract

Poultry farming is widely recognized as a highly efficient technique of animal husbandry, contributing significantly to the nutritional security of a substantial portion of the global population. The application of contemporary intensive farming methods has facilitated a notable increase in global production, which has reached a substantial quantity of 137.8 million tons in the year 2021. This upward trajectory has been consistently observed over successive years. However, these aggressive growth tactics result in a substantial environmental impact. The appropriate management of waste items, such as poultry litter and manure, is crucial due to their potential to significantly impact both environmental and human health. The emissions of ammonia, nitrous oxide, and methane are associated with poultry production and the disposal of its waste by-products. These emissions have significant implications for global greenhouse gas emissions, as well as the well-being of both animals and humans. Litter and manure have the potential to harbor pesticide residues, microbes, pathogens, pharmaceuticals (specifically antibiotics), hormones, metals, macronutrients (in imbalanced proportions), and other contaminants. These substances can contribute to the contamination of air, soil, and water, as well as the emergence of antimicrobial and multidrug-resistant strains of pathogens. The emission of dust from intensive poultry farming operations is comprised of various components, including feather and skin parts, feces, feed particles, germs, and other pollutants. These constituents have the potential to negatively affect the health of poultry, farm employees, and anyone residing in close proximity to these activities. The presence of noxious odors can pose a significant health concern for both workers and the surrounding population. This study examines the existing literature about the effects of intensive poultry production on both the environment and human health. Additionally, it explores potential strategies and approaches for achieving a sustainable future in this domain.

**Keywords:** Poultry, Environment, Health, Sustainability

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1- Department of Veterinary and Animal Sciences, University of Rajshahi, Rajshahi 6205, Bangladesh

2- Institute of Climate Change, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia

*Corresponding author’s Email: asifraihan666@gmail.com

## Introduction

The practice of raising domesticated avian species, commonly known as poultry, for the purpose of obtaining meat, eggs, and feathers, has been an integral component of food production since the emergence of agricultural practices. Poultry farming is considered to be a highly efficient technique of animal husbandry due to its utilization of diverse feedstock, including agricultural and home residuals, as well as leftovers from food production (Raihan and Himu, 2023). According to Vaarst *et al*. (2015), the provision of a consistent protein source, along with dietary and nutritional stability, plays a crucial role in addressing the needs of diverse populations residing in rural regions across the globe, particularly in developing nations. Nevertheless, apart from these small-scale home production systems with little environmental consequences, poultry is also a prominent animal category employed in the context of large-scale industrial livestock production. Industrial poultry production, specifically focusing on chicken and to a lesser extent turkey, duck, geese, and other poultry species, constitutes the overwhelming share of worldwide poultry output (Mottet and Tempio, 2017). According to the Food and Agriculture Organization (FAO, 2022), the global production of chicken meat has been projected to reach 137.8 million tons in 2021. Notably, the United States, China, Brazil, and the European Union emerged as the leading poultry meat producers in 2021, with production volumes of 23 million tons, 19.5 million tons, 14 million tons, and 14 million tons, respectively. In the European Union, the distribution of poultry production is concentrated in five member states, which collectively account for more than two thirds of the total production. Among these member states, Poland holds the highest share at 19.2%, followed by Germany at 13.1%, France at 12.8%, Spain at 10.1%, and Italy at 9.9% (AVEC, 2021). In general, there has been a consistent increase in global poultry production over the past decade. According to the FAO, there was a growth rate of 1.32% in 2021. It is anticipated that the growth rate for 2022 would be significantly lower, at 0.73% (FAO, 2022).

According to De Vries and De Boer (2010), although poultry farming is recognized as a highly effective method of livestock management in terms of natural resource utilization and protein acquisition, it remains associated with notable implications for human health and the environment. The majority of industrial poultry production, which includes broilers bred for meat production and layers used for egg production, is mostly conducted on intensive production farms. Intensive poultry production involves the management of large-scale flocks ranging from several thousand to several hundred thousand units. This is often carried out in indoor open floor housing or battery cages equipped with automated feeding and watering systems, resulting in a significantly high animal density (EPRS, 2019). The intensive nature of farming results in a substantial environmental footprint. The availability of feed is frequently reliant on the production of non-local commodities, such as grains, soy, and oil seeds (Mottet *et al*., 2017). The issue of water usage in both feed and poultry production is a serious concern, although it remains comparatively lower than in other animal production systems (Gerbens-Leenes *et al*., 2013).

Intensive chicken farming practices result in the release of emissions that have a significant influence on multiple environmental components, such as the air, water, and soil. Excessive quantities of waste products, such as chicken litter and manure, are frequently generated, beyond the necessary quantities for the fertilization of nearby agricultural land. Excessive utilization of resources might potentially represent a significant hazard to the quality of soil and water. Hence, the presence of surplus quantities necessitates the implementation of storage, transportation, and processing measures, resulting in the generation of waste by-products that necessitate effective management strategies to mitigate the risks of air, soil, and water contamination, as well as potential adverse effects on human health. The interconnection between poultry production, the utilization and storage of manure, and the release of ammonia (NH3), nitrous oxide (N2O), and methane (CH4) gases is well-established. Consequently, these activities significantly contribute to the emission of greenhouse gases, thereby influencing both the well-being of animals and humans (Dróżdż *et al*., 2020). Moreover, it should be noted that poultry manure has the potential to harbor bacteria and pharmaceutical substances, including antibiotics, that are commonly employed in poultry farming. This can result in the contamination of soil and water, thereby contributing to the emergence of antimicrobial resistance among microbial pathogens, including multidrug resistance. The spillover events of antibiotic resistance are depicted in Figure 1.

Dust is also generated within poultry facilities, including components such as feathers, skin pieces, excrement, feed particles, bacteria, and diverse chemical substances, including pharmaceutical compounds (EPRS, 2019). Dust is comprised of particulate matter (PM) with aerodynamic diameters ranging from 0.001 to 100 µm. This PM is further categorized into different fractions, namely PM10, PM2.5, and PM0.1, as described by Akhtar *et al*. (2014). The act of inhaling dust from poultry houses has the potential to cause inflammation and respiratory ailments, which can have negative effects on the well-being of poultry, as well as the health of those working on farms and residents residing in the vicinity of these farms (Viegas *et al*., 2013). According to Nowak *et al*. (2016), poultry farms emit noxious odors that consist of dimethylamine, ammonia, ketones, aldehydes, organic acids, and several other substances. These emissions can have detrimental impacts on the well-being and health of both farm workers and the nearby community. In conclusion, the production of poultry necessitates the utilization of energy and fossil fuels to facilitate various mechanized processes, such as heating, air conditioning, ventilation, and other operational activities within poultry farms. Additionally, the transportation of feed, waste materials, and poultry itself also relies on the consumption of energy and fossil fuels (Vaarst *et al.*, 2015).

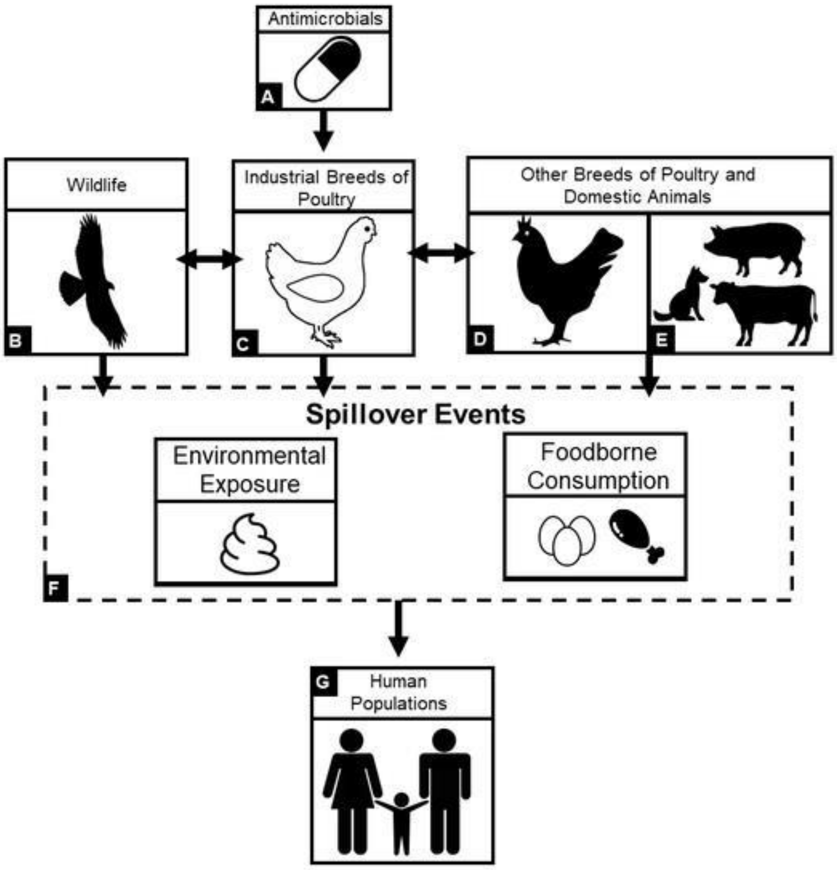

**Figure 1: Spillover events of antimicrobial resistance (Hedman *et al.*, 2020).**

Extensive farming practices, such as organic, free-range, lower-density, and low-impact production systems, have witnessed a surge in popularity, particularly within the European Union. This trend is driven by the desire to enhance farming conditions, promote animal welfare, mitigate environmental impact, and bolster the sector's sustainability. These systems exhibit certain characteristics, including the utilization of chicken genotypes with slower growth rates, reduced animal density accompanied with access to outdoor grazing areas, and a focus on the enhanced utilization of locally sourced feed (Dal Bosco *et al.*, 2021). For instance, the EU Commission Regulation No 889/2008 concerning organic agriculture mandates that chickens must be provided with opportunities to access fresh air, daylight, and outside areas, with a minimum of 4 m2 of room for running.

The regulations pertaining to feed are characterized by stringent guidelines. These guidelines mandate that at least 20% of the feed must be sourced from local or regional producers. Furthermore, the grains utilized in the feed must be free from genetically modified organisms (GMOs). Additionally, the regulations impose rigorous restrictions on the application of pesticides and fertilizers (EC, 2008). Currently, around 10% of the poultry generated inside the European Union (EU) originates from less intensive or extensive methods of production. This sector has shown a consistent annual growth rate of 12% (EPRS, 2019). When executed with precision, these comprehensive production systems have the potential to enhance sustainability by effectively integrating poultry production into the whole farming system. This can be achieved by utilizing locally sourced feeds and optimizing the utilization of marginal regions. Nevertheless, in order for the system to be deemed sustainable, it is imperative to address all facets of sustainability, encompassing environmental considerations (e.g., pollution, management of resources, breed diversity), economic factors (e.g., demand, availability, significance of poultry as a staple food), social dimensions (e.g., industrial farming, rights of employees, animal welfare), and institutional aspects (e.g., regulation, management) (Vaarst *et al*., 2015).

The objective of this review is to evaluate the existing body of information about the environmental and human health implications of intensive poultry farming. Additionally, it intends to examine the issues faced by the sector and provide insights into the most effective strategies for ensuring a sustainable future. The initial section of the study focuses on providing a comprehensive review of the impacts of pollutant emissions on the quality of air, water, soil, plants, and the associated biota. Emphasis is given to the depiction of the dissemination and influence of these entities on the aforementioned ecological domains. Significant emphasis is allocated to the role of antibiotics, particularly within the aquatic environment. The discussion of human health repercussions is also addressed indirectly due to the inherent difficulty in isolating the effects of pollutants on human health from those on the environment, particularly in relation to antibiotics. Nevertheless, our efforts have been focused on restricting the discussion just to the subjects that are inevitable. The latter half of this study centers on examining the effects of poultry farming activities on human health, with a specific emphasis on three vulnerable groups that are highly susceptible to pollution originating from intensive poultry production: agricultural laborers, nearby residents, and customers. In addition to the direct inhalation of agricultural pollutants, the topic of antibiotics is now again being examined due to their extensive utilization and the consequential development of antibiotic resistance, which poses a substantial risk to public health. The analysis concludes by addressing future views and the necessary trajectory that the sector must adopt to effectively address the issues that society will encounter in the future. These challenges encompass increasing populations, changing the climate, resource conservation, and various others.

## Methodology

The current investigation utilized the systematic literature review method as recommended by Raihan and Bijoy (2023). Raihan (2023) asserts that the systematic literature review strategy is widely regarded as a dependable methodology. A preliminary literature assessment was undertaken to identify relevant articles, validate the suggested concept, prevent duplication with previously addressed topics, and ensure the presence of an adequate number of articles for undertaking a thorough analysis of the topic matter. A comprehensive search was conducted using Google Scholar to identify and get both scientific and gray literature pertaining to the effects of chicken farming on the environment and human health. This study aims to assess the environmental and human health implications associated with chicken farming by a comprehensive evaluation of relevant literature published between 1990 and 2023. The Google Scholar search yielded close to one thousand outcomes. A secondary search was conducted to include scholarly articles that have undergone peer review, book chapters, as well as reports from government and international agencies. Subsequently, the investigation examined the titles, keywords, and abstracts of the retrieved search outcomes in order to ascertain their level of relevance. For example, any materials that did not adequately discuss the effects of chicken farming on both the environment and human health were excluded from the analysis. Figure 2 depicts the progression of review criteria utilized in the process of selecting appropriate documents for review assessment.

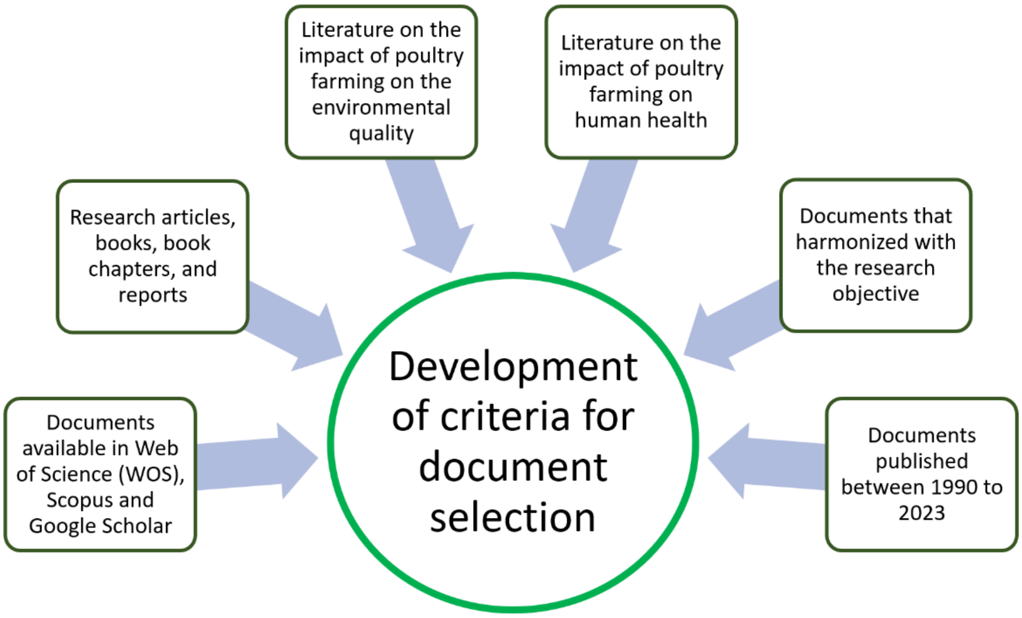

**Figure 2: The development of criteria for the selection of documents.**

The literature review conducted in this study included a total of 113 unique scholarly documents. The current study employed a data verification procedure, whereby each included item was cross-referenced with the associated entry in a portion of the sheet through the use of visual evidence. It is important to highlight that out of the 113 documents that underwent qualitative synthesis, only the publications that provided significant material were included in the reference list found in the manuscript. This suggests that specific articles were omitted from the list of references. Figure 3 depicts the systematic review methodology employed in the present investigation. Once the research topic had been selected, this study proceeded to carry out a methodical search for pertinent publications, analyze and amalgamate information from a variety of literature sources, and produce written materials for the purpose of article review. The synthesis phase involved gathering a diverse array of publications, that were then combined to form conceptual or empirical reviews that were pertinent to the completed research.

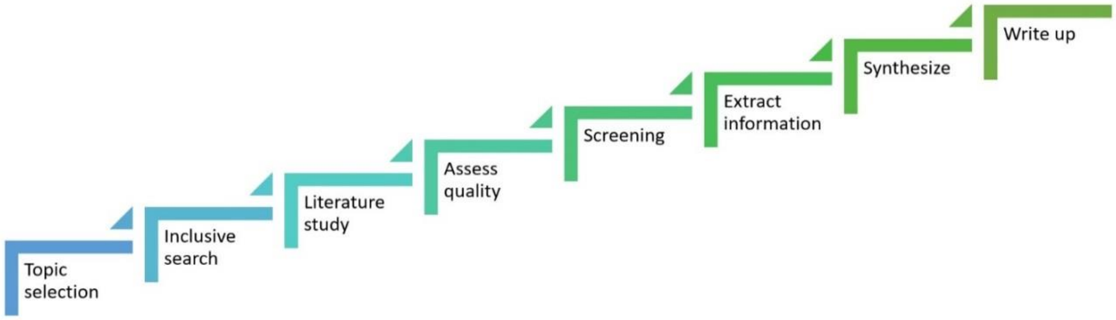

**Figure 3: The procedure of systematic review conducted by the study.**

## Results and Discussion

### *Impact of intensive poultry farming on the environment*

### *Air quality*

Intensive chicken farming, characterized by the concentration of numerous birds ranging from several thousand to several hundred thousand within one or more structures in close proximity, poses a substantial risk as a potential source of physical, chemical, and microbiological contamination to the surrounding environment. The purpose of implementing mechanical ventilation systems in these structures is to provide a continuous supply of fresh air to support the respiratory needs of the developing avian population. Nevertheless, it also releases contaminants originating from avian excrement that feed into the surrounding ecosystem. The potential consequences of this action could result in significant pollution of the immediate vicinity. The emissions of chicken houses can vary based on factors such as the design and operation of the building, the management of animal bedding, and the season of the year. Additionally, the direction of the wind and atmospheric conditions can also influence these emissions (Guo *et al*., 2022).

Poultry farm operations have been found to contribute to the release of several physical and chemical pollutants, including noise, particulate matter (PM), greenhouse gases such as methane and sulfur dioxide, nitrogenous compounds including ammonia (NH3), nitrous oxide (N2O), and nitrogen oxides (NOx), as well as volatile organic compounds (VOCs) (Baskin-Graves *et al*., 2019). The risks mentioned in the statement have adverse effects on both the environment, such as soil acidification resulting from air deposition, and human health, including respiratory illnesses like bronchitis, and asthma in children, as well as lung or heart disease and cancer. The primary source of noise pollution on poultry operations is attributed to the vocalizations and movements of the animals themselves. The acoustic levels within a poultry facility exhibit a variation between 50 dB and 90 dB throughout daylight hours. Exposure to noise levels exceeding 90 dB, which has been associated with heightened stress and anxiety in hens according to Campo *et al*. (2005), can occur when supplementary equipment is operational. It is worth noting that the suggested exposure threshold for employees varies between 85 and 90 dB, contingent upon the specific country, as stated by IOSH (2022). The study conducted by Ginovart-Panisello *et al*. (2020) reported a range of 44 to 63 dB for the environmental noise levels recorded outdoors.

The emissions of greenhouse gases, including carbon dioxide, methane, ammonia, and nitrous oxide, in chicken farming are typically influenced by the management practices employed for manure treatment (Kreidenweis *et al*., 2021). According to the findings of Anderson *et al*. (2021), as documented in the reviewed literature, it has been observed that the presence of aerobic conditions in solid litter originating from poultry houses results in negligible methane emissions from the litter's surface. Nitrous oxide emissions predominantly arise during the storage and field application of the litter, primarily as a result of the nitrification and denitrification processes. According to the European Union emission inventory report, a significant proportion of ammonia emissions in the EU in 2017, specifically 92%, were attributed to agricultural activities. Notably, Germany, France, and Spain emerged as the primary contributors to these emissions. Nevertheless, a study conducted by Strohmaier *et al*. (2019) in Germany examined the quantities of NH3 in the air at a broiler farm, revealing the presence of low levels of this compound. According to Baker *et al*. (2020), there exists a significant degree of variability and ambiguity in ammonia emission parameters. The presence of gaseous ammonia in the atmosphere has a role in the generation of fine particulate matter (PM2.5) by undergoing interactions with water vapor and other air pollutants, such as sulfur dioxide or nitrogen oxides. Hence, the mitigation of ammonia emissions has the potential to decrease the levels of PM2.5 particulate matter in the Earth's atmosphere, as indicated by the findings of Wiegand *et al*. (2022).

Odors are a notable form of gaseous pollution that arises from the practice of intensive poultry farming. These odors are generated as a result of both anaerobic and aerobic microbial processes that occur during the decomposition of waste materials, particularly primary litter. The waste generated during chicken farming consists of various components, including organic particulates, volatile fatty acids, sulfurous compounds (such as H2S and mercaptans), and nitrogenous compounds (such as NH3). These chemicals are released into the atmosphere as malodorous substances (Baskin-Graves *et al*., 2019). The creation of odorants exhibits variability that is influenced by various factors, including bird movement, moisture level, porosity, pH, ventilation, temperature, and air humidity. The emission of odors poses a significant challenge in the context of poultry farming, as it is regarded as a nuisance by neighboring communities, leading to the expression of complaints and protests (Dunlop *et al*., 2016). Another crucial field of research pertains to the detection and measurement of odorous chemicals.

According to Gladding *et al*. (2020), intensive poultry farms have the potential to release both saprophytic and potentially pathogenic bacteria into the surrounding outdoor air. Several studies have indicated that there is a potential increase in the concentration of microbes in the atmosphere up to a distance of 3000 meters from livestock husbandries (De Rooij *et al*., 2019a). The microbial population within chicken houses, encompassing both broilers and laying hens, can exhibit a substantial abundance of bacteria and fungi. In chicken housing facilities, the presence of fungi is typically observed to be comparatively lower in quantity when compared to bacteria. Furthermore, as avian organisms undergo growth and development, their emissions also experience a corresponding increase. Furthermore, it is worth noting that there is a discernible seasonal fluctuation, whereby increased ventilation is typically required during hotter months. According to Plewa and Lonc's (2011) study, there was a significant disparity in the quantity of microorganisms present in the vicinity of a chicken house throughout winter and summer seasons. Specifically, the number of heterotrophic bacteria and fungus was found to be roughly 100 times higher, while staphylococci exhibited an even greater discrepancy, reaching up to 1000 times more in the summer compared to the winter. Furthermore, the study also investigated the coarse (PM10) and fine (PM2.5) bioaerosol fractions in certain instances, as poultry houses have been identified as the primary sources of dust emissions within the animal intensive farming sector. The analysis of settled dust holds significant potential as a valuable means of gathering information pertaining to the presence of pollutants released by chicken buildings. According to Ahmed *et al*. (2020), the concentration of bacteria and fungus in settled dust is significantly elevated.

In addition to the quantification of microorganisms released through poultry house ventilation, the assessment of their variety holds significance. When considering metagenomics investigations, it has been observed that a diverse range of microorganisms is released from chicken houses (Wu *et al*., 2019). According to a study conducted by Wu *et al*. (2019), an analysis of settled dust samples collected from a hen house revealed the presence of around 139 bacterial genera and 107 fungal species. In contrast, a higher number of bacterial genera, specifically 293, were identified in settled dust samples obtained from a duck house. Bródka *et al*. (2012) discovered possible pathogens, including mannitol-positive staphylococci and bacteria belonging to the Enterobacteriaceae family, in the ambient air. Bacteria belonging to the Staphylococcus genus frequently exhibit the ability to synthesize colors, which serve as a mechanism for their enhanced viability in the atmosphere, a hostile milieu for bacterial organisms. Broilers and laying hens reared in intensive agricultural methods are also vulnerable to bacterial and viral diseases affecting the upper respiratory tract. The primary mode of pathogen transmission frequently involves the inhalation of infectious agents, as well as direct contact with diseased avian species, their excrement, litter, or equipment that has been contaminated. Insufficient implementation of bio-security measures can result in farm personnel and veterinarians inadvertently serving as passive carriers, facilitating the transmission of detrimental biological agents. According to Paudel *et al*. (2021), infectious bronchitis virus (IBV), avian pathogenic Escherichia coli (APEC) leading to colibacillosis, and ILT virus (ILTV) causing infectious laryngotracheitis are among the diseases that result in significant economic losses. Figure 4 illustrates contemporary advancements in diverse techniques for the conversion of noxious gases and their corresponding mechanisms within chicken farming operations.

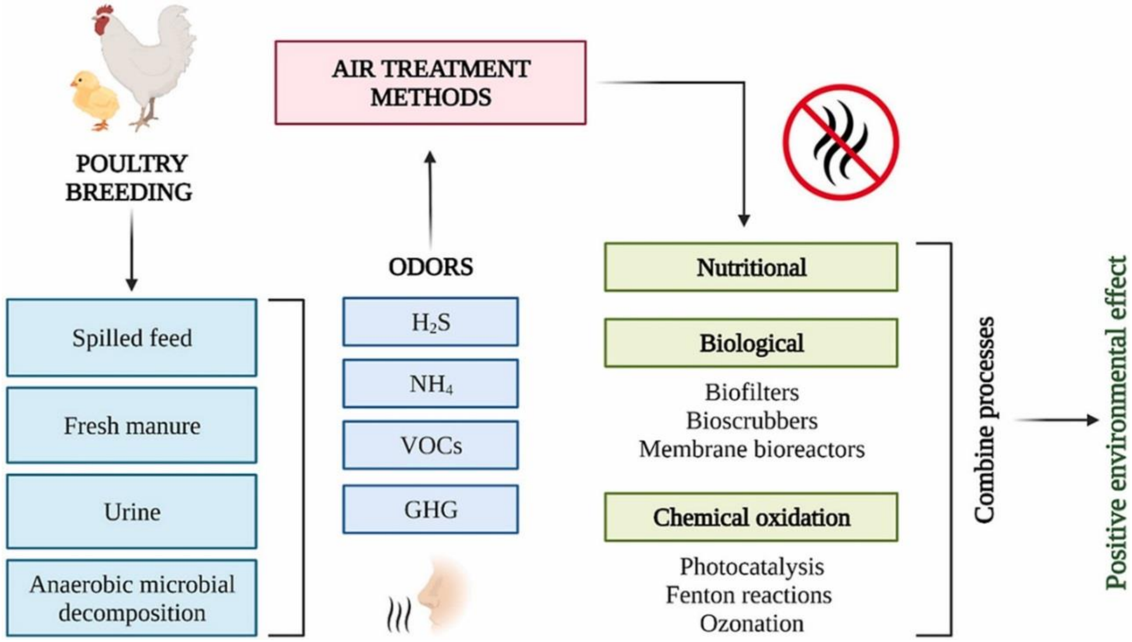

**Figure 4: Contemporary advancements in diverse techniques for the conversion of noxious gases and their corresponding mechanisms within chicken farming operations (Konkol *et al*., 2022).**

*Water quality*

An initial assessment of the influence of agriculture on surface water can be conducted by examining physico-chemical markers of water quality, including dissolved oxygen levels, pH levels, total solids in suspension, biochemical demand for oxygen, ammonium nitrogen concentrations, nitrite concentrations, and phosphate concentrations. The presence of naturally occurring chemical components in animal feces is associated with various detrimental impacts on the quality of surface water. The utilization of poultry manure on pastures and farms has been documented as an indirect source of nitrogen and phosphorus contaminants that can enter downstream water bodies through surface runoff or underground seepage (Bijay and Craswell, 2021). The contamination of water bodies with nutrients leads to the occurrence of hazardous cyanobacterial blooms, resulting in elevated fish mortality rates, a decline in biodiversity, the presence of unpleasant water odors, and potential adverse effects on human health (Cesoniene *et al*., 2019). According to a comprehensive and extensive study carried out in China, there has been a substantial fivefold escalation in the discharge of agricultural nitrogen into water bodies from 1990 to 2018. Notably, the emissions originating from poultry and fruit farming have emerged as the primary contributors to the overall nitrogen output. The overall emissions of phosphorus experienced a sevenfold rise, primarily due to the direct release of manure from animal breeding facilities in close proximity to the bay. Poultry farming has consistently been the leading contributor to phosphorus output in this region over a period of 28 years (Liang *et al*., 2022). Numerous research have also been dedicated to examining the influence of agricultural practices on the discharge of metallic elements into various aquatic ecosystems. Poultry farms were found as a single source of excessive levels of arsenic and nitrates in the context of the Pearl River. The significance of water quality in the examined area is of utmost importance due to the increasing need for agricultural, industrial, and potable water resources (Paul *et al*., 2021).

Pharmaceuticals are a significant category of anthropogenic substances employed in the practice of animal rearing. They are associated, among other factors, with the emergence of drug resistance in microorganisms found in the environment. In general, pharmacological substances supplied to livestock will be eliminated from their bodies through the process of defecation and urination. When appropriately gathered and stored within designated manure or slurry warehouses, the likelihood of their entry into surface waters is minimized. Nevertheless, under certain circumstances, these substances have the potential to be discharged directly into aquatic environments by organisms or inadvertently released due to inadequate handling and storage procedures. In addition, the utilization of animal manure as a means of enriching soil fertility opens a pathway for the dissemination of medicinal substances in many environmental settings, including aquatic ecosystems. This is attributed to the inherent characteristics of these substances, such as their durability, mobility, and ability to interact with solid particles, as highlighted by Sanseverino *et al*. (2018). Over the past twenty years, there has been a notable rise in the detection of various veterinary medications in farm wastewater, as well as in surface and groundwater that are subjected to agricultural practices (Martinez, 2009). The presence of these events is associated with detrimental effects on aquatic ecosystems as a result of the disturbance of natural processes, such as endocrine disruption and the emergence of antibiotic resistance in bacteria. Consequently, they have garnered attention as a subject of growing apprehension within the realm of safeguarding water resources (Sim *et al*., 2011).

Pharmaceuticals intended for human or veterinary use exhibit incomplete metabolism or elimination within organisms, resulting in a proportion, varying between 30% and 90%, being excreted into the environment without undergoing significant changes (Sanseverino *et al*., 2018). A study examining the presence of antibiotics in samples of wastewater has revealed that they are primarily detected in influent livestock wastewater, hence confirming the extensive utilization of antibiotics in animal agriculture. Furthermore, Sim *et al*. (2011) reported a marginal rise in the percentage of antibiotics detected in the effluent samples. According to Sengeløv *et al*. (2003), antibiotics are only partially eliminated in conventional wastewater treatment plants, and in certain instances, the presence of degradation products, which may exhibit higher toxicity than the original compounds, has also been detected. According to the findings of Savin *et al*. (2021), a significant proportion of the wastewater samples obtained from a chicken slaughterhouse exhibited the presence of antibiotic residues. This occurrence persisted even after subjecting the wastewater to both traditional and advanced treatment methods. The quantities of enrofloxacin identified in untreated wastewater were found to surpass the projected value of its no effect concentrations. This occurrence is likely attributed to an inadequate duration of the period of withdrawal following the usage of antibiotics.

Water ecosystems have been acknowledged as a substantial repository of medicines, as well as antibiotic resistance genes. The concentrations of antibiotics observed in aquatic samples are rather modest; yet, they have the potential to facilitate the development of antimicrobial resistance through the transfer of genes across bacteria (Sanseverino *et al*., 2018). In order to analyze the effects of antimicrobial agents on water compartments, it is necessary to conduct an environmental risk assessment (ERA) in accordance with established international and European norms. This assessment should be supplemented by up-to-date monitoring of the environment and toxicological data, as recommended by Tell *et al*. (2019). Furthermore, in order to accurately estimate the ecological risk assessment (ERA), it is imperative to ascertain the usage patterns of antimicrobial agents in both veterinary and human contexts (EMA, 2021). According to a study conducted by Li *et al*. (2012), it has been demonstrated that sulfamethoxazole has the potential to pose significant risks to both algae and plants. Nevertheless, ERA reports primarily concentrate on assessing the environmental ramifications of each individual component. In the context of actual ecological systems, both the biotic and abiotic components are concurrently subjected to combinations of chemicals. According to Guo *et al*. (2016), the combination of antibiotics may be leading to detrimental impacts on aquatic organisms.

Pesticides can be classified as water-based contaminants that result from animal farming, specifically through the runoff from farmland and agricultural soils when manure containing pesticides has been sprayed (WHO, 2019). Moreover, it has been observed that in certain geographical areas, pesticides are employed as disinfectants for agricultural structures, such as chicken facilities (Cabañes, 2021). Animals may also be subject to exposure through consumption of food that has been contaminated (WHO, 2019). Organochlorine insecticides are also employed for the purpose of eradicating agricultural pests that have a detrimental impact on cattle and poultry. In nations characterized by climates conducive to heightened mosquito proliferation, such as India, the application of insecticides is extensively employed as a means to eliminate mosquito larvae within breeding habitats.

Numerous research have been conducted on the subject of microbial contamination in various environmental compartments of water. *Campylobacter* spp. is frequently detected in surface water in Europe, primarily as a result of contamination from animal feces, wastewater effluent, and runoff from farms. The study conducted by Mulder *et al*. (2020) revealed that *Campylobacter* spp. strains were identified in 66% of the samples of surface water collected in the Netherlands. This finding indicates that these pathogens are widely distributed in surface water due to contamination from fecal sources. In contrast to the majority of animal sources, it was shown that European surface water had a predominant contamination with *C. coli*. The majority of human campylobacteriosis infections are attributed to these microbiological agents, with poultry-associated Campylobacter strains being predominantly detected in agricultural waters, at discharge points of wastewater treatment facilities, and in regions characterized by a high density of chicken. Contrary to this assertion, Mulder *et al*. (2020) discovered that in the context of identifying Campylobacter strains in wild birds, the prevalence was higher in regions characterized by low poultry population.

A research investigation carried out in the state of Maryland from 2007 to 2016 revealed a favorable association between the incidence of *campylobacteriosis* among the resident population and the frequency of wells in regions characterized by a high concentration of broiler chicken farms (Murray *et al*., 2020).

Furthermore, it is important to take into account the waste generated by slaughterhouses when assessing the influence of the poultry business on the water environment. This waste undergoes preliminary treatment on-site before being released either directly into water bodies or into municipal wastewater treatment facilities. A research investigation was undertaken in Germany to examine the prevalence of various microorganisms in effluent from poultry slaughterhouses. The use of both conventional and sophisticated methods of wastewater treatment has resulted in a substantial decrease in the presence of contaminants. To safeguard aquatic ecosystems, it is recommended to employ integrated treatment techniques when dealing with microbiologically heavily contaminated wastewater (Savin *et al*., 2021).

Various physicochemical and microbiological agents, as well as contaminants, can be present in wastewater and runoff water originating from farms or fields that have been subjected to intensive farming practices and treated with manure. The transfer of excessive quantities of naturally present constituents (such as nitrogen and phosphorus), contaminants (such as pharmaceuticals, steroid hormones, and heavy metals), and pathogens (including bacteria, fungi, and viruses) from agricultural waste to aquatic ecosystems can disrupt their equilibrium and have detrimental effects on plant life, as well as invertebrate and vertebrate organisms (Cao *et al*., 2021). Nevertheless, there can be substantial variations in the conditions and management practices associated with livestock manure across different regions, thereby leading to considerable disparities in their ecological impacts (Oyewale *et al*., 2019). Examining the impact of agricultural practices, such as animal husbandry, on aquatic ecosystems poses significant challenges, although it is of utmost importance in safeguarding water quality. In order to effectively address new difficulties, it will be necessary to employ innovative methodologies.

### *Soil quality*

Over the past few years, there has been a significant global growth in the poultry sector (AVEC, 2021). The proliferation of chicken production has resulted in a rise in the quantity of organic waste generated, such as manure and litter. As per the Animal by-products Regulation of the European Union (EU), manure is classified as an animal by-product. It is specifically defined as the excrement or urine of farmed animals, except farmed fish, whether or not it is accompanied by litter. Poultry litter is the term used to describe the combination of poultry feces with feed waste, feathers, and bedding materials such as wood shavings or sawdust. According to

Dróżdż *et al*. (2020), both animal byproducts include vital plant nutrients, including nitrogen (N), phosphorus (P), and potassium (K). The quantity and caliber of excrement generated are contingent upon the quantity and classification of avian livestock. The chemical composition of poultry dung and litter exhibits variability due to multiple factors, including the breed of poultry, the content of their feed, the kind and quantity of bedding material used, the density of animals within the poultry house, the duration of their stay in the house, and seasonal variations (Dróżdż *et al*., 2020). Nitrogen is eliminated from organisms in the form of both organic and inorganic substances. In the case of manure, nitrogen exists as uric acid, ammonium, urea, and feed protein nitrogen. Creatine is also found in trace quantities, contributing to the presence of nitrogen (N). The emission of nitrogen from manure encompasses four primary types, namely ammonia, dinitrogen, nitrous oxide, and nitrate. Conversely, phosphorus is predominantly released in the form of phosphates (Rayne and Aula, 2020). Poultry dung has the potential to include significant quantities of various contaminants, including pesticide residues, hormones, antibiotics, pathogens, and heavy metals (Li *et al*., 2020). The presence of these contaminants limits the suitability of poultry manure for use as a fertilizer. The repetitive and prolonged use of poultry manure that is polluted can lead to the buildup of contaminants in agricultural soils. This accumulation has the potential to increase the bioavailability and toxicity of these contaminants in the surrounding environment.

Poultry litter has been utilized for several decades as an economically viable organic fertilizer, exhibiting a beneficial impact on the growth and productivity of diverse crops while facilitating the rehabilitation of ecological soil structures (Kyakuwaire *et al*., 2019). The impact of manure on soil quality is contingent upon various factors, including its physical and chemical attributes, management practices, application rate and timing, soil composition, and climatic conditions (Rayne and Aula, 2020). The usage of organic matter (OM) and nutrients in soil has been found to have a positive impact on its physical, chemical, and biological aspects (Antonious, 2018). Soil organic supplements have been found to have a positive impact on soil attributes by increasing organic matter (OM) content. This increase in OM leads to improvements in various aspects of soil, such as enhanced retention of water and nutrient availability, increased total pore space, improved stability of soil aggregates, increased resistance to erosion, better temperature insulation, and reduced density of the soil (Rayne and Aula, 2020). The application of poultry manure has the potential to elevate soil pH levels and enhance nutritional composition. The aforementioned effects are primarily observable in sandy loam soils with a slightly acidic pH (Adekiya *et al*., 2020).

In a study conducted by Kobierski *et al*. (2017), it was noted that the application of poultry manure for a period of 10 years resulted in a notable rise in the levels of organic carbon, overall exchangeable cations, and soil pH. According to Kobierski *et al*. (2017), the application of poultry manure as a fertilizer resulted in an increase in the overall concentrations of zinc (Zn), copper (Cu), manganese (Mn), and iron (Fe), as well as enhanced availability of phosphorus (P) and potassium (K) for plant uptake. Hoover *et al*. (2019) conducted a comprehensive field study spanning two decades in the United States, which revealed that the extended utilization of poultry manure has a positive impact on soil health. Specifically, the study demonstrated a notable augmentation in particulate organic matter (POM), a labile component of organic matter (OM) that exhibits the potential to enhance soil particle stabilization, as well as improve infiltration and water retention capabilities.

According to a study conducted by Rayne and Aula (2020), the application of poultry manure has the potential to influence soil physical qualities. According to the findings of Agbede *et al*. (2017), the application of poultry manure at higher rates resulted in a decrease in bulk density of the soil and temperature, while simultaneously enhancing total porosity and the amount of moisture. According to the findings of Are *et al*. (2017), it was demonstrated that the application of poultry manure resulted in enhancements to the physical qualities of the soil. These improvements were observed in the form of reduced soil compaction, increased porosity, and enhanced stability of water aggregation.

Overall, the utilization of poultry manure has been found to have a beneficial impact on several soil biological parameters. The study aimed to assess the effects of manure fertilization on various soil parameters, including soil microbial biomass, soil respiration, nitrification, and enzymatic activity. According to Antonious *et al*. (2020), the introduction of chicken manure into silty soil resulted in an improvement in soil microbial activity, as evidenced by an increase in the dissolution of soil enzymes including urease, invertase, and acid phosphatase. The study conducted by Acosta-Martínez and Harmel (2006) examined the effects of varying rates of poultry application of manure on soil microorganisms. The results of their investigation revealed an increase in microbial biomass and enzyme activity related to the cycling of carbon, nitrogen, phosphorus, and sulfur. The study conducted by Kobierski *et al*. (2017) revealed the observation of a decrease in phosphatase activity and an upsurge in the biological index of soil fertility. On the other hand, Delgado *et al*. (2012) demonstrated that incorporating poultry manure, specifically bedding straw or sawdust, into a sandy loam soil resulted in a notable enhancement of soil enzyme activity and an increase in the degree of soil basal metabolism.

To date, the primary focus of research on chicken manure has been its efficacy as a fertilizer, as highlighted by Adekiya *et al*. (2020). Nevertheless, the excessive and frequent utilization of manure, coupled with inadequate or unregulated methods of managing and disposing of poultry waste, can potentially lead to the introduction of various antibiotics, heavy metals, steroids, and microorganisms into the soil (Dróżdż *et al*., 2020). This influx of substances has the potential to negatively impact the biological activity of the soil, contaminate both surface and groundwater, and accumulate within organisms and edible plants. An investigation conducted by Parente *et al*. (2021) in Brazil demonstrated the presence of fluoroquinolone antibiotics in soil following 1.5 years of consistent application of poultry litter as fertilizer. The observed antibiotic concentration has been found to pose a significant environmental danger. According to Dróżdż *et al*. (2020), upon introduction into the soil environment, antibiotics have the potential to impact both the composition and activity of soil bacterial populations. Additionally, they can contribute to the emergence and spread of antimicrobial resistance towards these compounds. In a recent study conducted by Xu *et al*. (2022) in China, it was shown that the utilization of fresh chicken manure (aged for a duration of one year) during field application resulted in a notable augmentation in the prevalence of antibiotic resistance genes.

Current scholarly investigations have primarily concentrated on the origins and presence of pharmaceuticals and veterinary medications in soil. Additionally, study has explored the processes of sorption and biodegradation of these substances within soil (Gworek *et al*., 2021), as well as their impacts on soil microbial activity (Antonious *et al*., 2020). In contrast, the literature pertaining to the ecotoxicity of these compounds in the soil environment is limited (Parente *et al*., 2021). Moreover, investigations in this area frequently include model systems and are carried out under tightly regulated laboratory settings. The research conducted by Parente *et al*. (2021) shown a substantial influence of poultry litter polluted with fluoroquinolones (ciprofloxacin and enrofloxacin) on the avoidance behavior, reproductive capacity, and mortality rates of earthworms. In a separate investigation, Delgado *et al*. (2012) documented the detrimental impact of poultry manure on both earthworm biomass and the germination process of two plant species.

In general, the existing body of knowledge regarding manure composition, its influence on soil quality, and its fertilizing efficacy is deemed satisfactory. However, there remains a dearth of information concerning the behavior of pharmaceuticals, specifically antibiotics, derived from poultry manure in both soil and natural fertilizers, as well as their potential ramifications on the soil environment. It would be beneficial to do additional research in this particular area, and it is recommended to promote the routine monitoring of chicken manure composition prior to its application in agricultural fields.

*Plant health*

Nitrogen (N), phosphorus (P), and potassium (K) are essential plant nutrients that can be found in manure. However, the presence of nitrogen and phosphorus in manure can give rise to notable environmental difficulties. Poultry litter contains four distinct kinds of nitrogen, including complex organic nitrogen, labile organic nitrogen, ammonium, and nitrates (Bolan *et al*., 2010). Ammonia is released in the form of nitrogen in broiler production (Belt, 2015). The substance is assimilated by the foliage of plants (Krupa, 2003), where it adheres to the external layer. The growth of tomatoes, cucumbers, soybeans, and Festuca grasses is hindered in an environment characterized by elevated levels of ammonia. Conversely, the growth rate of elm and cane plants is observed to increase when exposed to air with a greater concentration of ammonia. Broiler farms are known to emit substantial quantities of ammonia. However, the implementation of a carefully chosen vegetation cover surrounding chicken houses has been found to effectively mitigate its levels and thereby alleviate the associated odor.

The utilization of manure in accordance with the nitrogen requirements of crops frequently results in an overabundance of other nutrients, particularly phosphorus, in comparison to the crop's specific needs. According to the study conducted by Li *et al*. (2014), it was found that a significant proportion of the total phosphorus (P) present in broiler litter, namely 69%, is soluble in water. This characteristic makes it highly susceptible to leaching into the surrounding environment. Several organic phosphorus compounds, such as phytates, exhibit higher affinity for soil particles, whereas numerous other compounds have weak binding capabilities with soil. This phenomenon might result in localized phosphorus saturation and subsequent loss (Cade-Menun, 2005). The rapid growth of plant roots in nutrient-rich soil, particularly those containing high levels of phosphorus (P) and/or nitrogen (N), has been observed (Hodge, 2004). According to Havlin *et al*. (2014), the application of phosphates and ammonium at a local level has been found to have a substantial impact on phosphorus uptake and plant development. This effect is attributed to the encouragement of root proliferation and the acidity of the rhizosphere. The study conducted by Delgado *et al*. (2012) has provided evidence indicating that the impact of manure on the germination process, shoot length, and fresh weight of the stem is contingent upon the specific crop species involved. The overutilization of nitrogen (N) and phosphorus (P) in fertilizers has been identified as a contributing factor to the reduction of biodiversity in nature (Lambers *et al*., 2010). The disturbance of biodiversity within plant populations can lead to the prevalence of a small number of species, resulting in alterations to the overall structure of the plant community (Rohr *et al*., 2016).

On the other hand, by restricting the utilization of nitrogen (N) and phosphorus (P), it becomes feasible to employ the microbiome, specifically bacteria and fungus, as a means to enhance the absorption of nutrients, particularly phosphorus, by plants (Owen *et al*., 2015). According to Simpson *et al*. (2011), the quantity of phosphorus (P) utilized exceeds the amount present in the final plant output by a factor of two to five. Additionally, Kant *et al*. (2011) indicate that crops only absorb 30-40% of the nitrogen (N) employed, highlighting the significance of this phenomenon from both economic and environmental perspectives. Agricultural crops exhibit a significantly higher phosphorus content compared to wild vascular plants, with the latter displaying a phosphorus level that is nearly 50% lower. The utilization of substantial quantities of phosphorus by the application of manure has been seen to lead to a decrease in the levels of iron and zinc in plants. This drop in iron and zinc content has frequently been associated with the manifestation of deficiency symptoms related to these two essential micronutrients (Fageria, 2001). Zinc (Zn) holds significant importance as an essential trace element throughout biological processes. A shortage in zinc has a detrimental impact on the growth of plants, leading to the inhibition of growth, shortened internodes, reduced leaf size, and interveinal chlorosis.

In addition to nitrogen (N), phosphorus (P), and potassium (K), manure contains a variety of micronutrients, including aluminum (Al), iron (Fe), manganese (Mn), zinc (Zn), chromium (Cr), copper (Cu), nickel (Ni), cadmium (Cd), lead (Pb), and mercury (Hg) (Delgado *et al*., 2012). The poultry business utilizes trace elements such as arsenic (As), cobalt (Co), copper (Cu), iron (Fe), iodine (I), manganese (Mn), selenium (Se), and zinc (Zn) to mitigate deficiencies and illnesses in poultry, enhance weight gain and feed conversion ratio, and augment egg production (Patra and Lalhriatpuii, 2020). The primary approach of mitigating the presence of possible pollutants, such as nitrogen (N) and phosphorus (P), in chicken manure is through the optimization of nutrient utilization in feed. According to Jackson and Bertsch (2001), a significant proportion of the arsenic (As) present in poultry excrement exists in a water-soluble state, specifically as arsenate, arsenite, dimethyl arsenic acid, and monomethyl arsenic acid, constituting over 90% of the total As content. The study conducted by Jackson *et al*. (2006) provided evidence of a positive association between the presence of arsenic (As) in soils and the quantity of chicken litter applied, suggesting that the arsenic found in the soil can be attributed to poultry farming activities. The impact of abiotic factors on plant growth and productivity is well-documented in the scientific literature, as these factors play a crucial role in several biochemical and physiological processes (Abbas *et al*., 2018).

The utilization of antibiotics exerts a pronounced impact on the development and maturation of plants planted in soils enriched with manure derived from animals subjected to antibiotic treatment. The discoloration of leaves due to antibiotics and the occurrence of chlorotic and necrotic alterations are consequences of the disruption of chlorophyll levels in plants. This disruption is induced by the degradation or changing of the ratio between chlorophyll a and chlorophyll b (Liu *et al*., 2013). The evaluation of the photosynthetic machinery in plants under stress conditions can be effectively conducted by analyzing disruptions in the chlorophyll ratio, as suggested by Li *et al*. (2011). According to Liu *et al*. (2013), the presence of low and very low levels of antibiotics has been found to facilitate the process of chlorophyll biosynthesis. This effect is achieved by the alteration of nucleic acids and chloroplast proteins, leading to a decrease in the activity of chlorophyllase and therefore preventing the destruction of chlorophyll. The introduction of antibiotics into the chloroplasts has the potential to disturb the normal operation of the photosynthetic machinery at several stages, including the process of chlorophyll manufacture. The phenomenon of free radical buildup in various plant species has been seen in the presence of antibiotics. The presence of hydrogen peroxide within plant cells leads to the peroxidation of membrane lipids, resulting in the impairment of biological membranes (Gomes *et al*., 2020).

The study conducted by Adeel *et al*. (2017) has shown that there is a correlation between significantly reduced levels of estrogen and the disruption of reproductive cycles as well as the impairment of organ functions in aquatic animals in their natural habitats. In contrast, the impact of sex hormones on plants is contingent upon the specific species under investigation (Chen *et al*., 2021). The application of steroid estrogen hormones or their precursors to plants has been observed to have an impact on various aspects of their growth and development, including root and shoot development, flowering, and germination (Adeel *et al*., 2017). Manure plays a significant role in the process of plant production. Hence, the vital factors for producing high-quality plant material are its overall quality, absence of sex hormones, antibiotics, toxic metals, and a suitable nitrogen-to-phosphorus ratio.

### *Impact of intensive poultry farming on human health*

#### *Microbiological risks in poultry farms and the health of employees*

Intensive chicken farming practices have led to alterations in the breeding environment, which have subsequently facilitated the proliferation and dissemination of various microorganisms throughout all phases of poultry production. This encompasses breeding flocks, hatching plants, and commercial flocks. Irrespective of whether the farming process occurs in specialist poultry farms employing an intensive fattening method or on small-scale farms, it is frequently characterized by the prolonged presence of workers in an environment that is heavily contaminated with biological agents. The primary health hazard faced by this particular occupational cohort stems from exposure to organic particulate matter. The composition of the substance includes minerals derived from the soil, as well as particulate matter that has settled, such as feed particles, litter, excrement, fragments of feathers, and shed skin cells. Additionally, microorganisms such as bacteria, fungi, and viruses are present, along with harmful gases like ammonia (NH3), carbon dioxide (CO2), and hydrogen sulfide (H2S). Chemical particles originating from substances like fertilizers, pesticides, or disinfectants are also found within the substance (Awad *et al*., 2010). The available scientific literature indicates that prolonged exposure to deleterious biological agents present in dust derived from animals or plants can potentially result in various respiratory disorders and diseases. These include chronic obstructive pulmonary disease (COPD), bronchial asthma, chronic bronchitis, bronchial hyperreactivity, allergic alveolitis, organic dust toxic syndrome (ODTS), as well as irritation of mucous membranes, conjunctiva, and skin (Rylander and Carvalheiro, 2006).

In the past decade and a half, the avian influenza virus has emerged as a substantial concern, impacting not just the poultry industry with its substantial economic ramifications, but also posing a threat to public health, as acknowledged by the World Health Organization (WHO, 2020). The virus in question primarily resides in burrowing poultry, such as chickens and turkeys, as well as wild birds, which have the ability to transport it across significant distances. Since 1997, there has been a notable increase in reported cases of human infection with highly virulent viral strains of avian influenza, which were previously limited to birds. This phenomenon occurred after the epizootic avian influenza virus successfully crossed the species barrier (Wu *et al*., 2019). Based on data provided by the World Health Organization (WHO, 2020), a total of 862 instances of the aforementioned illnesses were identified globally by the conclusion of 2020. Out of this figure, 455 cases, accounting for 52.8% of the total, led to fatalities among the infected individuals. The primary mechanism by which avian viruses disseminate is via airborne transmission. The development of infection can occur through inhalation of infected droplets or their desiccated residue containing infectious material, as well as through direct contact with avian hosts that are ill. The potential outcomes of this phenomenon include the development of severe influenza, pneumonia, and respiratory failure (Uyeki and Peiris, 2019). The World Health Organization (WHO, 2005) has identified potential modes of virus transmission that include polluted water, direct injection through the nose or eyes, and the use of untreated poultry feces as soil fertilizer. According to a study conducted by the European Centre for Disease Prevention and Control, individuals who have prolonged and direct exposure to infected domestic or wild birds, particularly those working in small livestock farms, large commercial poultry farms, slaughterhouses, and involved in the culling of infected flocks, are considered to be at high risk for avian flu viruses (Kouimintzis *et al*., 2007).

Gram-negative bacteria, characterized by their allergenic and endotoxic qualities, along with Gram-positive bacteria and actinomycetes, provide a significant risk to the well-being of individuals engaged in the field of chicken breeding. According to Gladding *et al*. (2020), the measured levels of mesophilic bacteria in the air of chicken barns consistently surpass the suggested threshold limit value for acceptable microbiological condition in such occupational settings.

Gram-negative rods, known for their ability to induce occupational infectious diseases, typically zoonoses, as well as allergy and immunotoxic diseases, exhibit optimal growth and reproduction in environments characterized by high humidity and warmth, such as chicken buildings. According to Tang *et al*. (2006), the primary mode of infection is by the inhalation of droplets that are in the air through direct contact with birds that breed or suspended particles of dust containing feces and feathers. Ingestion is a less frequent route of transmission. The potential transmission of ornithosis, caused by Chlamydia psittaci, can occur when farm workers come into direct contact with birds, particularly those such as chickens, turkeys, ducks, and geese, which may serve as reservoirs for this bacterium. Poultry farm employees may potentially encounter Escherichia coli, a bacterium that can be found at elevated concentrations inside the air of poultry buildings (Chinivasagam *et al*., 2009). Non-infectious Gram-negative rods are also significant contributors to the production of endotoxins and allergens. According to Ivester *et al*. (2014), both of these elements, when present in organic dust, have the potential to contribute to a variety of respiratory ailments and diseases. Bacterial endotoxins represent a distinctive feature of the outer membrane of bacterial cell walls and are specifically recognized by human cells involved in the non-specific immune reaction. The quantities of bacterial endotoxins in the atmosphere of chicken barns are typically above the minimum limit value. The impact of endotoxins on human health has been extensively studied and is widely comprehended. When inhaled, endotoxin particles stimulate non-specific pulmonary macrophages, resulting in the secretion of several chemicals that possess potent biological activity. The potential consequences of this condition include pulmonary inflammation, elevated body temperature, disruptions in gas exchange, and bronchospasm. Bacteria belonging to the Enterobacteriaceae family including the species Alcaligenes faecalis are known for their notable endotoxic and allergenic qualities. Furthermore, it has been observed that several species of Acinetobacter, which are frequently found in organic dust within poultry buildings, are considered to be significant contributors to the development of allergy alveolitis and organic dust toxic syndrome (ODTS) in this occupational setting (Stuper-Szablewska *et al.*, 2018).

Gram-positive cocci are another abundant microbial species seen in chicken farms. The presence of emission sources such as the respiratory system and epidermis of reared birds confers a notable quantitative advantage to these bacteria in comparison to other microbial constituents in the atmosphere. These bacteria have the potential to induce purulent infections, respiratory tract inflammation, poisoning, and in severe instances, sepsis in persons who are exposed to them. According to recent scientific literature, there is an increasing concern regarding opportunistic infections in both humans and animals. These infections pose a significant hazard due to the wide range of antibiotic resistance found among the identified strains (Graham *et al.*, 2009). It is important to highlight that the spread of antibiotic-resistant bacteria can arise not solely from direct human interaction with poultry, but also from the dispersion of bacterial strains in natural environments caused by the application of poultry manure and litter as soil fertilizers (Graham *et al.*, 2009). According to Milanowski *et al.* (1998), there is a common occurrence of Gram-positive non-sporulating rods belonging to the genera Arthrobacter, Brevibacterium, and Corynebacterium, as well as various species of Bacillus, in the air of chicken houses. The significance of Gram-positive bacteria in the causation of occupational illnesses has thus far been inadequately comprehended. The assessment of their possible health hazards cannot be primarily based on their infectious and allergic qualities. Multiple studies have indicated that peptidoglycans released from the cell walls of bacteria, which are immunologically active when airborne, have a significant impact on the development of complex bacterial infections. These peptidoglycans enhance the immunological effects of endotoxins and initiate inflammatory responses in lung tissue (Myhre *et al.*, 2006).

One of the microbiological hazards faced by employees in the chicken industry involves the presence of mold. These molds tend to thrive in environments with high humidity levels, particularly on a range of organic substances including stored fodder, bedding, soil, and within breeding facilities. Poultry farm employees are regularly subjected to airborne fungal spores on a daily basis. However, this type of exposure has the potential to result in the emergence of significant immune system illnesses, such as allergy alveolitis and organic dust toxic syndrome (ODTS). The most often isolated genera from poultry buildings include Penicillium, Aspergillus, Mucor, Cladosporium, Alternaria, Scopulariopsis, Fusarium, and Acremonium. These genera are known to be associated with the growth of molds in such environments. Aspergillus fumigatus is a highly prevalent fungal species that is widely acknowledged for its significant pathogenicity. It is mostly associated with the development of allergic respiratory conditions such as bronchial asthma, asthma, and allergic rhinitis, as well as aspergillosis affecting the lungs, bronchi, and pleura. In addition to A. fumigatus, various other species of mold can also induce allergic alveolitis and organic dust toxic syndrome (ODTS) in individuals who come into contact with breathing of organic dust carrying fungal conidia. In breeding premises with high humidity levels, various microorganisms including molds and yeasts such as Geotrichum candidum, Cryptococcus neoformans, Rhodotorula, and Candida species can be found. These microorganisms have been associated with a range of negative health effects (Stuper-Szablewska *et al.*, 2018). Workers in the chicken industry may face particular risks from allergens, mycotoxins, glucans, and toxic volatile metabolites generated by these microorganisms. The predominant proportion of allergens derived from fungi are proteinaceous in nature, mostly found within the cellular wall and released into the extracellular environment as enzymatic entities. According to Stuper-Szablewska *et al.* (2018), the genera Alternaria, Cladosporium, Aspergillus, Penicillium, Trichoderma, and Mucor are particularly allergenic. The presence of fungal antigens in organic dust can result in hypersensitivity reactions, which can manifest as a range of allergic conditions such as rhinitis, bronchial asthma, urticaria, atopic dermatitis, bronchopulmonary aspergillosis, allergic sinusitis, and alveolitis (Bogacka, 2008).

Mycotoxins are a class of secondary metabolites produced by molds, which have been found to possess potent poisonous properties that can adversely affect both people and animals. These compounds have the ability to disperse through the atmosphere via conidia, fragments of mycelium, or a substrate that supports fungal growth. Fungal metabolites are frequently generated during the process of fungal proliferation and then discharged into the surrounding milieu in substantial volumes, particularly in instances where the fungal colony experiences deficiencies in both nutrients and water. The primary health hazards are aflatoxins generated by Aspergillus flavus and A. parasiticus, ochratoxins produced by Aspergillus ochraceus and Penicillium verrucosum, as well as trichothecenes and zearalenone produced by Fusarium, Cephalosporium, Myrothecium, Trichoderma, and Stachybotrys species (Awuchi *et al.*, 2022). Mycotoxins possess toxicological characteristics that include toxicity, carcinogenicity, teratogenicity, and mutagenicity. The reduction in macrophage activity contributes to the progression of infections and maybe promotes the growth of malignant tumors. Extensive research has been conducted on the deleterious impact of mycotoxins following oral exposure, however the consequences of inhaling dusts carrying these metabolites remain relatively understudied. According to Klich (2009), there is a belief that exposure to fungal toxins through inhalation could potentially contribute to the onset of liver, tracheal, bronchial, and lung cancer.

During a period of intense growth, molds have the ability to generate volatile organic compounds (VOCs). Typically, the aforementioned substances consist of aldehydes, alcohols, ketones, terpenes, esters, and amines, characterized by their relatively low molecular weight and possessing qualities that induce irritation, toxicity, and carcinogenicity. These chemicals impart a distinct odor to the indoor spaces inhabited by fungi. Fischer and Dott (2003) assert that mold is recognized as a contributing factor to the development of unfavorable health effects commonly referred to as "sick building syndrome (SBS)." These effects are typically observed in individuals residing in buildings that have been contaminated with mold. Fungi can have negative impacts on human health beyond their known allergenic effects, as they produce compounds that possess immunotoxic properties. Water-insoluble glucose polymers are a constituent of the cellular wall in the majority of fungus and certain bacteria (Douwes, 2005). Exposure to elevated quantities in the atmosphere has the potential to induce ocular and pharyngeal irritations, as well as provoke coughing and pruritus of the skin.

### *Health effects on neighbors*

The process of estimating the dispersion of bioaerosols in the vicinity of an emission source through concentration measurements is a highly intricate and labor-intensive task. Consequently, investigations into the health effects of bioaerosols rely on evaluating the well-being of the local community, without specific information regarding the structure of the bioaerosol and the length of its influence on residents. Nevertheless, the dispersion of bioaerosols can also be replicated by the utilization of mathematical models. An observable exponential decline in concentrations is evident as the distance from the emission source increases. Numerous research studies have been conducted to examine the potential health impacts of bioaerosol exposure on individuals residing in close proximity to farms with livestock (Hooiveld *et al.*, 2016). The majority of these papers highlight the adverse effects of this phenomenon on the respiratory system's functionality. Research undertaken in the northern region of Germany, characterized by a significant concentration of livestock farms, particularly those involved in poultry and pig production, has revealed a decline in overall well-being and an elevated occurrence of respiratory symptoms, specifically wheezing, among local inhabitants (Radon *et al.*, 2007). Furthermore, it has been observed that the most significant kind of chicken exposure is associated with acute respiratory illnesses.

The literature presents diverse findings regarding the heightened susceptibility to pneumonia in proximity to intensive chicken farming operations. Studies conducted by Smit *et al*. (2017) and Hooiveld *et al*. (2016) have identified a notable rise in lower respiratory tract infection, specifically pneumonia. According to the findings of Smit *et al*. (2012), there was a higher prevalence of pneumonia observed in the adult population residing at a proximity of 1 kilometer from a chicken farm. According to Smit *et al*. (2017), the findings indicate that individuals residing in close proximity to chicken farms and experiencing high levels of dust exposure are at an increased risk of developing pneumonia caused by human (non-zoonotic) commensal infections. Upon reviewing the provided articles, it becomes evident that there are several areas where knowledge remains incomplete and would greatly benefit from more research. The comprehensive investigation of the amount and makeup of bioaerosol in regions commonly visited by local residents, as well as its longevity and duration, and the specific direct effects on the health status of the nearby population, remains incomplete. Similarly, it is crucial to prioritize health assessment studies that rely on objective testing such as lung function and biochemical assays conducted over extended durations. Addressing these gaps would significantly enhance our comprehension of the pertinent matters.

The majority of microorganisms present in the atmosphere are typically observed in clusters or adhered to bigger particulate matter. These substances have the potential to induce mechanical, infectious, toxic, and/or sensitizing reactions inside the respiratory tract. Additionally, they can exhibit synergistic effects when combined with other irritants such as ammonia or dust, further exacerbating irritation of the mucous membranes. The dry matter content of broiler dust is estimated to be around 92%. In terms of chemical composition, it consists of roughly 60% crude protein, 9% fat, and 4% fiber. Among the inorganic elements present, calcium, originating from the feed, is the most abundant, followed by magnesium, and trace amounts of copper, iron, and zinc (Yusof *et al*., 2023). The deposition of dust particles in different regions of the respiratory system is contingent upon factors such as diameter and shape. The spatial distribution of particles and its subsequent retention inside the respiratory system plays a crucial role in determining the kind and extent of interactions between inhaled particulate matter and the tissues it comes into contact with. Numerous laboratory and field investigations have demonstrated the physiological effects of fine particulate matter. These research have established a significant correlation between exposure to fine particulate matter and an elevated occurrence of asthmatic episodes, as well as an increased incidence of chronic bronchitis and chronic obstructive pulmonary disease (COPD).

The concept put forth by Loftus *et al*. (2020) suggests that children diagnosed with asthma may encounter temporary rises in inflammation, heightened severity of asthma symptoms, and diminished lung function after being exposed to elevated levels of air pollutants originating from animal feeding operations (AFOs). The study investigated the relationship between a straightforward measure of time-dependent exposure to AFO (animal feeding operation) emissions and daily concentrations of ammonia in outdoor environments. In summary, it may be inferred that children diagnosed with asthma may have negative consequences as a result of their exposure to emissions from animal farm AFOs. In a study conducted by Borlée *et al*. (2015), it was discovered that there is a correlation between lung function deficiencies in non-farming residents of the Netherlands and the regional and temporal fluctuations in emissions of air pollution from cattle. The study conducted by De Rooij *et al*. (2019b) utilized farm-emitted endotoxin and PM10 levels in a dispersion modelling analysis to assess the exposure-response relationship within the population. The findings of the study demonstrated a positive correlation between current asthma prevalence and elevated levels of endotoxin and PM10, as observed by the utilization of an endotoxin exposure model. In contrast, there was a notable decline in asthma and COPD prevalence as the proximity to the closest farm decreased. The study conducted by Van Kersen *et al*. (2020) aimed to evaluate the immediate impacts of air pollution associated with livestock farming on individuals diagnosed with Chronic Obstructive Pulmonary Disease (COPD) residing in a region characterized by intensive livestock farming practices in the Netherlands. The findings demonstrate the immediate impact of air pollution caused by livestock activities on respiratory function in individuals with chronic obstructive pulmonary disease (COPD) residing in proximity to livestock ranches.

Multiple studies have provided compelling evidence indicating that exposure to NH3, which serves as a representative measure of exposure related to farming activities, is linked to the experience of odor annoyance among the general population. The unpleasant odor originating from farming practices is perceived by individuals residing in close proximity to these farms, and the level of annoyance appears to escalate in a dose-dependent manner. This relationship has been assessed using various indicators such as the number of farms in the vicinity (Hooiveld *et al*., 2015) or estimations of odor intensity (Boers *et al*., 2016). According to a study conducted by Pohl *et al*. (2017), it has been demonstrated that the levels of hydrogen sulfide and ammonia can surpass background values by a factor of ten within a radius of 1 kilometer near livestock structures. Consequently, this phenomenon has the potential to impact the air quality within a range of several kilometers (Pohl *et al*., 2017). In a research done in Lower Saxony, Radon (2005) examined the correlation between the exposure to odors emitted by livestock and the overall well-being of a significant population residing in close proximity to extensive swine and poultry farming operations. The assessment of exposure was conducted using subjective ratings of the degree of scent. The findings indicate that the degree of odor annoyance, as assessed through subjective evaluation, is a significant negative predictor of the affected population's quality of life. A majority of the participants, specifically 61%, expressed dissatisfaction with regards to the presence of disagreeable smells. Furthermore, a significant proportion, specifically 91% of those individuals, attributed the origin of these odors to animals. In their study, Hooiveld *et al*. (2015) examined a total of 753 individuals residing in a geographical region located within a 500-meter radius of concentrated animal feeding operations (AFOs) characterized by high livestock density, primarily consisting of cattle, pigs, and poultry. The researchers discovered a correlation between olfactory irritation experienced in the local community and a decline in overall well-being, as well as an increased incidence of reported respiratory and gastrointestinal complaints. A recent study conducted in the Netherlands has revealed a positive correlation between the estimated level of odor exposure, derived from the presence of animal farms, and the reported degree of odor irritation. Additionally, the study observed a notable escalation in the level of odor irritation over the past ten years (Boers *et al*., 2016). In summary, various investigations on the subject of odor have consistently demonstrated a correlation between heightened odor perception and increased levels of discomfort and adverse health effects experienced by individuals residing near livestock farms. Therefore, it can be inferred that odor is a bothersome presence inside the surroundings. Nevertheless, the task of deciphering the correlation between the intensity of odors and the occurrence of health-related grievances can pose certain difficulties.

### *Pharmaceuticals and consumer health*

The monitoring of pharmaceuticals in food is conducted to ensure adherence to maximum residue levels (MRLs). However, it has been observed that the quantities of these compounds in meat frequently surpass the acceptable thresholds (Chen *et al*., 2019). The detection of pharmaceutical residues in raw meat specimens from both intensive agriculture and organic sources can be attributed to the inadequate metabolism of these substances in animals (Davis *et al*., 2018). Antibiotics are commonly found throughout all phases of poultry production. Antibiotics have been identified in both meat samples obtained from slaughterhouses and in ready-to-eat goods that are ultimately consumed by individuals. In a study conducted by Jammoul and El Darra (2019), it was shown that tetracycline antibiotics and β-lactams were detected in meat samples obtained from slaughterhouses. This finding raises concerns regarding the potential hazardous consequences that these substances may have for human health. According to the findings of Asnoun *et al*. (2021), a significant proportion of meat samples obtained from slaughterhouses in Algeria, specifically 68%, were found to contain traces of antibiotic residues. According to the WHO (2019), macrolides are classified as secondary options for antibiotic treatment due to the potential risk of bacterial resistance development against this particular class of antibiotics. Residues of antibiotics have also been identified in meat originating from small-scale agricultural operations. In their study, Widiastuti and Martindah (2021) demonstrated the detection of enrofloxacin and ciprofloxacin in approximately 27% of the liver samples obtained from broilers reared in small-scale farms in Indonesia. Furthermore, it was shown that 80% of these samples surpassed the permissible thresholds for these antibiotics. The findings of this study indicate that the issue of excessive antibiotic usage in animal agriculture has implications not only for large-scale industrial farms but also for small-scale, community-based farms. The study conducted by Verma *et al*. (2020) demonstrated the detection of oxytetracycline in 18% of meat samples obtained from chicken farms and retail marketplaces throughout several districts within Uttarakhand State, India. The chicken liver and kidney exhibited the highest prevalence of antibiotic presence. In a study conducted by Baghani *et al*. (2019), it was discovered that a significant proportion of chicken meat samples obtained from local stores in Tehran, Iran was found to have tetracycline residues, with a prevalence rate of 58%. Furthermore, an alarming contamination rate of up to 95% was observed in the meat samples, indicating the presence of ciprofloxacin. Due to its classification as an antibiotic employed in human treatment, the utilization of ciprofloxacin in animal production needs to be subject to significant limitations. According to Li *et al*. (2017), it has been found that antibiotic residues are present in organically farmed meat as well. They posit that the presence of these residues could potentially be attributed to substantial environmental pollution stemming from the use of pharmaceuticals or inadequate management practices in chicken farming. The presence of antibiotics is prevalent in the region of Hong Kong and the Pearl River estuary, which served as the geographical scope for this investigation. Similarly, China and the United States are the nations that exhibit the highest levels of antibiotic consumption in the context of food animal agriculture, while also serving as significant meat providers for Hong Kong. The study identifies raw and cooked food as the key means of antibiotic exposure and suggests that traditional Chinese cooking methods may not completely eradicate them.

Despite the prohibition of antibiotic usage as promoters of growth in European Union nations since 2006, the presence of these compounds continues to be identified in chicken meat produced within these jurisdictions. In a study conducted by Bartkiene *et al*. (2020), it was shown that chicken meat obtained from shops in Germany and Lithuania contained enrofloxacin and doxycycline, which are commonly utilized as growth enhancers. Fifteen percent of the analyzed samples exhibited the presence of drug residues. Pena *et al*. (2010) additionally demonstrated the existence of antibiotics in beef retailed within Portuguese shops. A contamination rate of 20% was observed in the tested samples with enrofloxacin. The occurrence of norfloxacin residues was observed in 10% of the analyzed samples. The presence of antibiotic residues was observed in all beef samples obtained from a supermarket located in Moscow, as reported in a study conducted by Erofeeva *et al*. (2021). Majewski *et al*. (2020) revealed that broiler chicken meat in Poland exhibited a predominant presence of antibiotics during the period spanning from 2005 to 2017. The samples were obtained from agricultural establishments where the prescribed restrictions on antibiotic utilization in poultry farming were not adhered to. The aforementioned research indicates that despite the prohibition of antibiotic usage as growth enhancers, individuals in European nations continue to be exposed to medicinal substances through the consumption of chicken flesh.

The research conducted by Akhmet *et al*. (2021) examined the presence of antibiotics in chicken meat that was imported from Russia, Ukraine, and the USA. The concentration of tetracycline in imported beef from Ukraine surpassed the maximum residue limit (MRL) standard by a margin of 10%. The tetracycline content in imported meat from the United States above 80% of the permissible threshold. Additionally, the imported meat had notable levels of chloramphenicol, a pharmaceutical substance that is prohibited in animal farming practices in both the United States and European nations. Furthermore, the utilization of imported meat is prevalent in the manufacturing process of cold cuts and sausages. The restrictions pertaining to the examination of antibiotics and their residues in chicken meat mostly pertain to uncooked meat (Shaltout *et al*., 2019). Furthermore, it should be noted that there is a lack of Maximum Residue Limit (MRL) standards specifically established for processed chicken products. The European Union's implementation of the "farm to fork" policy posits that the surveillance of food contamination should encompass all stages of food processing, extending beyond the examination of raw materials alone.

According to a study conducted by Shaltout *et al*. (2019), the application of heat treatment to raw chicken meat did not result in the total elimination of antibiotic residues. Hence, pharmaceutical residues are also detected in the aforementioned "ready-to-eat products". In a study conducted by Nasir *et al*. (2019), sulfonamide antibiotics were identified in poultry items obtained from both local markets and farms in Malaysia. The analysis revealed that 80% of the chicken wings examined contained detectable levels of sulfonamide residues. In contrast, the ready-to-eat chicken balls were shown to have two distinct sulfonamide metabolites. In a study conducted by Kadim *et al*. (2020), it was demonstrated that tetracycline and streptomycin were detected in burgers and chicken sausages obtained from stores located in Muscat, Oman.

An additional factor to consider when evaluating consumer exposure to residual antibiotics through the consumption of chicken meat is the impact of elevated temperatures and processing methods. Typically, chicken flesh undergoes a process of heat treatment prior to consumption. To date, a limited number of research have been conducted to investigate the impact of elevated temperatures on the stability of antibiotics in poultry meat. Veterinary medications have diverse levels of stability when subjected to cooking, baking, and frying procedures. In their study, Shaltout *et al*. (2019) examined the extent of degradation observed in ciprofloxacin and oxytetracycline inside chicken meat that had been subjected to baking, cooking, and microwaving. The concentration of ciprofloxacin in chicken breasts exhibited reductions of 22%, 17%, and 36% when subjected to heating, baking, and microwave treatment, respectively. As with oxytetracycline, the decline was more pronounced. The utilization of a microwave oven led to a significant decrease of 82% in the oxytetracycline concentration. Similarly, when the antibiotic was subjected to heating, a substantial reduction of 78% in its content was found. Khan *et al*. (2016) reported comparable findings, demonstrating a reduction of 70% in the concentration of oxytetracycline in beef when subjected to microwave cooking. The authors also demonstrated a reduction in the concentration of enrofloxacin in meat subjected to heat treatment. The method of grilling demonstrated the lowest level of effectiveness. The concentration of enrofloxacin experienced a reduction of merely 30% during the process of grilling meat.

Prolonged and continuous exposure to pharmaceutical substances, even at low concentrations, has the potential to have detrimental effects on human health. The prevailing belief posits that the gastrointestinal tract primarily facilitates the introduction of antibiotics into the human body. The ingestion of antibiotics and their subsequent residues in conjunction with food might elicit both direct and indirect physiological consequences within the human body. The human body might experience several direct effects from antibiotics, such as allergic reactions that are characterized by symptoms including rash, difficulty breathing, and in severe instances, anaphylactic shock (Kyuchukova, 2020). Individuals who exhibit hypersensitivity to β-lactam antibiotics, namely penicillin, are susceptible to adverse reactions. According to estimates, almost 10% of the population exhibits hypersensitivity to β-lactam antibiotics. In their study, Teh and Rigg (1992) documented an instance wherein an individual developed an allergic reaction to penicillin subsequent to the consumption of chicken meat. According to Baynes *et al*. (2016), there is evidence suggesting a potential risk of reactions to allergens following the consumption of meat that has been treated with penicillin antibiotics.

According to Kyuchukova (2020), extended periods of antibiotic exposure have been associated with potential carcinogenic and teratogenic consequences, as well as adverse impacts on fertility and the development of antibiotic resistance. Chloramphenicol is an antibiotic with recognized carcinogenic properties. According to Menkem *et al*. (2019), the utilization of this chemical has been prohibited in animal production across the United States, Canada, Australia, and countries belonging to the European Union. Chloramphenicol continues to be employed as a booster of growth in poorer nations. Chloramphenicol, an antibiotic, exhibits a high propensity for accumulation inside the consumable portions of poultry, specifically chicken. In a study conducted by Tajik *et al*. (2010), the detection of chloramphenicol was demonstrated in chicken samples obtained from distribution facilities located in Iran. According to Menkem *et al*. (2019), prolonged exposure to chloramphenicol has been associated with the development of bone marrow aplasia. This condition is characterized by a decrease in the quantity of blood cells, ultimately leading to fatality. Enrofloxacin is an antibiotic that has the potential to be carcinogenic. The potential implementation of a prohibition on its utilization in the context of chicken production has been under deliberation (Menkem *et al*., 2019). According to Beyene (2016), extended exposure to antibiotics can potentially result in reproductive issues and the development of functional abnormalities in the fetus. Erythromycin, an antibiotic, has been identified as having the potential to induce teratogenicity, resulting in adverse effects on the development of the human embryo (Baynes *et al*., 2016).

Additional hazards associated with the consumption of leftover antibiotics encompass the potential for these substances to interact with the microbiota of the host organism. The human body harbors a diverse array of over 7000 distinct bacterial species. The majority, or around 95%, of these strains consist of probiotic and commensal bacteria, with the remaining 5% including opportunistic microorganisms. Prolonged and frequent exposure to antibiotics has been found to disrupt the composition of the human microbiome, resulting in the proliferation of opportunistic bacteria (Ben *et al*., 2019). The proliferation of opportunistic microorganisms results in inflammation, which in turn contributes to the formation of colorectal neoplasms (Damman *et al*., 2012). According to Ben *et al*. (2019), empirical evidence from clinical and epidemiological studies suggests that the utilization of antibiotics on a regular basis might lead to microbiota imbalances, which pose a significant risk to the health of children. During the initial phases of infancy, there exists a potential for infants to be exposed to antibiotics through the consumption of their mother's milk and introduction of solid foods. In a study conducted by Dinleyici *et al*. (2018), it was demonstrated that β-lactam antibiotics were detected in the breast milk of nursing mothers who did not get any antibiotic treatment during pregnancy. The administration of antibiotics to pediatric patients has been associated with potential implications for immune system functioning, perhaps resulting in the development of illnesses such as obesity and aberrant bone growth (Chen *et al*., 2019). According to Kümmerer (2009), the exposure of youngsters to tetracycline has been associated with the potential occurrence of atypical dental and skeletal development.

The dissemination of antibiotic resistance is identified as the primary peril to human well-being arising from the inclusion of antibiotics in food, as stated by the WHO (2021). In European Union member states, an estimated annual mortality of 33,000 individuals is attributed to infections caused by antibiotic-resistant bacteria. A significant proportion, specifically 39%, of global infections can be attributed to bacterial strains that exhibit resistance to "last-resort antibiotics," which are widely acknowledged as crucial for the management of various human ailments. Hence, the emergence of antibiotic resistance poses a significant peril to contemporary medical practices (WHO, 2021). According to Saharan *et al*. (2020), Salmonella spp. and Staphylococcus spp. are identified as bacterial genera that provide a significant concern in terms of antibiotic resistance, hence posing a substantial risk to human health.

Chicken farms are often regarded as significant contributors to the dissemination of antibiotic-resistant strains. Salmonella spp. is a commonly seen antibiotic-resistant bacterium found in chicken flesh, as reported by CDDEP (2021). Strains that exhibit multi-drug resistance pose a significant threat to human health. Castro-Vargas *et al*. (2019) reported that a significant proportion of Salmonella spp. strains obtained from raw chicken flesh worldwide, namely 41%, exhibit resistance to multiple drugs. The results indicate that a significant proportion of the isolated strains, specifically 80% and 65% respectively, exhibit resistance to nalidixic acid and ampicillin. According to a study conducted by Castro-Vargas *et al*. (2019), around one-third (33%) of the strains exhibited resistance to streptomycin. The issue of antibiotic resistance in Salmonella spp. strains extends beyond Asian countries, where the utilization of antibiotics in chicken production is prevalent, as highlighted in a report by the Center for Disease Dynamics, Economics and Policy (CDDEP, 2021). In the Italian context, it was shown that 58% of the strains exhibited resistance to ciprofloxacin, whereas 47% demonstrated resistance to tetracycline. In the context of Poland, it was shown that a considerable proportion of organisms exhibited resistance to ciprofloxacin (53%), tetracycline (36%), and ampicillin (27%). Antibiotic-resistant bacteria have been identified in various nations that engage in extensive chicken farming. In the context of Germany, it was shown that 22% of the Salmonella spp. strains exhibited resistance to ciprofloxacin, whereas 17% of the strains demonstrated resistance to tetracycline. The prevalence of antibiotic-resistant Salmonella spp. is notably low in Scandinavian countries. The prohibition of using antibiotics as growth promoters in animal production has been implemented for a longer duration in both Sweden and Norway, indicating a potential correlation between the prevalence of antibiotic resistance and the practice of intensive animal production.

Staphylococcus aureus is an additional public health concern. The primary mode of transmission is predominantly oral. According to the WHO (2021), the most perilous strains are those classified as Methicillin-resistant Staphylococcus aureus (MRSA). According to research conducted in China, it was found that antibiotic-resistant strains of Staphylococcus aureus were present in 68% of poultry samples. This finding indicates that the contamination of meat with Staphylococcus aureus is a prevalent occurrence (Wu *et al*., 2018). According to the findings of Ge *et al*. (2017), a study conducted in the United States, it was determined that approximately 28% of meat samples were found to be contaminated with S. aureus. The presence of antibiotic-resistant bacteria in commercially available chicken meat also results in contamination that impacts customers. According to a study conducted by Germanwatch (2020), an analysis of chicken meat samples obtained from the three prominent poultry manufacturers in Europe, who operate facilities in France, Germany, Poland, the Netherlands, and Hungary, revealed that 51% of the samples had strains of bacteria that were resistant to antibiotics. A total of 24% of the specimens obtained from the German company were found to contain strains of MRSA. Furthermore, the poultry meat that is produced in these manufacturing facilities is distributed to consumers in Poland, Spain, and Germany, and is made available for purchase at well-known cheap retailers (Germanwatch, 2020).

### *Future perspectives*

Various levels of alterations can be noticed in the context of intensive chicken production. Efforts are being made to optimize the raising process in order to maximize efficiency and profitability. The implementation of new regulations entails the imposition of more stringent limits on pollution and bioaerosol emissions. The monitoring and regulation of the utilization of manure and litter from agricultural operations as fertilizers on cultivable land is seeing a growing trend. The poultry industry is currently incorporating slower-growing genotypes in order to decelerate the growth cycle of broiler chickens. Significant importance is also attributed to the welfare of chickens and the restriction of their rate of body weight increase. The living circumstances of broilers, along with their stocking densities, are both significant factors to consider. Ultimately, consumers are impacted by intensive farming, constituting the final link in the chain.

The introduction of the EU Commission's Joint Research Centre reference document (BREF) in 2017 aimed to establish uniformity and ensure the well-being and living circumstances of chickens (EC, 2017). This document offers guidelines for the implementation of Best Available Techniques (BAT) in intensive poultry rearing operations that consist of more than 40,000 units. The guidelines primarily address various aspects of poultry management, including nutritional practices, feed preparation, rearing systems, manure management, storage of deceased animals without disposal, and the control of pollutant emissions, specifically ammonia, total nitrogen, and phosphorus. The aforementioned methodologies and corresponding surveillance possess the capacity to attain a heightened degree of environmental safeguarding. These encompass the technological apparatus employed as well as the strategic approach to the construction, maintenance, operation, and decommissioning of farms. The subject matter encompasses environmental management systems, strategies that are integrated into processes, and measures implemented at the conclusion of the production cycle.

The monitoring of pharmaceuticals, including antibiotic residues, as well as other contaminants such as heavy metals and microorganisms, in poultry manure intended for soil amelioration is a crucial component of manure management. This is particularly important due to the current limited understanding of the potential environmental effects on soils and plants in the vicinity of intensive poultry farming practices. Hence, it is of utmost significance to conduct compositional analysis of chicken manure prior to its direct application on agricultural fields.

With the ongoing global phenomenon of urban agglomerations expanding into rural regions, it becomes increasingly crucial to evaluate the direct health effects of intensive poultry and animal production on the surrounding population. This assessment will continue to grow in significance. Given that these issues have not been thoroughly investigated thus far, it will be imperative to do further research in the future. This research should encompass a diverse sample of individuals affected by the phenomenon, taking into account various demographic factors such as age, gender, health, and socio-economic position. Moreover, it should prioritize the implementation of long-term monitoring strategies.

Furthermore, it is important to prioritize the utilization of objective testing, such as lung function assessments and biochemical assays, whenever feasible.

It is imperative to underscore that the poultry and egg industries are subject to various legal actions within the European Union (EU). The aforementioned areas encompass many aspects such as food safety, health for humans and animals, environmental preservation, trade and marketing regulations, and animal welfare across the entire production cycle, including transportation and slaughter (EU, 2022). European Commission Directive no. 43/2007 introduced a set of basic regulations aimed at safeguarding poultry raised for meat production. In order to address the issue of overcrowding in chicken holdings and promote improved animal welfare, the European Commission (EC, 2007) has implemented regulations pertaining to maximum stocking densities and specific criteria related to lighting, litter, feeding, and ventilation. The sector is currently facing numerous challenges that can be attributed to its extensive and intense production methods. One potential answer involves the implementation of slower-growing broiler breeds. The aforementioned phenomenon yields favorable outcomes for both animal welfare and public health by diminishing the reliance on antibiotics within industrial systems. According to the Eurogroup for Animals (2020), an analysis of antibiotics consumption in the Netherlands from 2014 to 2018 revealed that a significant proportion of flocks consisting of slower-growing broilers, ranging from 91% to 94%, did not undergo any antibiotic treatment. In comparison, approximately 67% to 72% of typical fast-growing flocks were found to be devoid of antibiotics treatments.

The utilization of antibiotics is accompanied by economic and ethical dilemmas. Poultry production has a significant role in ensuring food security, alleviating poverty, and fostering growth in the economy in low to middle-income nations. Producers in nations of this nature sometimes employ antibiotics as preventative measures and for the purpose of promoting growth. The utilization of these activities is motivated by economic considerations, namely the desire for heightened productivity and income. Additionally, they serve as a substitute for insufficient infection control measures, such as inadequate hygiene, sanitation, and biosecurity procedures, which often necessitate substantial capital investments. Moreover, it is frequently seen that farmers possess insufficient understanding regarding appropriate utilization of antibiotics, and in many instances, the provision of veterinary support and infrastructure is insufficient or absent (Bamidele *et al.*, 2022). The economic impact of restrictions on antimicrobial promoters of growth is found to be low in high-income nations with efficient production systems. This is mostly due to the presence of strong cleanliness practices, veterinary services, and economic support, which collectively contribute to the reduction in the necessity of antibiotic use. Nevertheless, it is worth noting that the economic repercussions in countries with lower income levels have the potential to be significantly more significant, mostly as a result of the aforementioned considerations. Furthermore, the implementation of stringent regulations for the utilization of antimicrobial agents has the potential to augment the prevalence and amplify the transmission of diseases within flocks, particularly in situations where there is a lack of sufficient measures for preventing infections. This can result in substantial financial burdens for farmers, as highlighted by Hedman *et al*. (2020).

Hence, it is imperative for initiatives aimed at decreasing antibiotic consumption in developing nations to prioritize mitigating the financial strain on local producers and communities. This can be achieved by directing interventions towards other stakeholders involved in the production chain, such as commercial feed manufacturers and livestock pharmaceutical manufacturers. Additionally, support should be provided for the enhancement and financing of hygiene, sanitary, biosecurity, and veterinary care (Masud *et al*., 2020).

An additional approach to enhance the practice of intensive rearing, with the aim of augmenting production while reducing expenses and resource utilization, involves the adoption of intelligent poultry management systems. These systems encompass precision livestock farming (PLF) technologies, such as intelligent sensors, automated farm processes, and data-driven decision-making platforms. According to Astill *et al*. (2020), the utilization of technology aids in enhancing the farm's environmental conditions, including temperature, air velocity, ventilation rate, litter quality, humidity, and gas concentrations such as carbon dioxide and ammonia. Additionally, technology assists in optimizing feeding systems, ensuring proper standards of broiler welfare, and facilitating prompt diagnosis and detection of infectious diseases, such as the influenza virus. The advent of novel technology and sensors has facilitated the acquisition of substantial quantities of information from poultry farming operations in real-time, hence enabling prompt responsiveness and informed decision-making.

The adverse effects of high stocking densities and rapid growth on chicken welfare are well-documented. However, it is important to acknowledge that intensive production methods can also have significant consequences for the environment and human health. These elements necessitate additional research and attention, as the condition of the environment and the quality of our food directly influence our overall well-being.

## Conclusion

The poultry industry has experienced significant and consistent expansion over the past few decades because of the escalating worldwide need for food and nutritional security, which has been driven by population growth. Intensive poultry farming, a cornerstone of contemporary chicken production, possesses a substantial ecological impact and needs effective management to mitigate its detrimental consequences. The objective of this study has been to offer a thorough examination of the existing body of research regarding the effects of intensive poultry farming on both the environment and human health. This pertains to the interconnected environmental factors (including air, water, soil, plants, and human influence) associated with poultry production.

The extant literature on the subject matter demonstrates a significant scholarly interest in comprehending the environmental implications of intensive poultry farming, as well as cattle husbandry in a broader context. The understanding and description of pollutants, including greenhouse gases, nutrients, heavy metals, microbes, and their emission and movement across different environmental compartments, have been extensively studied. The impact of their activities can be effectively managed and reduced by the use of suitable strategies such as optimizing feeding regimens, implementing effective manure and litter disposal procedures, and controlling emissions. Nonetheless, it is imperative to acknowledge that there exist certain lacunae in our understanding, particularly about the effects of health on both farm employees and the surrounding community. It is crucial to conduct thorough assessments and studies in order to mitigate any potential adverse consequences. One element that warrants attention is the examination of the direct impacts of particulate matter (PM) and bioaerosols on both employees and the surrounding population. This can be effectively investigated by enhanced monitoring of PM levels, comprehensive cross-sectional research, and the utilization of objective medical and biochemical assessments, as previously described. An additional area of research that warrants attention in the future is to the utilization, environmental destiny, and effects on living organisms associated with developing contaminants, including pharmaceuticals, with a special emphasis on antibiotics. The latter refers to a contaminant whose both immediate and secondary ecotoxicological implications have yet to be comprehensively explored, including the effects of its mixes. Due to their association with the development of antibiotic resistance, which presents a substantial risk to the well-being of the general population, it is imperative to prioritize the monitoring and mitigation of their utilization. However, it is crucial to exercise caution in order to mitigate the adverse economic and social consequences of this measure on individuals who are more susceptible to its detrimental outcomes, such as ranchers and inhabitants residing in developed regions.

The resolution of these difficulties necessitates the active engagement of all stakeholders involved in the food cycle. Poultry producers are required to implement appropriate measures for the purpose of monitoring and mitigating emissions. In order to mitigate the adverse impacts associated with the utilization of their goods, feed and pharmaceutical manufacturers will be required to make necessary adjustments. It is imperative for governing bodies to establish comprehensive regulatory frameworks and extend financial support to farmers in order to effectively address the requisite modifications in production methodologies. In general, the acts delineated in this context present a formidable yet feasible endeavor. The successful execution of their implementation will rely on the effective installation of the requisite technology, as well as the presence of political determination and economic backing.

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