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Research Article

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Evaluation of the Harmful Gas Concentrations Emitted into the Water Buffalo Barns in Terms of Animal Welfare

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Abstract The purpose this study was to examine the effects of the harmful gas concentrations emitted into the closed-type buffalo barns on the animal welfare. This study was carried out in a livestock business located in the Thrace region of Turkey, which was selected as the pilot region. In the selected business, two groups were formed among the water buffaloes, the genetic similarities of which was accepted as the same. One of the water buffalo groups was housed in the Barn-I, where the climatic environment could be controlled; and the other was housed in the Barn-II, where the climatic environment could not be adequately controlled. As a result of the study, it was determined that while the harmful gases accumulated in the barn environment did not pose a problem in the Barn-I; in the Barns-II, especially CO_2 and NH_3 exceeded the limit values with 3330.6 ppm and 21.1 ppm, respectively, and reached the levels that could adversely affect the animal welfare. In order to eliminate these problems, it was recommended that, in winter, the capacity of the ventilation systems in the buffalo barns be 110.4 m^3/h BHB for the humidity balance and 97.1 m^3/h BHB for the carbon dioxide balance.

Keywords Water buffalo barns, harmful gases, animal welfare

Introduction

The term "cleanliness of the barn air" refers to the chemical composition of the air and the state of the dust and microorganisms in the barn. The chemical composition of the air affects the physiological condition of the animal. The gaseous pollutants such as C_2O, NH_3, H_2S, and SO_2 are emitted by the animals and as a result of the various microorganism activities in the barn. The type of these pollutants and their concentrations in the air vary depending on the breed of the animal, design of the barn and ground, feeding and water delivery system, type and composition of the feed, age of the animal, density of the housing, manure management, and the environmental conditions control systems [1]. These pollutants in the barns are tried to be kept under the harmful levels by means of the environmental control systems such as the ventilation systems. Otherwise, the accumulation of harmful gases above the limit values in the ambient air adversely affects the animal welfare. The rate of the gases causing problems for the animal health in the barn air should not exceed certain levels, that is, C_2O, NH_3, and H_2S should not exceed 0.35%, 0.03%, and 0.001%, respectively [2].

The main source of the carbon dioxide in the animal barns is the respiration of animals and workers [3]. In addition to this, the carbon dioxide can be generated as a result of the microbial decomposition of the organic substances under the aerobic and anaerobic conditions.

On a global scale, it is estimated that around 20 million tons of ammonia nitrogen are annually emitted from the animal barns. This amount accounts for about 50% of the total ammonia emissions originating from the terrestrial system [4]. The hydrogen sulfide emissions originating from the animal barns are at a very low level compared to other atmospheric sulfur sources. However, in the regions where the animal barns are concentrated on a regional scale, they significantly contribute to the sulfur load of the atmosphere [5].

The methane emission in the livestock is caused by the digestive system of ruminants and the fermentation of manure and silage [6]. The generation of methane varies depending on various factors such as the energy content, quality, and quantity of the feed; the weight and age of the animal [7]. In the livestock business, in addition to the feed fermentation, the manure storage and discharge processes are also the most important sources of methane [8].

The purpose of this study was to examine the effects of the harmful gas concentrations on the animal welfare in the controlled barn conditions where the climatic environment can be optimally controlled and in the uncontrolled barn conditions where the climatic environment cannot be adequately controlled.

Material and Method

This study was carried out in a livestock business located in the Thrace region of Turkey, which was selected as the pilot region. The study area is located between the latitude of 41° 12' North and the longitude of 28° 44' East and its average altitude from the sea level is 119 m [9].

In the selected business, two groups were formed among the water buffaloes; which were born in the same period and had the same lactation numbers; the genetic similarities of which was accepted as the same. One of the water buffalo groups was housed in the Barn-I, where the climatic environment could be near-optimally controlled; and the other was housed in the Barn-II, where the climatic environment could not be adequately controlled. The study was carried out in winter. This is because the Anatolian buffaloes are housed in the closed-type barns all the time in the winter months due to their physiological characteristics and the climate of the region. In the study, the same feed ration was given to both buffalo groups. Over the course of the study, in order to determine the harmful gas concentrations inside and outside the barn, the measurements were made at 10-minute intervals using a multi-gas meter with data logger. For this purpose, one gas meter was used for each barn and the outdoor environment. Although the measurement precision of the devices varies according to the gas measured, it is generally between 0.01-1 ppm for the gases measured in the study (NH_3, H_2S, CH_4, and CO_2). Furthermore, in order to determine the ventilation flow rate in the current situation, the air flow rate was measured in the air outlet chimneys using the digital anemometer. At the end of the study, the harmful gas concentrations were compared with the ones in the literature and the possible risks were evaluated in terms of the animal welfare. The statistical analyses of the study were carried out according to descriptive statistics and the Duncan's multiple comparison test [10].

Results and Discussion

In general, in controlling the climatic environment in closed-type barns, the temperature and humidity balance are emphasized and the chemical composition of the air is often neglected. However, various harmful gases such as carbon dioxide, ammonia, hydrogen sulfide, and methane are emitted into the ambient air as a result of the animal metabolism and the decomposition of the manure and urine. If these gases are not vented out of the barn in parallel with the rate of generation, they can reach the concentrations that may adversely affect the animal health and yield.

For ensuring the homogeneity in the comparison of the data obtained from the study, the ground area and internal volume per buffalo in the barns were tried to be balanced by the number of animals. The ground area and internal volume per buffalo were 3.41 m^2 and 12.03 m^3 in the Barn-I and 3.27 m^2 and 12.25 m^3 in the Barn-II, respectively. In the calculations, the AU (Animal Unit) was used based on 454 kg of live body weight. The average live weight of the buffaloes was found to be 537.25 kg according to the measurements made using the electronic scales in the research farm. Based on this value, 28.4 AU was housed in the Barn-I and 17.7 AU was housed in the Barn-II.

The minimum, maximum, and average values for the harmful gas concentrations were calculated on a daily basis for each barn by means of using the data obtained from the measurements. The calculated values were compared with the ones suggested by Stowel et al. [11] and Olgun [12] as the maximum permissible concentrations in the animal production structures given in Table 1 and the possible risks were evaluated in terms of the animal welfare.

Table 1: The maximum permissible gas concentrations in the animal production structures

Harmful gas	Maximum gas concentrations (ppm)
Carbon dioxide (CO_2)	3000
Ammonia (NH_3)	20
Hydrogen sulphide (H_2S)	0.5
Methane (CH_4)	10000

The daily changes in the CO_2 concentration in the Barn-I, Barn-II, and in the outdoor air were given in the Figure 1 and Figure 2, respectively.

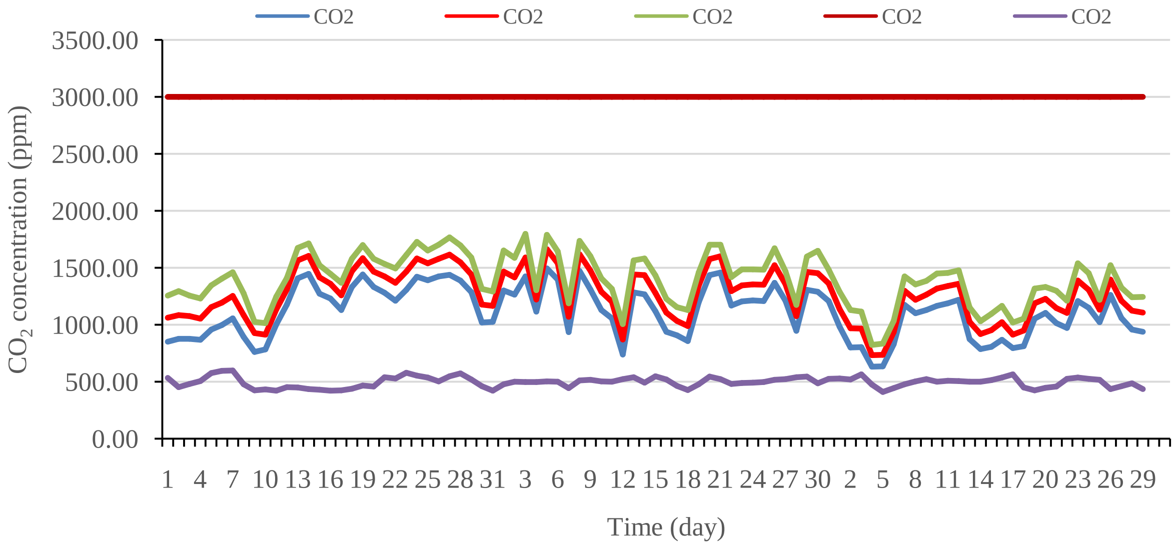

Figure 1: The daily changes in the CO_2 concentration in winter the Barn-I

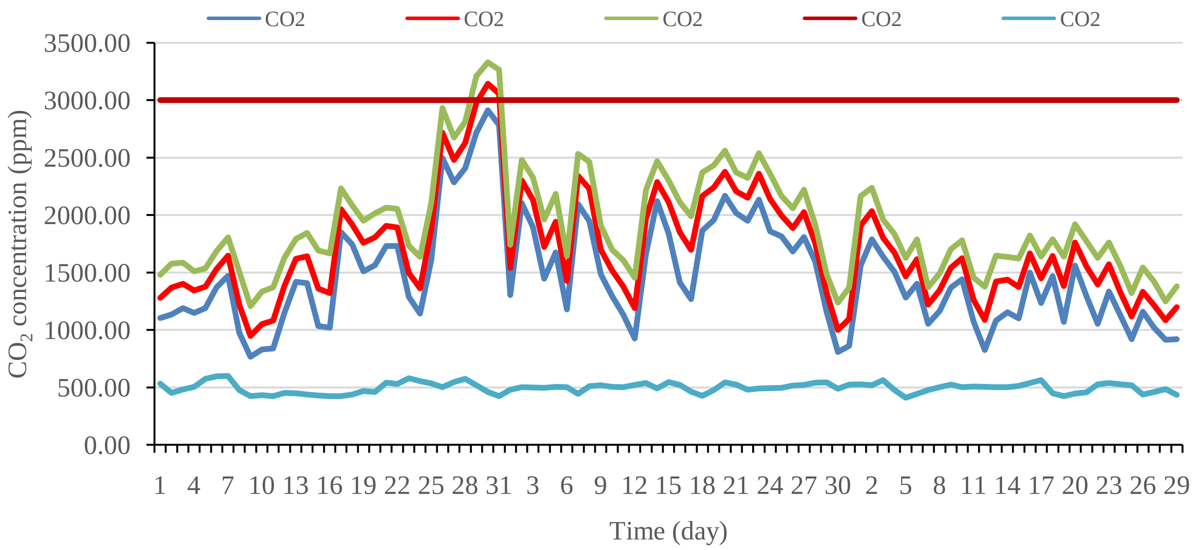

Figure 2: The daily changes in the CO_2 concentration in winter the Barn-II

When the Figure 1 and Figure 2 were examined in terms of carbon dioxide, it was seen that the CO_2 concentrations varied within the range of 630.6-1796.5 ppm, 766.2-3330.6 ppm, and 422.2-563.5 ppm in the Barn-I, Barn-II, and in the outdoor environment, respectively. 3000 ppm is accepted as the upper limit for the carbon dioxide concentration in the farm animals [11,12]. Based on this value, it was observed that while the CO_2 accumulation did not pose any problem in the Barn-I; in the Barn-II, the upper limit value was sometimes exceeded and the carbon dioxide concentration generally progressed higher than the Barn-I.

The daily changes in the NH_3 concentration in the Barn-I, Barn-II, and in the outdoor air were given in the Figure 3 and Figure 4, respectively.

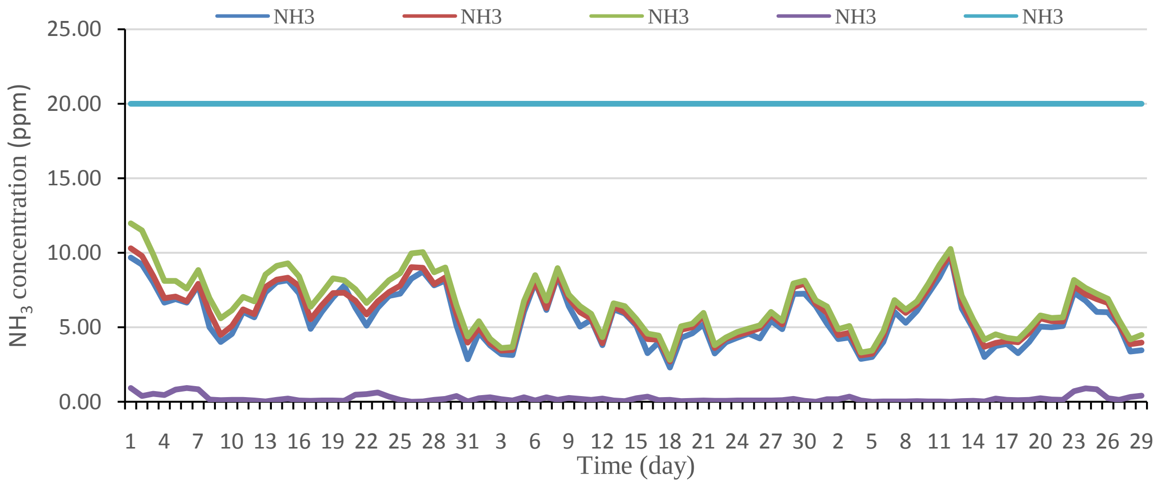

Figure 3: The daily changes in the NH_3 concentration in winter the Barn-I

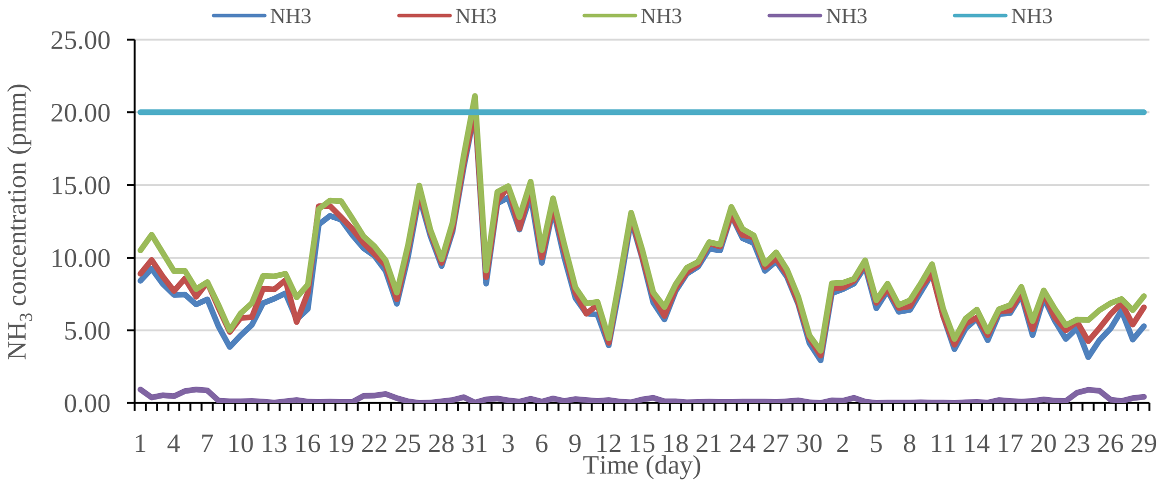

Figure 4: The daily changes in the NH_3 concentration in winter the Barn-II

When the Figure 3 and Figure 4 were examined in terms of ammonia, it was seen that the NH_3 concentrations varied within the range of 2.3-11.9 ppm, 2.9-21.1 ppm, and 0.02-0.9 ppm in the Barn-I, Barn-II, and in the outdoor environment, respectively. 20 ppm is accepted as the upper limit for the ammonia concentration in the farm animals [2]. Based on this value, it was observed that while the NH_3 accumulation was not at a harmful level in the Barn-I, the upper limit value was exceeded for short times in the Barn-II, especially during the cold times when the ventilation was turned down.

The minimum, average, and maximum ppm values for the harmful gas concentrations per AU in the barns were given in the Table 2 and Table 3 for the Barn-I and Barn-II, respectively.

Table 2: The monthly average concentrations of harmful gases measured in Barn-I

Month	**CO_2 concentrations for AU (ppm)**		
	Min. avg	**Avg.**	**Max. avg**
December	43.6	48.8	53.1
January	42.3	47.5	52.1
February	34.4	40.8	43.7
NH_3 concentrations for AU (ppm)			
December	0.23	0.24	0.27
January	0.18	0.19	0.20
February	0.19	0.20	0.20

Table 3. The monthly average concentrations of harmful gases measured in Barn-II

Month	CO_2 concentrations for AU (ppm)		
	Min. avg	**Avg.**	**Max. avg**
December	87.1	99.6	111.8
January	91.9	105.8	117.6
February	71.8	94.4	95.2
NH_3 concentrations for AU (ppm)			
December	0.53	0.54	0.59
January	0.51	0.52	0.56
February	0.34	0.35	0.39

When the Table 1 and Table 2 were examined together, it was seen that the minimum, maximum and average values for the harmful gas concentrations per AU were quite high in Barn-II compared to the Barn-I.

When a general evaluation was made for the winter season; the inadequacy of the natural ventilation chimneys and the uncontrolled ventilation carried out using the windows in the Barn-II made the control of the climatic environment difficult and sometimes caused a harmful gas accumulation above the limit values in the barn. This situation mainly stemmed from the inadequate ventilation capacity in the Barn-II, and consequently the low air change rate. Ekmekyapar [13] suggests that in order to keep the climatic environment at the optimum levels in winter, the air change rate per hour should be at least 4-6 in the barns According to the calculations made based on the measurements in the air outlet chimneys using the digital anemometer, the air change rate per hour was found to be within the range of 5-7 for the Barn-I and within the range of 3-5 for the Barn-II. The current ventilation capacity per AU in the barns was calculated based on the ventilation rates measured in the chimneys using a digital anemometer and was given in the Table 4. Furthermore, the ventilation capacities required for the humidity and the carbondioxide balance in the barns were calculated in line with the principles provided by Ekmekyapar [13] and Mature [12] and were given in the Table 4.

Table 4: The calculated ventilation capacities according to different approaches for winter conditions

Barn no	Amounts of the ventilation capacity calculated by different method		
	Existing system (m^3/h AU)	**Humidity balance (m^3/h AU)**	**CO_2 balance (m^3/h AU)**
Barn-I	118.5	110.4	97.1
Barn-II	91.5	110.4	97.1

When the Table 4 was examined, it was seen that whereas the ventilation capacity available was sufficient for the humidity and carbon dioxide balance in Barn-I, it was insufficient in the Barn-II. In this case, due to the insufficient ventilation, the CO_2 and NH_3 concentrations sometimes exceeded the limit values in the Barn-II and reached the levels that may adversely affect the animal welfare.

Although methane (CH_4) gas, one of the other harmful gases, remained at trace levels in both barns, it increased especially during the cold periods when the ventilation was limited. In the Barn-I, the highest methane gas was measured to be 1505 ppm in December. Similarly, in the Barn-II, the highest methane gas was measured to be 1660 ppm in December. These values were quite low compared to 10000 ppm, the recommended upper limit for the animal barns [12]. It is clear that this will not pose a problem in terms of the animal welfare.

Hydrogen sulphide (H_2S) was at trace levels in both barns and could not be recorded in ppm since it was below the precision limit of the gas meter. The most important reason for this was the fact that the gas emitted into the environment was mostly generated as a result of decomposition of the animal wastes and the cleaning of the wastes in the barn on a daily basis ensured this gas remaining at trace level.

The descriptive statistics and the significance test results for the NH_3 and CO_2 gas values in the Barn-I, Barn-II, and outside the barns were summarized in the Table 5. In addition, the differences found to be significant in terms of averages were shown using different letters.

Table 5: The descriptive statistics and the significance test results for the NH_3 and CO_2 gas values in the Barn-I, Barn-II, and outside the barns

Feature	Barn no	N	Average	Standard error	VK (%)
	I	91	6.285^B	0.188	28.47
NH_3	II	91	8.736^A	0.330	36.04
	Outside the barns	91	0.117^C	0.022	182.89
	I	91	1261.9^B	23.6	17.85
CO_2	II	91	1714.0^A	48.8	27.15
	Outside the barns	91	458.3^C	4.35	9.05

For both gases, the averages were found to be statistically different in all three conditions (P <0.01). The coefficients of correlation between the features used in the study were shown in the Table 6.

Table 6: The correlation coefficient and importance test results between the features used in the study

	NH_3 Barn-I	CO_2 Barn-I	NH_3 Barn-II	CO_2 Barn-II	NH_3 outside the barn
CO_2 Barn-I	0.45**				
NH_3 Barn-II	-0.007	0.36**			
CO_2 Barn-II	- 0.11	0.33**	0.78**		
NH_3outside the barn	0.29	-0.11	-0.09	-0.25*	
CO_2outside the barn	0.18	0.25*	-0.02	0.05	0.26*

*P<0.05, **P<0.01

Conclusion

The harmful gases in the animal barns are mostly emitted as a result of the animal metabolism and the decomposition of the manure and urine. In the barns which are not well planned and do not have an adequate ventilation system, the harmful gases reach the undesired concentrations and adversely affect the animal welfare and yield. It was found that while all harmful gases did not pose a problem in the Barn-I where the climatic environment was controlled well, the CO_2 and NH_3 values sometimes exceeded the limit values in the Barn-II where the climatic environment was not controlled well. In order to eliminate these problems, the ventilation capacity of the barn should be 110.4 m^3/h AU for the moisture balance and 97.1 m^3/h AU for the carbon dioxide balance, especially during the winter months when the animals are housed in the closed-type barns all the time.

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