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Full Length Research Paper

A calculation program for real-time production of ammonia gas in animal houses

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Ammonia is the major air contaminant in poultry houses. Ammonia emissions from animal houses influence the atmospheric environment, since aerial ammonia is one of the so called greenhouse gases and has a negative effect on vegetation and ecosystems. There are many researches on ammonia emissions from the animal houses but, there aren't such many researches on the real-time production of ammonia in the animal house. For this reason, a calculation method along with the software for practical prediction has been developed for real-time production of ammonia gas inside the animal house. This method is based on mass balance equilibrium concerning the forced or natural ventilation conditions inside the barn. The software is developed in MS Visual Basic 6.0 language and can be demanded from ggurdil@omu.edu.tr.

Key words: Ammonia, animal, barn, computer program.

INTRODUCTION

The air contaminants in poultry housing are generally classified as respirable dusts from feed, manure, animal skins and feathers; microbes, both pathogenic and nonpathogenic, hosted in the respiratory tracts or animal wastes and gases of many types (Gürdil, 1998). The most common gases inside the animal houses are ammonia, hydrogen sulfide, carbon dioxide and methane. Dust is generated primarily from the feed and by animal activity and air movement causing re-entrainment of settled dust. Gases are produced from the metabolic processes of animals and from the anaerobic microbial degradation of wastes.

The major air contaminant in poultry houses is ammonia (NH_3). The ammonia released in livestock buildings influence the animal environment, the working environment and the chemical and physical environment for the building materials (Jeppsson, 2000). Ammonia concentration, thermal and humid conditions in the building can influence the state of health of workers and animals, as well as the durability of building materials. High concentrations of ammonia inside the animal houses represent potential health hazards to humans and animals (Groot, 1994). It can cause acute and chronic respiratory diseases, and allergic responses in exposed workers (Jeppsson, 2000). The concentration of ammonia also affects the growth rate, feed efficiency and mortality of the animals (Anderson, 1994). Real - time production of ammonia gas must be derived by mass balance equilibrium because they are dependent on various factors; ventilation rate, air temperature and moisture content inside the house, moisture content and deterioration of litter, number of animals, etc. A calculation method along with the software for practical prediction of real-time ammonia production level inside the barn has been developed by using MS Visual Basic 6.0 language.

THE EXPERIMENT AND THE SOFTWARE

The software, developed in MS Visual Basic 6.0 language, enables us to calculate the real-time production of ammonia gas inside the animal house according to the mass balance equilibrium considering the real forced ventilation or real natural ventilation rate in the animal house. An example of the code from the software is given below;

```
Private Sub Command 4_Click ()
Form1.Width = 13005
Left = (Screen. Width - Width) \ 2
Top = (Screen. Height - Height) \ 2
b = Val (Text6) + 273.15
a = 2.7182 ^ ((-7511.52 / b) + 89.63121 + 0.02399897 * b -
(1.1654551 * b * b / 100000) - (1.2810336 * b * b * b / 100000000)
 + (2.0998405 * b * b * b * b / 100000000000#) - 12.150799 * Log
(b))
```

```
d = a * Val(Text7) / 100
E = 0.62198 * d / (101.325 - d)
e11 = E * 1000
h = 0.28705 * b * (1 + 1.6078 * E) / 101.325
i = 1 / h
b11 = Val(Text8) + 273.15
a11 = 2.7182 ^ ((-7511.52 / b11) + 89.63121 + 0.02399897 * b11 - (1.1654551 * b11 * b11 / 100000) - (1.2810336 * b11 * b11 * b11 / 100000000) + (2.0998405 * b11 * b11 * b11 * b11 / 100000000000#) - 12.150799 * Log(b11))
d1 = a11 * Val(Text9) / 100
e1 = 0.62198 * d1 / (101.325 - d1)
e21 = e1 * 1000
h1 = 0.28705 * b11 * (1 + 1.6078 * e1) / 101.325
i1 = 1 / h1
s1 = Val(Text12) * (i - i1) * 9.81
If s1 < 0 Then s1 = s1 * (-1)
Label26.Caption = Int(s1 * 100) / 100
m = i * s1 * 0.49 * Val(Text11) * Val(Text11) / (i * 0.49 * Val(Text11) * Val(Text11) + 0.36 * Val(Text10) * Val(Text10) * i1)
n = s1 - m
p = 0.7 * Val(Text11) * ((2 * n * i) ^ 0.5)
```

A portable gas detector OLDHAM MX 21 PLUS is used for ammonia concentration measurements. Air temperature, air relative humidity and air velocity values of inside and outside air is recorded by Testo 400 data logger. This software is tested in a broiler house having dimensions 12 × 60 × 2.5 m with 11500 broiler capacity and 16 broilers.m^{-2}. The broilers were 5 weeks old and had an average weight of 1.35 kg.broiler^{-1}.

Real-time production of ammonia gas in an animal house according to the mass balance can be expressed as:

$$O.dk_i = K.dt + V_e.k_e.dt - V_e.k_i.dt \quad (1)$$

That is; variation of ammonia gas inside = gas production + gas entering – gas outgoing and where;

K: Real-time production of ammonia gas (mg.s^{-1})
V_e: Air flow rate (m^3.s^{-1})
k_e: Concentration of ammonia gas in outside air (mg.m^{-3})
k_i: Concentration of ammonia gas in inside air (mg.m^{-3})
O: Volume of the animal house (m^3)
t: Time (s)

If we derive both sides by time and solve the equation for dt, we get:

$$\int_{ki1}^{ki2} \frac{O}{K + V_e . k_e - V_e . k_i} dk_i = \int_{t1}^{t2} dt \quad (2)$$

Where;

t_1: Beginning of measurement (s)
t_2: End of measurement (s)
k_{i1}: Ammonia concentration in inside air at time t_1 (mg.m^{-3})
k_{i2}: Ammonia concentration in inside air at time t_2 (mg.m^{-3})

If we solve the equation then the real-time production of ammonia gas will be;

$$K = -V_e\left(k_e + \frac{k_{i1} - k_{i2}\, e^{\frac{V_e}{O}(t_2 - t_1)}}{1 - e^{\frac{V_e}{O}(t_2 - t_1)}} \right) \quad (3)$$

This developed equation is the theoretical production level of ammonia gas in (mg.s^{-1}) inside the poultry house according to the mass balance equilibrium. The equation enables us to determine the amount of ammonia produced inside the poultry house by defining the volume of the barn, ammonia concentrations at the beginning and at the end of the measurement, duration of the measurement, and also the amount of air flow rate inside the house.

There's another and an easier way of determining the ammonia production rate inside the animal house. In this method the animal house must be closed tightly and no air flow must be occurred into the animal house or out from the animal house. By this way a closed system is created. As being a closed system the ammonia concentration inside the house will tend to rise up by time since there will be no replacing fresh air. The initial ammonia concentration must be recorded and then the increase in ammonia concentration must be carefully observed by a gas detector until the maximum allowable safety limit has been achieved (for example; 25 ppm for poultry). The production rate of ammonia inside the house can be determined by the difference between initial and final ammonia concentrations, the elapsed time and the volume of the house.

$$K = \frac{k_{i2} - k_{i1}}{t_2 - t_1}.O \quad (4)$$

But, this method is rather risky and no farmer will allow the application of this method. Therefore, it' strongly advised to determine the real-time ammonia production rate as in equation 6. As mentioned before, V_e is the amount of air flow inside animal house. If there is forced ventilation inside the house V_e can be taken as the amount of ventilation rate, which is the capacity of running fans. But, if there is natural ventilation inside the house (usually in spring and in fall breeding period) the amount of air flow inside the animal house can be calculated by the inside and outside air temperature and relative humidity values and concerning total static pressure balance (Gürdil et al., 2001).

$$M_v = \mu_i.S_i.\sqrt{2.pi.\rho_e} \quad (5)$$

$$p = p_i + p_o \quad (6)$$

$$\mu_i.S_i.\sqrt{2.(p - p_o).\rho_e} = \mu_o.S_o.\sqrt{2.p_o.\rho_i} \quad (7)$$

$$V = \frac{M_v}{\rho_e} \quad (8)$$

Where;

M_v: Mass flow of ventilation air (kg. s^{-1})
V : Volume flow of ventilation air (m^3. s^{-1})
μ_i: Correction factor for air inlets
μ_o: Correction factor for air outlets
S_i: Area of air inlets (m^2)
S_o: Area of air outlets (m^2)
ρ_i: Density of inside air (kg. m^{-3})
ρ_e : Density of outside air (kg. m^{-3})

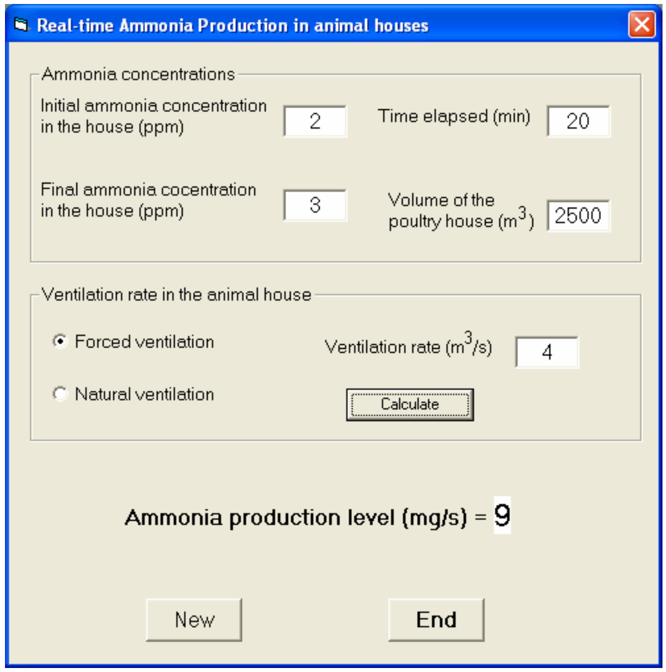

Figure 1. Ammonia production level under forced ventilation conditions.

p : Total static pressure (Pa)
p_i : Inside static pressure (Pa)
p_o : Outside static pressure (Pa)
h: Vertical distance between air inlet and outlet (m)
Calculation of air density according to air temperature and relative humidity is given below (Wilhelm, 1976):

$$\ln(p_{ws}) = \frac{-7511.52}{T} + 89.63121 + 0.023998970T - 1.1654551x10^{-5}T^2 - 1.2810336x10^{-8}T^3 + 2.0998405x10^{-11}T^4 - 12.150799\ln(T) \quad (9)$$

$$\phi = \frac{p_w}{p_{ws}} \quad (10)$$

$$W = 0.62198\frac{p_w}{P - p_w} \quad (11)$$

$$v_h = \frac{R*T}{P}(1 + 1.6078W) \quad (12)$$

$$\rho = \frac{1}{v_h} \quad (13)$$

Where;

p_{ws} : Water vapor saturation pressure (kPa)
p_w : Water vapor pressure (kPa)
ϕ : Relative humidity (decimal)
W : Humidity ratio (decimal)
R : Gas constant (J.kg^{-1}.K^{-1})
T: Temperature (K)
P: Total pressure (kPa)
v_h : Specific volume (m^3.kg^{-1})
ρ: Air density (kg. m^{-3})

By equation 13 density of outside air is calculated from outside air temperature and relative humidity values and density of inside air is calculated in the same way. Then, natural ventilation rate due to thermal buoyancy is calculated by equation 8. Natural ventilation rate due to wind forces is calculated as follows (Albright, 1991);

$$Q = E.A.v \quad (14)$$

Where;
Q: Ventilation rate (m^3.s^{-1}),
A: Area of air inlets (m^2),
v: Wind velocity (m.s^{-1}),
E: Efficiency of air openings.

For the wind blowing perpendicular to air openings; E = 0.50…0.60 and for the non-perpendicular blowing wind E = 0.25 to 0.35 is recommended. The wind rarely blows perpendicular to agricultural structures and for this reason (E = 0.35) is recommended for the agricultural structures (Albright, 1991).

Total natural ventilation rate will be the sum of V (eq.8) and Q (Equation 14). This sum is representing V_e in Equation 3 while calculating real-time ammonia production rate (K) under natural ventilation conditions.

RESULTS AND DISCUSSION

The confirmation of the developed software was done in a broiler house with dimensions 12 × 60 × 2.5 m. There were 11500 broilers inside the house (16 broilers. m^{-2}) and the broilers were 5 weeks old and had an average weight of 1.35 kg.broiler^{-1}. The software is tested for both forced ventilation and natural ventilation conditions. The result of the program for forced ventilation condition is

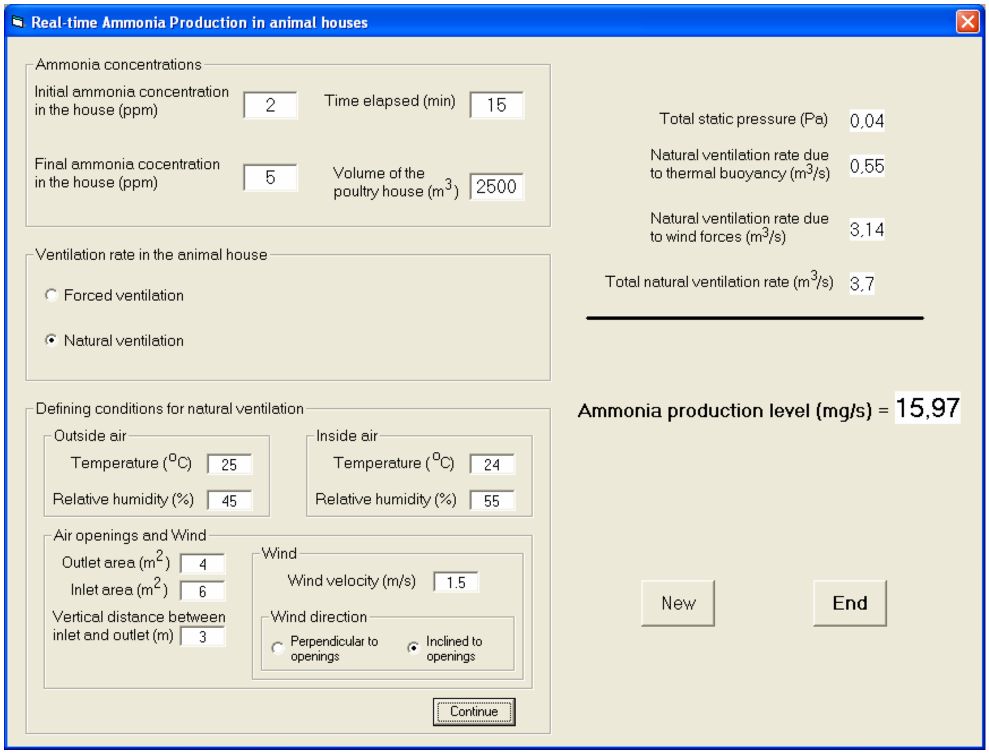

Figure 2. Ammonia production level under natural ventilation conditions.

given in Figure 1. Forced ventilation rate inside the house was 4 $m^3.s^{-1}$ and the measurement was done for 20 minutes inside the broiler house with. The air quality inside the house was quite good. The initial ammonia concentration was 2 ppm inside the house, which is under safety limit (25 ppm) for the poultry. No increase in ammonia concentration was observed during the running of ventilation fans. Ammonia concentration inside the house rose up just 1 ppm more in 20 min. This could be a result of the increase in bird activity. The real - time ammonia production inside the broiler house was calculated as 9 $mg.s^{-1}$ (referring equation 3) under forced ventilation for this house.

The software is tested for natural ventilation conditions for the same broiler house. Natural ventilation conditions were defined (inside and outside conditions, wind characteristics and air inlet and outlet openings) for prediction of the real-time ammonia production. Total natural ventilation rate and the real time ammonia production level were calculated (referring equation 8, 14 and 3). Real-time ammonia production under natural ventilation conditions was calculated as 15.97 $mg.s^{-1}$ (Figure 2). The aim of this work was to determine the real-time ammonia production level, which is a major hazardous gas for the animals and for the environment, under any condition. The theory is based on mass balance equilibrium and explained clearly with the equations in the text and software was developed for determination of real-time ammonia production level in any type of animal housing. Considering the negative effect of air contaminants and greenhouse gases for the environment and for the human life this developed theory and software can be applied for any type noxious gases. These types of tools will be useful for the farmers, agricultural or environmental engineers.

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