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Chapter 12
Review of Publications on the Study of Poultry Manure Problems in Environmental Pollution and Its Reuse

Yan Li and Viktar Lemiasheuski

Abstract The environmental pollution caused by poultry manure has become a hot issue that needs to be solved urgently in the world. In order to solve the environmental problems caused by poultry manure, it needs to be treated and utilized. This paper analyzes the impact of different harmful substances in poultry manure on the environment from the perspective of ecology and organic agriculture, as well as the potential environmental and economic benefits of the secondary use of poultry manure. Through literature analysis, the author compares and summarizes the advantages and restrictive factors of anaerobic digestion, anaerobic co-digestion, gasification, pyrolysis (thermochemical technology) and cobalt 60 radiation technology in sustainable development. The advantages and disadvantages of cobalt 60 irradiation technology were screened out to treat poultry manure, the advantages, and disadvantages of cobalt 60 irradiation technology were explained, its new advanced technology was proved sideways, and the sustainable and stable development of poultry manure was put forward. The corresponding proposals have made a significant contribution to reducing the pollution of poultry manure to the environment, so as to promote the harmonious development of the environment and economy.

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12.1 Introduction

Currently, the poultry industry has become one of the world's leading industries due to the rapid growth of the population, resulting in a progressive increase in the demand for poultry meat, poultry eggs and their products [1]. According to statistics, China (FAO), the United States, Brazil, the European Union (27) (FAO) as the main poultry meat producing countries and regions, poultry meat production in 2020 were: 23.15 million tons, 22.06 million tons, 14.38 million tons 13.43 million tons, in addition, the Eastern European region (FAO) is also an important production region cannot be ignored, the production of 10.59 million tons in 2020, Fig. 12.1 shows the trend of poultry meat production in the above countries and regions from 1961 to 2020 [2]. This shows that poultry meat production shows a fluctuating upward trend, and with the large output of poultry meat, environmental pollution and human health problems associated with poultry waste are bound to arise.

Although the use of poultry manure for farming is one of the most effective ways to recycle natural resources to enhance cattle feed protein, improper treatment and use can still have a significant impact on human health and the environment [3]. Considering the positive impact of the secondary use of poultry manure in the circular economy, how to reduce the high number of hazardous substances contained in poultry manure is a hot topic of research today. Therefore, more and more experts and scholars have set out to study the nutritional and availability characteristics of poultry manure and related value-added technologies. Based on this premise, the author found in the literature that the longest three methods used for poultry manure value-added technology are physical–chemical processing, microbial fermentation, and irradiation treatment.

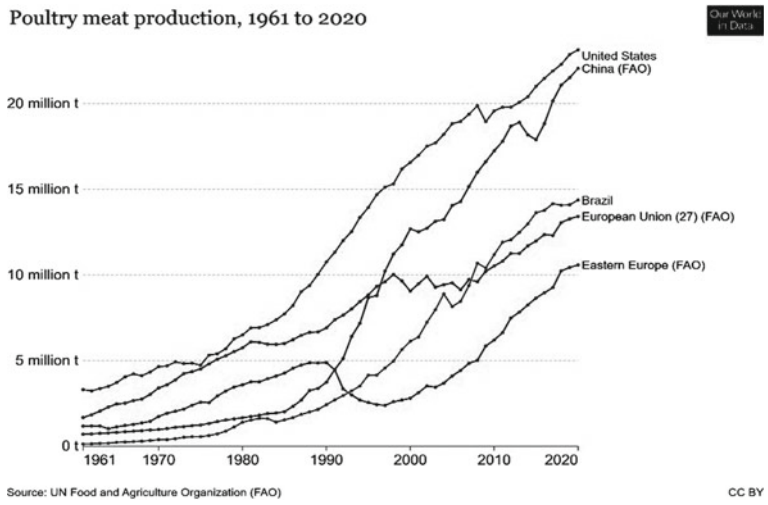

Fig. 12.1 Trends in poultry meat production from 1961 to 2020 [2]

The physicochemical approach is based on the use of solid–liquid separation, drying, pyrolysis, gasification, and exogenous chemical agents as the main treatment methods. For example, Septien S. et al. determined the nutrient content, calorific value and thermal properties of dried fecal sludge samples at different moisture contents and under different drying and operating conditions, and their results showed that drying did not affect the nutrient content and calorific value, but caused changes in the chemical form and thermal properties of nitrogen, and the dried products proved to be suitable for reuse as agricultural products and biofuels [4]; in addition, the United States widely utilized In addition, chemical amendments such as alum [$Al_2(SO_4)3–14\,H_2O$], sodium bisulfite ($NaHSO_3$), and acidified clay are widely used in the United States to control or reduce the release of NH_3 from poultry bedding and manure, and the application of these chemical amendments lowers the pH of poultry bedding or manure and inhibits NH_3 emissions to reduce the concentration of NH_3 in poultry house air to levels sufficient to maintain poultry health and productivity [5]. However, when dried and treated manure is used as organic fertilizer for agricultural cultivation, the dried poultry manure will slowly release N, which will prolong soil fertilization and may risk burning plant roots for crops that can more easily absorb nutrients; on the other hand, drying as a physical processing method will produce a large amount of harmful greenhouse gases during the process, which may cause surrounding air pollution and human health threats. Special attention is paid to the treatment of whether the residue after treatment has harmful substances and is released in the food chain when adding exogenous chemical agents becomes a problem that needs urgent attention at this stage; in addition, pyrolysis and post-incineration gasification of poultry manure are the same thermochemical process, and greenhouse gases will still be produced during the treatment process, which will pose a threat to the atmosphere of the environment.

The microbial treatment method includes composting, anaerobic digestion, and co-digestion. Composting under anaerobic conditions can eliminate pathogenic microorganisms in poultry manure to a certain extent, can create valuable outputs, and can improve soil structure, enhance soil fertility, and promote increased nutrient uptake by the community of microorganisms and other organisms [6, 7]; however, composting has some disadvantages that cannot be ignored: 1. time cost and mechanical cost; 2. compost processing, fermentation, and finished products need to occupy land cost; 3. the effect of cold weather on the temperature of composted materials. On the other hand, methane gas produced by anaerobic digestion is a renewable energy source, for example, the main purpose of biogas anaerobic fermentation technology for poultry manure is to obtain energy and combat environmental pollution, which can better realize the green energy project of an agro-ecological virtuous cycle, but there are some factors that may lead to the failure of this technology, such as excessive ammonia, toxic substances, sulfides and heavy metals, unstable pH or temperature levels, which can strongly inhibit the metabolic activity of methanogenic bacteria [8, 9]. At the same time, the by-products (digestate and wastewater) after production, both of which are composed of partially undecomposed raw materials and nascent microbial organisms, are highly concentrated organic substances and will cause secondary pollution if they are directly discharged into the environment

without treatment. Therefore, the technology has not been vigorously promoted and applied in time.

Cobalt 60 irradiation in irradiation technology is the latest sterilization treatment technology, which works on the principle of using β-radiation ions to inactivate or destroy spoilage pests, microorganisms, and their toxins in waste without significantly increasing their original temperature [10]; Studies by Chinese scholars have shown that the use of cobalt-60 radiation technology can effectively eliminate microorganisms in manure, and subsequently slow down the spread of antibiotic resistance genes in manure soil to a large extent [11]. On the other hand, the radiation energy of cobalt 60 can only penetrate the cell wall of bacteria, and there will be no ray residue, so it will not cause harm to human beings, and it does not require any chemical substances, nor will it produce harmful exhaust gases, and the investment in equipment is single and uncomplicated, with high environmental value. In summary, cobalt 60 irradiation technology is an optimal sterilization treatment technology.

The purpose of this paper is to discuss the composition of poultry manure and its harmfulness to the environment, the recycling technology of poultry manure, summarize the current research progress and achievements in this field, discuss the current situation and problems of this research topic, and propose the future research direction and development trend. It also provides a reference for related scholars and promotes the research and development of the field.

12.2 Materials and Methods

This paper focuses on the environmental pollution of poultry manure and its recycling. A large amount of literature was collected and retrieved, including but not limited to academic journals, conference papers, experimental data, and research reports.

In this paper, the literature related to the environmental pollution of poultry manure and its recycling was selected according to the research topic. The selection criteria include: (1) the research object is poultry manure or the pollutants in it; (2) the research content includes the impact of poultry manure on environmental pollution, and the treatment and recycling technology of poultry manure, etc.; (3) the time range is the last 7 years. The databases were Google Scholar and CNKI, using the keywords "poultry manure", "environmental pollution", "organic farming", "reuse" and "recycling". "Organic farming", "reuse" and "cobalt 60 irradiation" were searched extensively.

The selected literature was comprehensively analyzed and compared to summarize the current status and progress of the research on the environmental pollution of poultry manure and its recycling, and to discuss its problems and future development directions.

12.3 Literature Survey and Research

12.3.1 Environmental Hazards of Poultry Manure and Associated Pathogenicity to Humans

In poultry production, heavy metals, including arsenic (As), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), selenium (Se) and zinc (Zn), which are added to feed in the form of minerals such as zinc oxide and manganese oxide in various formulations for disease prevention and to improve feed conversion efficiency for weight gain and egg production, are ingested in the feed only 5–15% are absorbed and most of them are excreted into the bedding through feces and urine [12]. Meanwhile, a study by Oyewale A. T. et al. in southern Nigeria showed that the poultry industry uses a variety of heavy metals as additives in feeds, but excretion, runoff and dumping of heavy metals threaten water bodies and have negative impacts on the local population with heavy metal concentrations above acceptable limits [13]. In the long term, the accumulation of heavy metals in soils can lead to the degradation of agricultural land, eutrophication, and uptake of toxic substances, which may have long-term effects on the quality of agricultural soils, which in the context of the human food chain will lead to the transfer of toxic elements into the human diet [14]. The ingestion of food with heavy metals by humans through the food chain can cause health hazards and, consequently diseases. For example, chronic human intake containing excessive amounts of arsenic, e.g., more than 10 g/L in drinking water, may lead to malnutrition, upper gastrointestinal tract cancer, reproductive cancer, lung cancer and neurological diseases such as skin cancer; cadmium causes kidney, liver and brain damage and is carcinogenic; mercury and lead cause fatal brain damage and cobalt causes infertility [12].

According to the literature survey, it was found that sulfonamides, fluoroquinolones, tetracyclines, methicillin, metronidazole, β-lactamases and macrolides antibiotics are known to be commonly used in animal breeding and the order of excretion rate is as follows: sulfonamides and tetracyclines > methicillin > metronidazole > fluoroquinolones > macrolides. Whereas most of the β-lactamases are digested in the intestine of animals and their excretion rate is relatively lowest [15, 16]. Meanwhile, a study in Brazil showed that after 1.5 years of conventional fertilization of soil using poultry manure, continuous accumulation of fluoroquinolone antibiotics in soil was measured, with 330–6138 $\mu g\ kg^{-1}$ for enrofloxacin and 170–960 $\mu g\ kg^{-1}$ for ciprofloxacin, indicating a trend of fluoroquinolone antibiotic accumulation in soil associated with increased ecological risk, and pointed out the need for management measures to reduce antibiotic levels before using poultry bedding as a soil fertilizer [17].

Meanwhile, these antibiotics in the environment (soil, water) cause antibiotic resistance in bacteria by activating antibiotic resistance genes. In recent studies [18], it was shown that the interaction between bacterial microorganisms and antimicrobial agents in the environment might contribute to the development of antimicrobial-resistant strains, and the development of these antibiotic-resistance genes and

antibiotic-resistant bacteria leads to non-negligible physical and economic losses, since these bacteria cannot be treated with commonly used antibiotics. In the ecological context, soil and water are important vectors for the transmission of antibiotic-resistance genes to humans, and the continuous application of poultry manure in the cultivation industry has led to the continuous accumulation of antibiotic-resistance genes in the soil from manure.

Excreta from intensive poultry farms are a source of saprophytic and potentially pathogenic microbial emissions to outdoor air. In the UK, bacterial and fungal counts in poultry houses (including broilers and laying hens) can be very high, ranging from 3.6×10^3 CFU m^{-3} (colony forming units per m^3) [19]. Also, some studies can indicate microbial contamination in aquatic environments. For example, the release of excess pathogens (including bacteria, fungi, and viruses) from agricultural waste into aquatic ecosystems may affect the balance of aquatic ecosystems and harm plants as well as invertebrates and vertebrates [20]. A study conducted in the United States showed that the incidence of campylobacteriosis in local populations was positively correlated with the prevalence in areas with a high number of recorded poultry farms; many chicken farms may lead to groundwater contamination [21]. Meanwhile, Mulder et al. showed that *Campylobacter jejuni* and *Escherichia coli* strains were detected in 66% of surface water samples in the Netherlands, suggesting that these pathogens are equally widespread in surface water due to manure contamination [22].

Therefore, if protection measures are inadequate, the population in the surrounding area may become a passive vector for the transmission of harmful pathogenic microorganisms, thus triggering a risk to human health; meanwhile, the pathogens that cause diseases are infectious bronchitis virus (IBV), avian pathogenic *Escherichia coli* (APEC), which causes *E. coli* disease, and infectious laryngotracheitis in chickens (ILTV), which causes infectious laryngotracheitis [23–25].

12.3.2 Literature Review of Poultry Manure Secondary Use Technologies

The current technological approaches for the treatment of poultry manure contain anaerobic digestion, anaerobic co-digestion, gasification, pyrolysis, and a technology with potential: irradiated ray (cobalt 60 ray) technology. Anaerobic digestion is a digestion technology that converts biodegradable organic matter into methane (CH_4) and carbon dioxide (CO_2) by parthenogenic and anaerobic bacteria under anaerobic conditions. The main advantages of this technology are that it can process fresh poultry manure without pretreatment and that it is a relatively straightforward and reliable method for producing biogas.

In anaerobic co-digestion, it is the anaerobic digestion of poultry manure into one or more additional organic feedstocks with a lower nitrogen content and the ability

to increase biogas yield by diluting ammonia and minimizing hydraulic residence time [26, 27]. In a study by Bres P. et al. it was shown that co-digestion of poultry manure with fruit and vegetable wastes produced the highest biogas and methane yields and organic matter removal compared to single digestion of poultry manure, which had the lowest nitrogen concentrations and lower digestate toxicity for both nitrogen concentrations and digestate toxicity [28]. In addition, the feed of poultry manure is also an anaerobic co-digestion technique, where poultry manure is silaged with plant waste (straw, etc.) and the output is used as ruminant feed, which is also an effective and current technological approach to increase the source of non-protein nitrogen for ruminants. However, the disadvantage of anaerobic co-digestion is the choice of co-digested substrates, which is still in the laboratory stage and requires consideration of the spatial distribution of digested substrates.

In terms of gasification and pyrolysis, the former is a thermochemical process that converts carbon-rich materials into syngas, which can be adaptable to a variety of materials and process conditions to selectively separate different gas products [29], the resulting gas can be used as heating and power transport, among other directions, and the recycling of poultry manure biochar as mineral nitrogen fertilizer after passing through gasification means has a positive compared to the direct land spreading of manure net effect [30]; while the latter is a thermal conversion method that can use heat to convert waste into bio-oil or biochar [31]. The similarities between the two are thermochemical processes, and thus they can be applied in agriculture and energy industries, among others. Although both can be used as promising technological methods under certain conditions, they also have certain disadvantages, such as the disposal of hazardous waste after technological treatment, and the implications for this aspect still need further research.

In addition, irradiation (cobalt 60 radiation) technology is also a promising technology for treating poultry manure. Currently, cobalt 60 radiation technology is mostly used in the food industry, manure and sewage treatment, and the feed industry, among others, to inactivate or destroy spoilage pests, microorganisms and their toxins in commodities or wastes by using their β-radiation ions [11]. By utilizing this technology of feeding poultry manure for ruminant feeding, it can serve as a potential sustainable utilization tool in the future.

12.4 Discussion

Poultry manure has the following related effects on environmental pollution and affecting human health. Poultry manure contains many organic substances, including nutrients such as nitrogen, phosphorus and potassium, which can be absorbed by plants, but if there are too many of these nutrients, it can lead to a decrease in dissolved oxygen in the water body, which can lead to water pollution and affect the survival of aquatic organisms. In addition, poultry manure contains many pathogens, such as bacteria, viruses, and parasites, which can also be spread through water bodies, soil and air and pose a threat to human health. Therefore, the harmless treatment

of poultry manure is very important, and it is necessary to adopt relevant technical means to reduce the impact of poultry manure on environmental pollution and human health.

There are four technological approaches for the secondary use of poultry manure, all of which can enhance the value of poultry manure stability through various system configurations, however, each of them faces some drawbacks and challenges. For the anaerobic digestion of poultry manure treatment technology, it requires a large amount of equipment cost, which increases the fixed investment assembly and thus reduces the economic benefits. Secondly, the process of anaerobic digestion of poultry manure produces many pollutants, such as ammonia and sulfur dioxide, which can pollute the environment and thus affect the environmental quality. Meanwhile, the process of anaerobic digestion of poultry manure produces a large amount of greenhouse gases, such as methane and carbon dioxide, which can affect the climate and thus aggravate global warming, and in addition, the scale of its potential sustainability benefits is currently undetermined, which likewise limits the widespread application of this technology. For anaerobic co-digestion of poultry manure, the disadvantages are like those of anaerobic digestion, however, many toxic substances, such as cyanide and nitrate, are produced during anaerobic co-digestion, and these toxic substances can pose a certain threat to human health. On the other hand, the selection of substrate in the anaerobic co-digestion process needs to be considered, which leads to economic issues related to substrate transportation and whether there are positive economic and environmental benefits of its use as a technical means.

Both gasification and pyrolysis seem to show positive environmental and social benefits. However, the potential impact of gasification residues on the parties involved still needs further study; pyrolysis likewise generates many harmful gases, thus leading to air hazards, and the reuse value of biomass char as a by-product of pyrolysis should be further improved to enhance the net benefits of pyrolysis.

It is worth mentioning the cobalt 60 radiation technology, which has many superiorities. According to the literature survey, cobalt 60 emits gamma rays during the radioactive decay process. Gamma radiation easily passes through the material and inactivates bacteria by breaking the covalent bonds of bacterial DNA [32]; meanwhile, gamma radiation reduces the abundance of four macrolide resistance genes (ereA, ermB, mefA and mpfB) by 1.0–1.3 log with a removal rate of 90–95%, and at an absorbed dose of 30 kGy and at room temperature, about 56% of erythromycin is removed (19–22 °C). The direct effect of gamma radiation accounted for 42–53% of the removal of antibiotic resistance genes, and 84% of the removal of erythromycin was in the indirect effect (free radical reaction) [33]; in addition, gamma radiation had the same elimination and inhibition effect on parasites such as Cyclospora and Toxoplasma [34].

It can be seen that, compared to the other three poultry treatment technologies, the superiority of cobalt 60 irradiation technology lies in the higher technical control, lower equipment cost, smaller protein damage rate, and excellent microbial disinhibition; at the same time, cobalt 60 irradiation technology does not produce toxic substances, greenhouse gases, and other pollutants in the process of treating

poultry manure, so it does not cause pollution to the environment, thus protecting environmental quality and this protects the environmental quality and human health.

12.5 Conclusion

According to the analysis of the literature, the threat of poultry manure to the environment and human health is objective. At this stage, the secondary use of poultry manure has been mainly studied in the areas of energy and fertilizer-feed, however, in recent years, there have been few studies on the use of poultry manure as feed for ruminants, which has great potential for development as a source of non-protein nitrogen for ruminants and for harmonious environmental and economic development. As far as the secondary use of poultry manure is concerned, anaerobic digestion, anaerobic co-digestion gasification and pyrolysis have certain environmental benefits; in addition, cobalt 60 irradiation has a more advantageous aspect than other technical means.

Based on the survey and analysis of the literature in this paper, the following recommendations for currently applicable poultry manure stabilization technologies have been identified as part of future developments, the implementation of which will help to gain a more accurate understanding of the scalability, reliability, and compatibility of each technology:

1. Currently, most technologies for the secondary use of poultry manure exist at the laboratory level and appear to be disconnected from large-scale commercial applications. Therefore, comprehensive, detailed, context-specific assessment studies are necessary to identify and compare the potential resource use and environmental costs and associated benefits of each technology, and to consider the constraints to their application to identify priority technologies more accurately for commercial use.
2. Finding the benefits of different technologies based on their advantages and disadvantages to maximize their benefits in the appropriate industries and considering disposal options for the by-products of each technology to maximize their environmental and economic benefits.
3. Regarding cobalt 60 irradiation technology, relatively little research has been conducted on its application to poultry manure, and it needs further research as a promising treatment technology to understand whether the technology changes the traits of proteins in poultry manure and, in addition, to assess the biosafety of its treated poultry manure for use in agriculture and farming.

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