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## Reducing air pollution from broiler farms

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**Abstract.** Broiler farms are the main supplier of national meat needs in Indonesia. Production of broilers in Indonesia continues to increase every year as a consequence of the Indonesian population increase. The main issue in animal production is environmental pollution including in broiler production. This study aimed to identify the source of air pollution related to broiler farms and how to overcome air pollution from broiler farms. The result of the study showed that there were several primary air pollutions from broiler farms, i.e., the pollution from emissions of ammonia, hydrogen sulfide, greenhouse gasses, odor, and dust. Generally, air pollution from the broiler farm resulted mainly from broiler manure. It has been concluded that manure management is the main way in the reduction of air pollution from broiler farms. Management of feeding is the other way to reduce air pollution from broiler farms, it is because the air pollution from broiler manure resulted from excess nutrients from feed which released through manure. Applying feed additives and waste additive is the other way which recommendation to reduce air pollution from broiler farms, besides other kinds of approaches.

### 1. Introduction

Broiler farms are the main supplier of national meat needs in Indonesia. The level of meat production of broilers in Indonesia continues to increase every year from 2013 to 2016 has increased by 3.10; 5.43; 17.02%, respectively [1]. This steady increase in demand for broiler meat in Indonesia above caused by the increasing Indonesian people population, so that requires more broiler production in the future. The side effect of broiler production is resulting in air pollution. Broiler farms may increase air pollution, i.e., harmful emissions to the atmospheric air, and increase the risk of odour nuisance. Broiler farms resulted in some gasses which affected odor to the environment, some gasses released from broiler farms, i.e., methyl mercaptan, dimethyl trisulphide, dimethyl disulphide, hydrogen sulphide (H<sub>2</sub>S), and dimethyl sulphide [2]. Besides, undesirable odors from broiler farms caused by the concentration of sulfuric gas, ammonia, and methane, to the suspension of particulate matter and dust [3]. Furthermore, manure chickens are among the main contributors to ammonia emissions, globally [4].



The unpleasant odor is the most sensible form of pollution to humans [5]. Accordingly, in many cases of Indonesian farmers, air pollution frequently became the reason why several broiler farms have to close because being denied by many people which has a house that located neared to the broiler farms. Recently, environmental issues, mainly for air pollution, becoming a critical point to the animal production industry which invited criticism to animal production [6]. Therefore, several studies reported that air pollutants presence has a negative effect on animals and people, particularly impact on respiratory diseases [7]. Furthermore, poultry feeding operations have relation to diminished air quality through excreta [8]. In the other side, the quality of air is one of the most influenced factors to support the production of poultry [9]. Accordingly, it is necessary to study of caused factors that affect air pollution by broiler farms and how to reduce the real impacts of air pollution from broiler farms. Hence, the aim of this review article was to identify the source of air pollution related to broiler farms and how to overcome air pollution from broiler farms.

## **2. Broiler farms and air pollution**

There are three most important topics related to the air quality of animal production, ie., ammonia, odor, and dust [10]. Meanwhile, air pollutions related to animal production are volatile organic compounds (VOC), odors, ammonia, hydrogen sulfide, methane, nitric oxide, nitrous oxide, particulate matter (PM)/dust [11]. The other analysis stated that broiler farms through broiler manure identified as the one of contributor in the greenhouse gas emission. It is because broiler manure has been identified producing carbon dioxide CO<sub>2</sub>, methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) [12]. Air pollution caused by the addition of components which are normally absent in natural air composition. Some parameters related to air quality are carbon dioxide (CO<sub>2</sub>), hydrogen sulfide (H<sub>2</sub>S), ammonia (NH<sub>3</sub>) and aerosolized particulates or dust [13]. The most main gaseous pollutants from poultry farms are hydrogen sulphide, methane, ammonia, carbon dioxide, and carbon monoxide. Meanwhile, other air pollution, namely odor [14]. The odor from broiler farms produced by a combination of hundreds of odorants, which may be classified as volatile organic compounds (VOC) or gases such as NH<sub>3</sub> or H<sub>2</sub>S [15]. Odor released in animal production caused by incomplete anaerobic decomposition of stored manure, in which these processes resulted in malodors [16]. If there are insufficient populations of bacteria that degrade these compounds, malodorous are produced and accumulate during these decomposition process. Conversely, if the odor substrate is completely decomposed, the odorless gases are produced. Accordingly, in poultry production, the management of litter storage is the main factor related to odor produced in those farms [17].

High levels of odor have a negative effect not only to the environment but also reportedly reduce growth performance and increase susceptibility to disease [18]. Besides, odor also has a negative effect on worker health. Poultry manure is the main source of air pollution from poultry production. Poultry manure can be an air pollution source from broiler farms through ammonia volatilization. Ammonia emissions from poultry farms produced from the process of aerobic and anaerobic bacterial fermentation of nitrogen which happen in the manure [19]. Ammonia volatilization resulted from N in poultry manure, in which most of the N in poultry manure (>50%) losing through a process of volatilization of ammonia [20]. Ammonia volatilization from poultry manure will happen because of poultry manure contains N compounds including uric acid, urea, ammonia/ammonium, and undigested proteins. Some factors which affected the volatilization process, i.e., dry matter content, physical properties of the feces, acidity (pH), and temperature [21]. NH<sub>3</sub> and nitrous oxide (N<sub>2</sub>O) emissions lead to conditions detrimental to the environment [22]. NH<sub>3</sub> emissions from manure make affected problem on chicken farms, either for chicken or farm worker [23]. The maximum concentration of NH<sub>3</sub> level at poultry farms is 7 ppm [24]. Meanwhile, ammonia reduced poultry production, the study by Anderson et al. [25] showed that maximum doses of ammonia in poultry farms are 20 ppm. Furthermore, ammonia exposure has a negative impact on the system of respiratory and then caused irritation to mucous membranes in the eyes of poultry [26]. Ammonia is not volatilized at a pH of 7 or

below, because all of the ammonia is bound as ammonium. Furthermore, the volatilization of ammonia increases at high temperatures [27]. Generally, inorganic N form in manure is ammonium, increasing pH will convert ammonium to ammonia [28]. Ammonia volatilization is affected by manure moisture content. N retention of the manure is related to manure moisture content, in which manure moisture tends to decrease with storage time [29].

The moisture content of poultry manure has a negative correlation to the height of the manure pile [30]. The one kind of air pollution from broiler farms is Hydrogen sulfide. Hydrogen sulfide is malodorous gas which has a highly toxic characteristic. Hydrogen sulfide ( $H_2S$ ) is formed in chicken farms when decomposition process of organic compound which contain sulfur in manure and broken eggs happened under anaerobic conditions [31].  $H_2S$  resulted in a negative effect on animal and human.  $H_2S$  affect negatively for animal because of  $H_2S$  exposed animal became more susceptible to pneumonia and respiratory diseases [32]. Tri hundred (300) ppm doses of  $H_2S$  in the air in the long-term exposure caused human death [33]. Greenhouse gasses (Methane/ $CH_4$ ), nitrous oxide ( $N_2O$ ) and carbon dioxide ( $CO_2$ ) produced by agriculture [34]. Even though monogastric methane production lower than ruminant, methane considered as one kind of gas mitigation which produced by poultry [35]. It is because methane is one of the by-products of plant carbohydrates broken down by bacteria in the digestive system of animal (both ruminants and monogastric). Related to broiler farms, methane also produced from storage manure. There are several factors which affecting methane emission, i.e., retention time, temperature, manure composition, and the inhibitor compounds presence [36]. One kind of air pollution from broiler farms is dust. The dust has been considered as a serious contaminant [37]. The dust from poultry farms contained 3,4-dimethylphenol and L,6-dimethyl phenol [38]. Combination of dust and  $NH_3$  reported found in the farm's environment [39]. Odorous compounds tend to be carried through dust particles [17].

### **3. The way to reduce air pollution from broiler farms**

There are several kinds of main air pollution produced by broiler farms, i.e., ammonia emission, hydrogen sulfide emission, greenhouse gasses (GHG) emission, odor pollution, and dust pollution. Many studies have reported how to reduce those air pollutions.

#### *3.1. Reducing ammonia emissions*

Ammonia volatilization from broiler farms can be reduced through several approaches. Firstly, manipulating feeding strategies [40]. Secondly, adding additives to feed and manure [41]. Thirdly, manure management [42]. Based on the nutritional aspect, nitrogen content in manure originates from dietary protein, dietary free amino acids, and dietary non-protein nitrogen. Therefore, one strategy to minimize ammonia emission through a nutritional approach can be done through the way of matching protein intake to those broilers required protein. Synthetic amino acids (lysine and methionine) supplementation to the diet reduced total protein intake. Supplementation of acidifying feed additives, such as, gypsum, to diet reduce pH of manure, which reduced the potential for  $NH_3$  emissions [43,44]. Using gypsum as limestone replacer on poultry diet reduced pH of the manure (8.3 to < 7), so that, reduced 15% ammonia emissions from manure [45]. Supplementation of 10% adsorbent additives (zeolites) into the broiler diet reduced aerial  $NH_3$  concentrations up to 8% [46]. Reducing  $NH_3$  volatilization can be done through inhibiting microbial uricase activity in poultry manure [47]. Inhibiting microbial uricase in poultry manure are critical ways to reduce  $NH_3$  volatilization.  $NH_3$  gas from poultry manure produced by uric acid hydrolyzing by microbial uricase. Supplementation 1000 ppm inorganic zinc to laying hens diet reduced 16% ammonia level with no negative effect on performance production [47].

Reducing ammonia volatilization can be done by directing an air flow across the manure, in which this way will accelerate the drying of the manure. Adding acidifier and adsorbent additives to manure have can be reducing  $NH_3$  volatilization [41]. Several researchers reported that there are various acids which have the

ability to reduce ammonia volatilization, i.e., sulfuric acid and hydrochloric acid, chloride and nitrate salts of magnesium and calcium, and base precipitating salts [48–50]. There are adsorbent additives which can adsorb  $\text{NH}_3$ ,  $\text{NH}_4^+$ , or both, such as zeolites. Zeolites can use as both as a feed additive and waste additive which can reduce ammonia volatilization [51]. Zeolite doses addition for broiler litter are  $5 \text{ kg/m}^2$  which reduced  $\text{NH}_3$  concentrations by up to 35% [46]. Uricase inhibitors addition to manure will inhibit ammonia volatilization. The addition of 3 and 6 g Zn to 600 g poultry manure reduced  $\text{NH}_3$  volatilization approximately 15 and 26%, respectively, during the 3-week incubation. Zn has the ability to block the activity of microbial uricase. Besides Zn, Cu reported has used as a uricase inhibitor [47].

### 3.2. Reducing hydrogen sulfide emissions

Hydrogen sulfide is produced of anaerobic processing from the microbial reduction of sulfate in water and the decomposition of sulfur-containing organic matter in manure.  $\text{H}_2\text{S}$  which produced in poultry farms reported harmful for poultry itself, humans, and the environment. There are several ways to reduce  $\text{H}_2\text{S}$  emission from manure, the first is through agitating the manure, it is aimed to promote  $\text{H}_2\text{S}$  release at the manure which results in a much smaller volume of  $\text{H}_2\text{S}$  in the manure [52]. The second, reducing dietary sulfur, because dietary sulfur is the major source of sulfur in the manure. Lowering dietary sulfur, which can be accomplished by selecting low sulfur content feedstuffs or adding additives which have the ability to improve digestive efficiency [52]. The third way is adding feed-additive to diet. Adding probiotics and prebiotics reduced the amount of left-over S in manure [53]. The moisture content of manure significantly influenced the  $\text{H}_2\text{S}$  emission from manure, high moisture content of manure resulted in high  $\text{H}_2\text{S}$  emission from manure [85]. Addition 0.05% chlorine dioxide to broiler diet reported significantly reduced  $\text{CH}_3\text{SH}$  emission up to 62.5% [54]. Reducing  $\text{H}_2\text{S}$  on broiler manure resulted with addition 0.2% lactulose to broiler diet as a result of increasing Lactobacilli and decreasing *Escherichia coli* in excreta [55]. Addition probiotic (*Enterococcus faecium*) on poultry diet significantly reduced in  $\text{H}_2\text{S}$  emissions or total  $\text{CH}_3\text{SH}$  from manure which freshly collected [56,57]. Addition of 105 CFU/kg of *Bacillus subtilis* on broiler diet significantly reduced  $\text{H}_2\text{S}$  concentration up to 37.9%. Other report showed that addition of probiotic (*Bacillus subtilis*) significantly reduced  $\text{H}_2\text{S}$  concentration on manure up to 29.9% [58]. Addition of 5 g/kg *Bacillus amyloliquefaciens* to broiler diet has a significant effect in  $\text{H}_2\text{S}$  fecal emission reduction [59]. The addition of 3 g/kg feed (107-8 CFU/g) probiotics (i.e., *Saccharomyces*, *Streptococcus*, *Bacillus*, *Lactobacillus*, *Clostridium*, and *Candida* species) on broiler diet reduced manure gaseous compounds ( $\text{NH}_3$ ,  $\text{H}_2\text{S}$ , and  $\text{CH}_3\text{SH}$ ) [60].

Animal housing facilities and manure storage sites significantly influenced the reduction of hydrogen sulfide emission from manure in which manure pH plays a crucial role in emissions of  $\text{H}_2\text{S}$  [61]. Reduction of emission of  $\text{H}_2\text{S}$  produced by higher manure pH.  $\text{H}_2\text{S}$  produced maximum at physiological pH (6.5-7.5), in which, 50% inhibition  $\text{S}_2$ - production resulted at pH 4.0 and pH 9.0 [62]. Addition of bacteria and yeast (*Bacillus subtilis* subsp. spizizenii, *Leuconostoc mesenteroides*, *Candida inconspicua*, and *Psychrobacter faecalis*) in the water as poultry manure deodorization reduced  $\text{H}_2\text{S}$  from the exhaust gas up to 17.5%. *Yucca schidigera* reported has the ability to reduce  $\text{H}_2\text{S}$  emission from poultry manure [63]. *Yucca schidigera* contain saponin which has the ability to inhibit microbial fermentation of protein [64]. Therefore, adding water which contains *Yucca schidigera* to manure reduced  $\text{H}_2\text{S}$  concentration from poultry manure up to 64% [65]. The use of deodorization that using a combination of bacterial species (*Leuconostoc mesenteroides*, *Bacillus subtilis*, *Pseudomonas fluorescens*, *Enterococcus faecium*, *Bacillus megaterium*, and *Lactobacillus plantarum*) in manure reported significantly reduced  $\text{H}_2\text{S}$  concentration from the exhaust air by 60% [66]. The one important thing to reduce  $\text{H}_2\text{S}$  emission from poultry farms is how to reduce the moisture content of the manure. Therefore, making the good of ventilation system in the poultry farms is the one important way to control manure moisture [67]. Accordingly, good air quality in the poultry farms can be produced through a good ventilation system. So that, minimizing  $\text{H}_2\text{S}$  emission. High reduction of

H<sub>2</sub>S concentration up to 98% can be achieved through using *Thiobacillus thioparus* as a biofilter in the condition of manure temperature between 20–37°C. It is because *Thiobacillus thioparus* has the ability to oxidize H<sub>2</sub>S to SO<sub>4</sub><sup>2-</sup>, elemental S, SO<sub>3</sub><sup>2-</sup>, and S<sup>2-</sup> [68]. Other biofilters, i.e., *Acidithiobacillus thiooxidans* and *Hyphomicrobium VS* reduced more than 99.8% H<sub>2</sub>S concentration [69]. Besides, adding sawdust to manure reduced production of H<sub>2</sub>S.

### 3.3. Reducing Greenhouse Gas Emission (GHG) emissions

Broiler manure has been identified producing carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), in which those gasses is greenhouse gasses (GHG) contributor [12]. Greenhouse gas emission (GHG) generally produced by the combustion process. The major contributor of GHG is CO<sub>2</sub>. There are several factors which influenced the amount of GHG emissions from animal manure, i.e., the moisture content of manure, manure temperature, manure loading rate by the animal, depth of manure in the pen, redox potential, available carbon, diets, and microbial process [70]. There are several ways to decrease GHG emissions. First, lowering the temperature of storage manure. Second, making filter tools for ventilation air. Third, facilitating the manure storage house which can reduce anaerobic digestion process. Fourth, management of feed. Fifth, adding acidifier to manure. Sixth, increasing the aeration of the storage manure [71]. Methane produced by the anaerobic process. Therefore, increasing the oxygen level in a manure storage place will inhibit methane emission. Manure management is the main way to minimize GHG emission. There are several options of manure management which reduced GHG emission, i.e., application composting technology, control of aeration, use of amendments, or co-composting manure with other organic waste [72].

### 3.4. Reducing odor pollution

Emission of odor from poultry farms resulted from fresh and decomposing waste products, i.e., bedding litter, manure, carcasses, feathers. Manure storage is the main source of odor emission [73]. Odor from livestock farms produced by complex compound including hydrogen sulfide (H<sub>2</sub>S), ammonia (NH<sub>3</sub>), and volatile organic compounds (VOCs). There are several ways to reduce odor pollution from broiler farms, i.e., using of biofilters, agent of neutralizing, and scrubber of air, besides, application management litter, treatment of ozone, walls for a windbreak, short stack, even though those ways is expensive and unpractical. [74]. Odor emissions from poultry production can be controlled in several approaches. First, cleaning poultry manure as often as possible, recommended cleaning litter can be done once a week for the dry season, and twice a week during the rainy season. Second, the use of a closed house equipped with biofilter and air purifier. Third, reducing manure water content can be done sprinkling rice husk/sawdust regularly to the litter cage. Fourth, adding deodorant products to the feed, or directly in the farms. Fifth, build a cage structure that provides protection against wind exchanges. Sixth, applying feed management [75]. Based on poultry nutrition aspect, the way to reduce odor pollution from broiler farms is how to give broiler diet which has sufficient to broiler nutrient requirement. The principle of odor pollution from animal manure is based on the amount of excessive nutrient which is released through the manure. The major source of odor from broiler farms is litter, in which dominant part of litter is excreta [76]. The content of fecal portion is undigested dietary nutrient, endogenous secretions, and microflora in the gastrointestinal tract, and their metabolites. Feed management has an important role in minimizing odor emission from broiler farms [77].

Many researchers reported that the role of management of feed to odor emission from broiler farms related to the role of dietary nutrient toward gut microflora, fecal microflora, litter moisture content, litter pH, litter water activity, in which all of those affected the odor emission of from litter [78-82]. Using low crude protein (CP) poultry diet reduced odor emission because reducing litter pH, nitrogen excretion, NH<sub>3</sub> emissions, and litter moisture [83]. Furthermore, broiler's low CP diet reduced the concentration of putrefactive metabolites in the caeca (i.e., ammonia, skatole, phenols, amines, indoles, cresol and branched

chain fatty acids) [84]. Nutrient content of diet-related to water intake, therefore, nutrient content has relation to a moisture content of litter, the water activity of litter ( $A_w$ ), litter pH and odor emissions [80]. Reducing litter moisture content and  $A_w$  reduced odor emission from broiler farms [85]. Reducing moisture litter content and maintaining litter pH above 7.5 effective reduced odor emission. The use of an enzyme (i.e., protease, phytase) in broiler diet which increasing nutrient utilization hopefully reducing the release of excess nutrient through excreta [76]. Therefore, adding an enzyme to a broiler diet can be reducing odor emissions. Adding feed additive that is lactobacillus containing probiotics on the broiler diet reported reducing odor emission from broiler farms [86]. The use of saponin has a positive effect to reduce odor emission. It is because saponin has the ability to inhibit microbial fermentation of protein [64]. Reducing odor emission from broiler farms can be done by using Vegetative Buffers [87]. The strategy of Vegetative Buffers is through planted grasses, shrubs and trees in the near area of broiler farms. The general way to reduce odor emission from poultry farms is through covering manure storage and anaerobic lagoons. This method has proven to control odor emissions. The covering manure method reduced odor emissions from poultry manure through making a physical barrier which inhibits the release of volatile chemical compounds from leaving the liquid. The several kinds of cover type are the permeable floating covers, i.e., straw or geotextile and plastic covers.

### 3.5. Reducing dust pollution

Dust is a component that plays a role in the transport of gaseous and odorous compounds, so that dust classified as one of the kinds of air pollution. Dust has a negative effect on the health and welfare of animals and humans, particularly farms worker. The concentration of dust in poultry houses vary from 0.02 to 81.33 mg/m<sup>3</sup> for inhalable dust and from 0.01 to 6.5 mg/m<sup>3</sup> for respirable dust [88]. There are several sources of dust in poultry houses, i.e., litter, down feathers, crystalline urine, feed, excrement, and microorganisms [89]. Litter is the primary source of dust emissions in broiler houses. Dust level in poultry houses influenced by several factors, i.e., moisture conditions, animal activity, and animal density. There are several approaches which can we do to reduce dust pollution in broiler farms, i.e., vacuum cleaning, adding fat to feed, purge ventilation, fogging with water and oil-based sprays, electrostatic filtration, ionization, and wet scrubbers [90]. One way to reduce dust pollution is using air ionization [91]. Air ionization method has several benefits, i.e., transform, destruct, and remove volatile organic compounds and potentially hazardous [92]. Air ionization is the dust reduction method that has the ability to reduce livestock dust up to 90% [93]. Several researchers reported that air ionization has many benefits besides reducing dust pollution in poultry houses, such as; having bactericidal effects and can reduce airborne micro/organisms, generating of submicron aerosol particles, settling of precipitated dust on surfaces in the room [94–96].

## 4. Conclusion

One problem in broiler production is air pollution from broiler farms. There are several primary air pollutions from broiler farms, i.e., the pollution from emissions of ammonia, hydrogen sulfide, greenhouse gasses, odor, and dust. Generally, air pollution from the broiler farm resulted mainly from broiler manure. Therefore, manure management is the main way in the reduction of air pollution from broiler farms. Management of feeding is the other way to reduce air pollution from broiler farms, it is because the air pollution from broiler manure resulted from excess nutrient from feed which released through manure. Applying feed additives and waste additive is the other way which recommendation to reduce air pollution from broiler farms, besides other approaches which recommend in this review.

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