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Measures to Protect Environmental Problems Caused by Animal Wastes in Rural Settlement Areas: A Case Study from Western Turkey

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Abstract: The objectives of this study were to investigate environmental pollutions by animal wastes from the livestock farms around the rural settlement areas to examine their consequences and finally to find practical solutions. To do this, 135 livestock farms in 45 different settlement areas (villages) were investigated. It was seen that 85.2% of the livestock farms were closer (1.0-500 m) to the residential area than they should be while 94.8% them disposed or stored their wastes carelessly in open places around the barns. Majority of the people (91.8%) living in the research area complained of uncomfortable smells and sights. Water samples collected from the water sources in theses villages showed that nitrite under harmless level, varying between 0.06 and 0.22 mg L^{-1} were detected in 54.5% of the sources but excess coliform bacteria (75-600 kob/100 mL) were observed in 27.2% of the samples. In order to prevent all theses environmental problems, small farms should be unified under a cooperative and shifted to a certain safe distance. Wastes from the farms should be stored in leakage proof stores and be used for biogas and organic fertiliser production. The biogas production potential of the research region is computed to be 23 483 275 m^3.

Key words: Zero waste, biogas, organic fertiliser, renewable energy, farm, bacteria

INTRODUCTION

Considerable efforts have been made by many scientific disciplines to overcome progressive environmental problems both in regional and global scale. Studies in different disciplines suggest solutions observing these environmental pollutions in different dimensions. Recently developing conscious about the environment has brought new phenomena and tendencies in waste management. Within this context, zero waste phenomenon is seriously considered by many countries and sectors and zero waste production technologies are foreseen to apply in the near future (Arol, 2005; Anonymous, 2005). Presently although, zero waste production is applied more in domestic and industrial area, in the future this will be inevitable in all production sectors for sustainable development, clean production and livelihood environment.

To sustain intense animal production in agricultural sector is a compulsory to meet animal protein requirements of continuous population growth sufficiently. Application of zero waste production principle properly is of great importance to prevent or minimize environmental pollution due to the animal wastes from the animal production farms located in or around the rural settlement areas.

Animal wastes from a farm may be listed as manure and urine, bedding materials, waste water from milking unit, surface water from paddocks and silage water from silage stores. Environmental pollution by these wastes is not a point sourced pollution as seen in industrial and domestic areas but non-point sourced or diffused pollution. When animal wastes also known as scattered pollution are stored carelessly in or around the barns, they adversely affect well-being of human life through diffusing harmful gases and causing sight pollution. Additionally, these pollutants destroy surface and ground water resources by surface run off or percolating into the aquifers (Edwin, 1996).

On the other hand energy resources are getting more limited and more expensive with rapid population growth and industrial development. It is obvious that the deficit in energy resources will increase in the coming decades. Therefore, studies have been conducted on obtaining energy using alternative energy resources such as wind, sea waves, thunder, sea moss and many other interesting resources in addition to conventional resources. Significant increases in environmental pollution to a level threatening human life forces to find not only cheap but also clean and sustainable resources. Baring all these in

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mind with biogas production within the context of zero waste in rural areas where intensive animal production is practised contribution of animal wastes to environmental pollution and global warming may be minimised. To realise this, biogas production plants compatible to mechanised animal production farm are becoming more and more technological product.

Biogas systems are based on the fermentation of organic residues from animal production at a constant temperature under a closed environment with the aid of bacteria. Two important gasses, Carbon dioxide (CO_2) and Methane (CH_4) are obtained after the fermentation. Particularly use of CH_4 may contribute significantly to meet part of the energy consumption in the farm in heating, lighting and kitchen.

Residues after biogas production turn into a more precious liquid form of fermented organic fertiliser. One of the main advantageous of this organic fertiliser is that considerable number of the protein microorganisms are removed after fermentation. The obtained fertiliser can be applied to the field either in liquid for or in granular form after granulation or may be stored in concrete or earth pools. Use of organic fertilisers in plant production not only enhances quality and quantity of products but also improves physical, chemical and biological properties of the applied soil and therefore sustain the productivity of soil. As a result of this, chemical fertilisers use will be limited, environmental problem due to excess chemical fertilisers utilisation will be prevented and cost will be decreased significantly.

Numerous studies have been conducted to investigate the principles of sustainable management practices of animal wastes after the intensification animal production.

Recently, Sommer *et al*. (2002), Tilche and Galatola (2008) and Bernet and Beline (2009) investigated the biological treatments available for the treatment of animal manure including aerobic processes (nitrification, denitrification, enhanced biological phosphorus removal) and anaerobic digestion. These processes were discussed in terms of pollution removal, ammonia and greenhouse gas emissions (methane and nitrous oxide) and pathogen removal. Application of emerging processes such as partial nitrification and anaerobic ammonium oxidation (anammox) applied to animal manure was also considered.

Tricase and Lombardi (2009) evaluated the state of the art in the use of biogas in Italy as well as in Europe and its production potential with regard to animal sewage in the light of the current technical-economic and legislative obstacles.

Lansing *et al*. (2008), Cantrell *et al*. (2008) and Albanis *et al*. (2008) quantified the electricity generation and waste transformations in a low-cost, plug-flow anaerobic digestion system.

Chowdiah and Gowda (2004) carried out a micro-level study in a typical south Indian village to assess the quantity and type of wastes generated and its present mode of management and used the information to identify the appropriate technologies which could enhance the value of the waste produced and at the same time, improve the economic conditions of rural people to alleviate poverty and improve ambience, health and income.

Chen (2001), Shehata *et al*. (2004) and Burton (2009) investigated the environmental and health aspects of animal waste management in rural areas. Kaygusuz and Turker (2002) tried to determine the Biomass energy potential in Turkey.

The objectives of this study are to assess the quantity and type of wastes generated from the livestock farms and their present mode of management in a typical West Turkish rural area and to use the information to identify the appropriate technologies which could enhance the value of the waste produced and at the same time improve the economic and social conditions of rural people.

MATERIALS AND METHODS

The research was conducted in a plot area located at Uzunkopru town of Edirne province in the European part of Turkey. The plot area was selected considering its representativeness of the whole population, density of rural settlements in the plot area, density of the animal farms in a single settlement area, size of the field farm owners have. Uzunkopru Town is located at 41°16'N latitude, 26°41'E longitude and 18 m average altitude above mean sea level. Its climate is characterised between continental and Mediterranean types. Annual mean temperature is 13.9° while the average yearly precipitation is around 600 mm (Anonymous, 2006a). The plot area covers 57 rural settlement units (villages). There are totally 85 894 cattle all of which are purebred or crossbred of purebred (Anonymous, 2009a).

The research was realised in tree stages: selection of the research farms in the plot area, field studies and analysis of the finding in the office. Probability sampling method based on the averages of population arithmetic in the selection of villages and farms in these villages. The principle of this method is to exclude the settlement areas with very small and large number of animals to obtain a homogenous population. The procedure to obtain parameters of finite population of this method was explained as:

- N = 57 (the total number of unit settlement areas forming population)
- μ = 1506.912 (average number of animal per unit settlement area in the population)
- σ = 1344.226 (standard deviation of the population)
- D = $\mu \times 0.10$ = 150.6912 (sampling error)
- $Z_{\alpha/2}$ = z value (statistical value) (1.645)

Sampling error (or forecasting error) was assumed to be ±10% of arithmetic mean (μ). In the other words, arithmetic mean of any arbitrarily chosen sample may deviate 10% from the population mean (Arikan, 2000) which also means that the probability of the arithmetic mean of any arbitrarily chosen sample to take place in the population limit is 90%.

The following equation was used to compute the number of sampling unit area with the above assumptions (Mcclave and Benson, 1988):

$$n = \frac{\left(\frac{Z_{\alpha/2} \cdot \sigma}{D}\right)^2}{1 + \frac{1}{N} \cdot \left(\frac{Z_{\alpha/2} \cdot \sigma}{D}\right)^2} \quad (1)$$

Using Eq. 1, the number of unit sampling areas was calculated 45 and the research was carried out with totally 135 farms, 3 arbitrarily chosen farms from each settlement area.

Under the field study, a survey study was conducted in order to investigate environmental problems due to the animal wastes and to have detail information about the farms. The survey was realised interviewing with the farm owners face to face and a database was formed. To investigate whether the animal wastes from these farms caused any contamination, samples from the water sources were collected and analysed for nitrite by Spektrofotometrik method and coliform bacteria by membrane filter method (Anonymous, 2007). Soil samples from selected 45 settlement units were also collected and analysed for their textures and organic matter content so that to decide how much manure they need for improvement and to produce a manure application guideline according soil textures.

Under the office work, data obtained from the field studies and environmental problems due to animal wastes from the farms were evaluated. The observed problems were analysed and commented with the previous finding and suggestions in the literature and finally practical solutions were suggested.

RESULTS AND DISCUSSION

Evaluation of studied farm administration: Investigations, observations and results obtained for the selected 135 farm administrations in the plot area according to the principle explained in the method section were evaluated.

Plant and animal production are done in all studied farm administrations. In animal production, cattle (mainly dairy farming) were the major production type.

As for the number of animals per administration, 7.4% of the total studied administrations had 5-10 cattle, 50% had 11-20 cattle, 14.8% had 21-50 cattle, 27.8% had 51 and more cattle. Farm owners indicated in survey study why they preferred dairy cattle because dairy industry in the region was well develop and no marketing problems was encountered and also central government subsidised dairy cattle farming. However, 72.2% of the administrations was classified as small family type administration in terms of the number of animals which made difficult to control animal waste properly.

The main criterion in the selection of the place of animal barns was claimed to be closeness of the barns to the farmer residence by 89% of the farmers. It was observed that majority of the barns, 85.2% were located at 1-500 m distance to the residence, in or around settlement area. Farmers stated in the survey that safety of animals and saving of time and work power were effective in the preference of a closer barns. The survey also revealed that adverse effects of the produced animal wastes on human health and environment were not taken into consideration. Present small family type administrations which were scattered, unproductive, placed in or around the residential area and causing health and environmental problems should be unified under a cooperative to from modern administrations and shifted to a certain safe distance from settlement area.

A safer preservation belt distance should be investigated by a technical commission considering the place, properties and capacity of animal barns. In investigation of this healthy preservation belt, adverse effect of animal barns on human beings and environment and aspects of minimising contaminating elements and invasion of animal diseases should also be taken into account. The size of land the farmer held, distance of barns to the other barns around to the highways and to the residential area are the other parameters to be considered. Accounting all these, a minimum 500 m distance between the animal barns and residential areas is suggested (Anonymous, 1996b). However, Cayley proposed a minimum 1600 m distance.

Environmental problems from the animal wastes in the administrations: In general, animal wastes from a farm may consist of manure and urine, bedding materials, waste water from milking unit, surface water from paddocks and silage water from silage stores. These wastes cause harms to the ecosystems when stored improperly under unsuitable places and conditions. In the pilot area the study conducted, 94.8% of the administration holders claimed that they disposed the animal wastes into an open area anywhere in the farm, edge of a creek, sides of the animal barns or into the garden without taking any precautions for environmental pollution whereas the remaining holders (5.2%) stated that they stored their manure in manure storage holes. However, the observations revealed that the manure holes were not built according to the ideal standards. Storage of animal wastes in these ways cause not only sight pollution but also adversely affect human health and quality of life by diffusing harmful and smelly gasses, spreading dust and bacteria (Waskom and Davis, 1999). Presently, there is no regulations forced by the authorities to regulate the disposal of the animal wastes. About 76.3% of the farmers indicated that they are not warn against these improper disposal by the local authorities whereas 23.7% claimed that they were warn. The survey studies showed that 91.8% of the farmers adversely affected by the sight pollution and smells while the reaming 8.2% were not affected. Yaldiz (2004) found in a study that the smells from the animal waste may be felt from a 400 m distance under normal conditions.

On the other hand, these wastes improperly stored around may be mixed into the surface and subsurface water resources by run off or deep percolation and cause microbiological and chemical pollution. There are four components from the animal wastes causing pollution for water resources namely, nitrogen, phosphorus, pathogens microorganisms and organic matters. These components may affect river, lake and sea ecosystems adversely even lead to contamination of ecosystems completely and to the death of living beings. Similarly, analysis of water samples collected from the pilot study area showed that 54.5% of the water sources were contaminated by Nitrite (NO_2) while about 27.2% were infected by coliform bacteria. Nitrite amounts in the nitrogen contaminated water sources determined by spectrophotometric method varied between 0.006-0.22 mg L^{-1}. This amount is below the suggested limit level of 0.5 mg L^{-1} (Anonymous, 2007) for drinking and household water. However, the number of coliform bacteria (75-600 kob/100 mL) determined by membrane filter method were found to be above the suggested (Anonymous, 2007) limit (0) and the water from those sources cannot be drunk without any precautions. This coliform contamination is believed to be caused by the animal wastes around the water sources.

Animal wastes produced should be stored properly as suggested by regulation in order to control or decrease the above mentioned problems. Stores should be located far enough to the house in the administration and at a suitable place in terms of topography and level of ground water. Underground or surface closed concrete stores are suitable for solid waste while leakage proof closed concrete holes or tanks must be used for liquid wastes. In investigating the design capacity of a store, a minimum 0.028 m^3 manure per 454 kg (1000 pounds) cattle may be considered as proposed by Harner. Regional climatic conditions, duration of manure destruction, type of farming practices, methods of waste usage, management principles of the administration and rules and regulation by local and central government are the main factors to be taken into account in the determination of storage duration (Anonymous, 1996a).

Turkish Environmental Regulation states 3 months duration for the storage or animal wastes (Anonymous, 2004). Therefore, in the design of storages this duration should be considered. In the survey study in the pilot area, 15.6% of the farmers claimed 4 months storage duration while 36.3% did 6 and 48.1% did 8 months which are longer than the duration suggested in the regulation. This indicates that the farmers ignore the environment. To prevent this, farmers should be educated on the disposal and storages of animal wastes, environment and environmental regulation by regular seminars publications and they should also be informed about the offered subsidies when they obey the regulations. About 83% of the farmers participated in the survey study answered that they were not aware of the law published by the central government in 2007, released to improve animal production, decrease environmental pollution and arrange subsides if the law is applied by the farmers. After all these, farmers not obeying to the law and regulation may be punished.

Profitably using possibilities of animal wastes: Biogas and organic fertilisers, very important for plant production are obtained as outputs when the animal wastes are fermented under anaerobic conditions with a suitable technology. Particularly solid animal wastes are seen as ideal source for biogas (65% methane, 35% CO_2) production (Ozturk, 2005). The obtained biogas is used either for electric or heat energy sources. As known, energy issue is of great importance and the most actual subject of today. Global energy need is continuously increasing. Some international institutes and companies foresee that the energy requirements will have increased 3-7 folds mostly in the developing economy by the year 2050 and 2100, respectively (Anonymous, 2006b; Anonymous, 2008).

On the other hand, probable exhausted fossil fuel energy sources in the near future, damaged natural balance showing itself in the form of climate change and temperature increase inevitable lead scientists to the studies on effectively use renewable environmentally friendly alternative energy sources. Environmental problems reaching to an extent of threatening human health requires that technology used in energy production should not only be cheap but also cause no or minimum damages to the environment. In this context, biogas production from animal wastes is of great importance for an health environment and decreasing energy cost of farm administrations. Turkey is significantly foreign dependent country in energy supply. However, it is one of the leading country in the world regarding the number of animal administrations and animals of it has. But it takes place in the backwards of the list concerning the use of animal wastes profitably as renewable energy sources.

The survey studies revealed that 82% of the farm administration owner applied the animal wastes as fertiliser to the fields without any treatment while 18% of them left the wastes in an empty area. Damping the animal wastes in an uncontrolled way into any available places and then use for plant production is not so useful as expected for the plants causes the toxic gasses to diffuse in to the environment after the destruction of organic matter and to invasion of the field by weeds.

As for the number of the animals (cattle) per farm owner, 92.6% of the owners had 10 whereas 7.8% of them had 5-10 animals. Considering the farms capacities in the area, it may be concluded that the wastes can be used for biogas production as a renewable energy source. As project criterion to produce biogas it may be assumed that cattle can produce waste as much as 5-6% of their body weight in a day which equals to 22.7 kg for about 454 kg (1000 pounds) cattle and that 33 m^3 biogas can be produced from 1 ton manure at 18°C optimum fermentation temperature (Shell International BV, 2008). Based on the above criteria, the potential animal waste amount and biogas production from this waste per administration depending on their capacity is shown in Table 1.

Considering the administration capacities (i.e., the number of animals per farm) and produced animal waste data in Table 1, a family type biogas production unit may be suggested for small (6-12 m^3 waste) administrations whereas a farm type production unit is suggested for large (50-100 m^3 waste) administrations (Topkaya, 2008). The produced biogas will enable to save considerable energy consumption.

The number of animals in the pilot area where the study conducted and in Turkey, respectively are 85 984 and 10 946 239 (Anonymous, 2009b). When considering the project criteria defined above, the potentials of animal waste and biogas production possibilities that may be produced in the Project area and in Turkey are shown in Table 2.

Table 1: The potential of biogas production against the number of animal and amount of waste

Number of animals	Amount of waste (kg day^{-1})	Potential of biogas production (m^3 day^{-1})
5	113.5	3.75
10	227.0	7.49
20	454.0	14.98
30	681.0	22.47
40	908.0	29.96
50	1135.0	37.45
100	2270.0	74.91

Table 2: The potentials of animal waste and biogas production possibilities that may be produced in the project area and in Turkey

Research area	No. of animals	Animal waste amount (ton $year^{-1}$)	Biogas production (m^3 $year^{-1}$)	Equivalent to coal (ton $year^{-1}$)
Pilot area	85,894	711,675	23,485,275	21,137
Turkey	10,946,239	90,695,063	2,992,937,079	2,693,644

Table 2 shows that a considerable amount of biogas production is possible from the cattle farms only. Turkey is a foreign-dependent country in energy. This foreign dependency may be decreased considerably using the produced biogas in farm administrations as a clean and renewable energy source. On the other hand, 65% of biogas is formed of methane which is 21 folds more effective than CO_2 in causing to global warming. Therefore methane is also as important as CO_2 in global warming. Biogas technology may help in decreasing air pollution and global warming due to the use of premier energy sources. The increase in the number of biogas production units will not only decrease the use of fossil energy sources but also decrease the environmental pollution and global warming through using the organic wastes from the animal administrations.

One of the outputs of the biogas production is organic fertilisers. In general, 40-60% of organic waste may be turned into biogas (Anonymous, 2009b). During biogas production process, weed seeds lost the germination capabilities and uncomfortable smells decrease to level that may not be felt. The other main advantage of producing organic fertilisers is that a considerable part of pathogen microorganisms is destructed. This offers an opportunity that the organic fertilisers which will be used becomes 10% more productive in comparison to the use without fermentation (Topkaya, 2008). The use organic fertilisers provides the following advantageous in plant production: increase the water holding capacity of the soil, help the soil to come mellow easily contribute soil textures and structures positively, prevent erosion by providing better aggregation, improve soil aeration and pH. The amount of organic fertiliser to applied per unit area varies between

Table 3: Organic matter contents of the soil sample collected from the pilot study area

Soil texture	Organic matter content (%)
Sandy	0.69-1.10
Clayey	1.70-2.22
Loamy	1.20-1.83
Sandy loam	0.79-1.32
Clayey loam	1.23-1.66

20-40 ton ha^{-1} depending on the organic matter content and texture of the soil, amount of precipitation and fertiliser requirement of the plant. In average, 2.0-2.5 kg N, 0.5 P_2O_5 and 2.0-2.5 kg is added by the application of 1 ton organic fertiliser into the soil (Aygun and Acar, 2004). Application of organic fertilisers in right amount and at right time decreases the commercial chemical fertilisers use and therefore the cost of administrations.

Soil samples were collected in the pilot study area and their organic matter contents were determined and shown in Table 3. Table 3 shows that the organic matter contents of the farm soil in the study area vary between 0.69-2.22% which is well below the value for ideal farm soil, 4.0-5.0%. This also reveals that the animal wastes are not applied to the farm soil to improve soil productivity. As many other sectors, the wastes are not used properly in agricultural sector within the concept of zero waste principle. Therefore, the animal wastes, crucial for plant production, continue to contaminate the environment and threaten the human health.

CONCLUSION

Turkey is one of the leading countries in terms of owned number of animals. The animal farm administrations in Turkey are generally small size family type administrations intensify in or around the rural settlement areas. This introduces environmental problems. Particularly, animal wastes released from the animal farms and stored open with no care causes in sight and air pollution and adversely affect the ecosystems due to drainage effluent from the animal wastes after the rain.

RECOMMENDATIONS

The following precautions should be taken to prevent or minimize all these problems:

- Non-profitable family type small administrations should be unified under cooperatives
- A safer preservation belt around the settlement area should be investigated by a technical commission and animal barns should be carried beyond this belt. In the determination of the belt length, human and environmental health due to contamination by the animal waste and causing diseases should be considered
- Animal wastes should be stored as defined in the Turkish Environmental Regulation. Stores should be built in a suitable place far enough from the family houses considering topography and groundwater level of the location. Solid wastes are suggested to stored in a close area whereas the liquid wastes in leakage proof tanks or concrete digs
- In the investigation of the storage duration, climatic condition of the region, destruction time period of the wastes, farming practices, methods how and where the wastes are used, administration principles and regional or central regulations should be taken into account. Turkish Environmental Regulation states 3 months duration for the storage or animal wastes (Anonymous, 2004)
- Animal wastes should be used to produce biogas. Farmers should be educated and subsidised by the Central government for motivation. By this way, environmental damages may be decreased to minimum while the considerable part of the farm energy requirement is met
- Organic fermented fertilisers, main residue after the biogas production should be used in plant production to decrease commercial chemical fertiliser and decrease the cost
- Farmers and people living in rural areas should be educated on environmental pollution and ecological balance by seminar, group meetings, leaflets and other suitable publications

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