Sjournals
Scientific Journals
Scientific Journal of Review (2012) 1(2) 17-32

Contents lists available at Sjournals
Scientific Journal of REVIEW
Journal homepage: www.Sjournals.com

Review article

Livestock waste and its impact on the environment

I.P. Ogbuewu*, V.U. Odoemenam, A.A. Omede, C.S. Durunna, O.O. Emenalom, M.C. Uchegbu, I.C. Okoli, M.U. Iloeje

Department of Animal Science and Technology, Federal University of Technology, Owerri, Nigeria

*Corresponding author: Department of Animal Science and Technology, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria

ARTICLE INFO

Article history:
Received 31 June 2012
Accepted 26 July 2012
Available online 31 August 2012

Keywords:
Livestock
Health
Water
Air
Soil
Management

ABSTRACT

Livestock industries produce meat, milk and egg, and also generate large volumes of wastes that could be harmful to the environment if not well managed. The demand for animal products is driven by increasing per capital incomes, urbanization, changing lifestyles as well as rapid population growth. These increases in demand for animal products are expected to continue in the years to come. Livestock keepers on the quest of optimizing the benefit of the ever increasing demand for their products have resorted in the production and accumulation of large volumes of wastes. However, the disposal of these wastes continues to be a challenge from the standpoints of cost, environmental safety, and biosecurity. The question remains how would these livestock wastes be managed without detrimental effects on food security, natural resources and health? This review was necessitated in an attempt to answer these questions.

1. Introduction

Livestock and poultry industries produce meat, milk and egg, and also generate large volumes of waste water and solid wastes that could be beneficial or harmful to the environment. The waste products which includes livestock or poultry excreta and associated feed losses, beddings, wash -water and other such waste materials represent a valuable resource that if used wisely, can replace significant amounts of inorganic fertilizers (Bouwman and Booij, 1988; Leha, 1998; Smith and Vanduk, 1987), conventional feedstuffs (El Boushy and Vander Poel, 2000) and cooking gas (Henuk, 2001), but may be a direct threat to human and animal health (Taiganides, 2002).

Animal wastes in the form of manures are valuable sources of nutrients and organic matter for use in the maintenance of soil fertility and crop production. Studies with animals have shown that 55–90% of the nitrogen and phosphorus content of animal feed is excreted in faeces and urine (Tamminga *et al.,* 2000) normally used as manure. Poultry and swine manure collection in confinement feeding facilities have been recovered for re-feeding to beef cattle, dairy cattle and sheep (Bell, 2002) and have been found to present no serious health hazards to ruminants and poultry or posed any negative effects on meat, egg or milk quality (Mcllroy and Martz, 1978). Animal waste has been traditionally used in the production of biogas in Asia, particularly in tropical areas such as Indonesia, India and Vietnam (Henuk, 2001). However, careless dumping of livestock waste on farm lands and direct discharge to waterways and percolation to groundwater, usually in by-pass flow *via* cracks and fissures, is a great risk to human and animal health because livestock waste contain myriads of pathogens (Davies, 1997; Dizer *et al*., 1984), some of which may be zoonotic and can cause systemic or local infections (Dizer *et al*., 1984; Mackenzie *et al*., 1994; Davies, 1997; Stanley *et al*., 1998; Fischer *et al*., 2000; Cameron *et al*., 2000). Transmission of disease causing microbe is enhanced by mismanagement of animal waste and may be reduced by proper waste handling methods (Mackenzie *et al*., 1994). Highly contagious and pathogenic diseases, such as Foot and Mouth Disease and Swine Fever may spread with animal effluent through waterways and, when one farm is infected with the disease, farms downstream will be at considerable risk of infection (Cameron *et al.,* 2000). Livestock waste produces ammonia that can be a potential pollutant causing serious eutrophication of rivers and lakes, characterized by a high concentration of nutrients that creates an ecological imbalance in the water system that support abnormally high levels of algae and aquatic plant growths (Burton and Turner, 2003; IAEA/FAO, 2008). This reduces oxygen levels in the water and has serious implications on the survival of aquatic organisms and, consequently, on food supply and biodiversity (IAEA/FAO, 2008).

Livestock wastes are sources of malodours originating from livestock buildings, storage and field application of animal manures. The intensity of malodours is often unacceptable, especially for neighbours in surrounding residential areas. Globally, the concentration of the greenhouse gas methane (CH_4) in the atmosphere has increased by 45% since 1850 (Lelieveld *et al*., 1998). Increases in livestock production have contributed significantly to this increase and it has been estimated that enteric fermentation of ruminants contributes some 13–15% and livestock waste 5% to the total emission of CH_4 in the 1990s (Hogan *et al*., 1991; Lelieveld *et al*., 1998). Agriculture was estimated to have contributed almost 80% to the anthropogenic emissions of N_2O in the 1990s (Khalil and Rasmussen, 1992) and further emission inventories show that livestock production contributed 70–80% of the anthropogenic NH_3 emission in Denmark and Europe (Hutchings *et al*., 2001).

Animal wastes are generally associated with health risk to humans and animals if not properly managed. There is a pressing need therefore, for a holistic research into effective strategies and techniques in utilizing livestock waste tailored towards the development of sustainable environmental friendly livestock production systems. It is believed that such system(s) will ensure its sustainable use as organic manure, non-conventional feedstuff, a source of biogas as well as reduce its environmental impacts (air and water pollution, ammonia and greenhouse gas emissions) on human and animal health. The objective of this paper was to review the animal production trend, animal waste management and utilization, and its environmental/health implications.

2. Global trends in livestock production

Livestock production in developing countries has increased rapidly during the last decades because of the policy of these countries to further increase meat and milk production (Nguyen, 1998; Delgado *et al*., 1999; Gerber *et al.,* 2005; Steinfeld and Chilonda, 2006; Faostat data 2006). The growth of meat and milk production is driven by the growth in demand, increasing per capital income, urbanization, changing lifestyles, and population growth. The term 'Livestock Revolution' has been used to describe this development. The trends in per capita meat and milk consumption in developing countries in comparison with developed world are presented in Table 1.

Simultaneously with the increase in livestock production in developing countries, production patterns have changed and more industrial livestock production systems have emerged (Bouwman and Booij, 1998). At present, a large proportion of livestock is kept for food production and the traditional functions of providing draught power, manure and serving as a capital asset are becoming less important (Bouwman and Booij, 1998). This also means a shift from livestock in the back-yard of small farms as converters of household residues and low-quality forages to livestock in specialized production units fed home-grown or purchased feedstuffs. The increased demand for fresh meat, milk and egg within prospering urban centers and the lack of efficient infrastructure in rural areas have resulted in a large concentration of livestock production near cities (Gerber *et al*., 2005). This in turn has result in the production of large quantities of animal waste near cities.

Table1

Projected per capita consumption of meat and milk in developing and developed countries in 1983, 1993 and 2020.

Region	**Per capita meat consumption (g)**[*]			**Per capita milk consumption (g)**[+]		
	1983	**1993**	**2020**	**1983**	**1993**	**2020**
Developing countries	14000	21000	30000	35000	40000	62000
Developed countries	74000	76000	83000	195000	192000	189000

Adapted from Faostat data (2006); [*]Meat includes beef, pork, mutton, goat, and poultry carcass weights; [+]Milk is cow and buffalo milk and milk products in liquid milk equivalents.

3. Production and composition of animal waste

The quantity and quality of Animal waste produced by animals varies between animal species .Within species, the exact proportion excreted varies according to a range of factors including diet composition, animal performance (*e.g.* amount of milk produced, live weight gain), size, age, sex and husbandry practices (Ketelaars *et al*., 2000). The volume of manure per animal (litre/day) ranged from 5.4 – 45.3, 5.1 – 11.3, 0.08 – 0.14, 0.13 – 0.34, 0.71, 2.8 ewe and 28 for cattle, swine, chickens, turkey, rabbit, ewe sheep and horses, respectively. Ryser *et al*. (2001) reported that diet composition, feed conversion and animal size and performance are the factors with the most important impact on manure production and composition. Studies by Tamminga *et al.,* (2000) and Ryser *et al*. (2001) have shown that 55–90% of the nitrogen and phosphorus content of animal feed is excreted in faeces and urine. Data on typical nutrient contents of manure from the major livestock categories from different countries including that of piggery waste water and solids from studies in Thailand and Singapore (Taiganides, 1992; Sommer, 2000) are available and have been summarized in Table 2.

Table 2

Percentage of dietary nitrogen (N) and phosphorus (P) excreted by livestock.

Animal category	**N excretion (% of intake)**	**P excretion (% of intake)**
Dairy cow	65-80	65-80
Growing cattle (beef)	75-80	70-85
Sow with piglets	75-80	75-85
Growing – finisher pigs	70-80	75-85
Laying hen	65-80	85-90
Broilers	55-65	50-65

Source: IAEA/FAO (2008)

3.1 The phosphorus and nitrogen content in animal products

There are variation in the nitrogen and phosphorus content of milk, meat and eggs. The differences are generally small in relation to their content in feed and are affected by weather conditions. For example, the phosphorus content of whole cow milk produced during the winter and summer months are given as 96 and 93 mg/100 ml (Anonymous, 2002). The standard values for nitrogen and phosphorus contents in live animals and animal products obtained from the Mineral Accounting System (MINAS) in The Netherlands (Table 3), is currently used for the calculation of the nitrogen and phosphorus excretion in animal production systems.

Table 3
Nitrogen (N) and Phosphorus (P) contents of livestock (g of N and P per kg live weight) and livestock products (g of N and P per Kg products).

Animal product	g N/kg	g P/kg
Cow milk	5.4	0.92
Calf lean beef	29.4	7.6
Dairy cow	25.6	7.4
Young stock, dairy beef	25.6	7.4
Sheep	25.0	6.0
Goat	24.0	6.0
Piglet, at weaning	24.0	5.2
Slaughter pig	24.8	5.0
Sow	25.5	5.0
Eggs	19.2	2.1
Broiler chicken	28.0	4.7
Laying hen	28.0	3.1
Duck	25.9	5.7
Turkey	33.0	7.2

Source: IAEA/FAO (2008).

4. Livestock waste and the environment

4.1. Water quality

Water quality has received much attention in environmental protection in developed countries such as Europe (IAEA/FAO, 2008). Animal wastes are spread as slurry over crops and pastures to fertilize the ground and enrich the soil with various forms of nitrogen. If an excess amount of animal droppings are applied to crops that are unable to fully utilize the nitrogen, the residual large nitrate content may leach through the soil to the ground water after harvesting and causes problems. One of the main pathways of field nitrogen loss is through leaching and runoff losses to ground and surface water (Rotz, 2004). The resulting leachate and runoff enters the ground water and subsequently the drinking water sources of both human and livestock are polluted by high concentration of nitrates. Pollution of drinking water sources by nitrates is of serious concern in most Member States of the European Union. According to international standards, nitrate concentration in ground and surface water that can be used for the preparation of drinking water should not exceed 50 mg per litre (*i.e.* 11.3 mg nitrate-N per litre) (EEC, 1980; CEC, 1991). In addition, a target concentration of 25 mg nitrate per litre has been established (EEC, 1980; CEC, 1991) and nitrate content exceeding 50 mg per litre is unacceptable (Van Der Meer and Wedin, 1989).

4.2. Soil contamination

Nitrogen and phosphorus may pollute the soil after manure application (Correll, 1999). Inorganic fertilizer (e.g. nitrogen) is lost by ammonia volatilization (Sommer *et al.*, 2003), depending on the rate and period of application, weather conditions and soil type (Jarvis *et al.*, 1987; Smith *et al.*, 2001). The volatility of nitrogenous source is important when selecting the mode of application of animal dropping. After volatilization, about 30% of the ammonia returns as wet or dry deposition to soils and vegetations within 5000 m of the source. A large part of the remaining 70% reacts in the atmosphere with SO_2 and NO_x and is transported over a distance of 5 to about 1×10^6m (Lekkerkerk *et al.*, 1995). High rates of N deposition cause ecological damage to forests and nutrient-poor natural ecosystems (Heij and Schneider, 1995; Krupa, 2003). These vegetations absorb and accumulate this N effectively (Berendse, 1990) with a resultant undesirable floristic changes, loss of biodiversity and physiological problems to trees, such as increased susceptibility to abiotic and biotic stress and deficiencies of other nutrients. Besides, deposition of NHx potentially contributes to soil acidification which may also affect vegetation. This acidifying effect only occurs after nitrification of NHx in the soil, particularly when part of the nitrates produced is lost by leaching (UKTERG, 1988; Lekkerkerk *et al.*, 1995). It has been reported that when animal droppings are applied to the soil surface only about, ½ of the nitrogen and other components are available for the plant to use

(FDACS, 1999). The excess phosphorus presents special problem, as a result of its low solubility in the soil, contaminates surface water and cause erosion.

4.3. Heavy metal contamination

Intensive livestock farming generally contributes to the accumulation of heavy metals in soils. Some heavy metals, in particular copper (Cu), and zinc (Zn) are essential minerals for farm animals. Although the requirement of these metals by most livestock categories can be completely or almost completely met by the feed ingredients, it is a common practice to supplement them *via* mineral mixtures, thereby resulting in excess supply. Other heavy metals, like cadmium (Cd), chromium (Cr), mercury (Hg), lead (Pb) and nickel (Ni) are nothing but pollutants. Livestock farms import heavy metals *via* purchased feeds, chemical fertilizers, sewage sludge and other types of waste. Large fractions (generally > 90%) of the heavy metals in livestock diets are excreted in manure. A study on soil-crop balances of the heavy metals Cd, Cr, Cu, Hg, Ni, Pb, and Zn in agricultural soils in The Netherlands showed surpluses of all the metals studied (Delahaye *et al*., 2003). This is a point of concern, because accumulation of heavy metals in the soil increases their availability and uptake by plants as well as leaching to groundwater and surface water (Van Riemsdijk *et al*., 1987). A prerequisite to sustainable agriculture is to control inputs of heavy metals in such a way that soil and water functions and product quality will not be impeded in the future (Moolenaar *et al*., 1998; Moolenaar,1999). Consequently, the concentrations of heavy metals in manure strongly depend on their concentrations in the feeds consumed and the subsequent use of such manures on soils leads high concentration of the metals. The Commission of the European Communities has established maximum values for the intake of iron (Fe), cobalt (Co), copper (Cu), manganese (Mn) and zinc (Zn) by different livestock categories based on the physiological requirements of the animals and aimed at restricting oversupply. (CEC, 2003). Other toxic substances that require attention in livestock production are antibiotics, hormones, and veterinary medical residues. These elements may have negative effects on food quality and human health as well as on the health of aquatic ecosystems.

4.4. Air quality

Most gaseous pollutants from the livestock industries originate from the breakdown of fecal matter and the concentration of such gases in part depend on the ventilation efficiency and rate of emission, as well as stocking density. Aerial pollutants include organic and inorganic dust, pathogens and other micro-organisms as well as gases such as ammonia, nitrous oxide, carbon dioxide, hydrogen sulphide and methane (Harry, 1978; Okoli *et al*, 2006).

When the pH of livestock waste increases, the ammonium ion is converted to ammonia gas (Moore, 1998) which easily volatilized to air. Ammonia volatilization contributes strongly to the high rates of atmospheric N deposition (Van Breemen *et al.,* 1982; Apsimon *et al*., 1987). Ammonia emissions from wet animal droppings were found to coincide with odours, which are nuisance in area of intensive livestock production (Chavez *et al*., 2004; Cole and Tuck, 2002).

Decomposition of organic materials in livestock manure results in the generation of malodorous and low molecular weight compound (Merril and Haverson, 2002). O' Neil and Philips (1992) reported that 60% of the compounds with the lowest odour thresholds in animal manure contain sulphur. The environment in the animal house is a combination of physical and biological factor which interact as a complex dynamic system of social interactions, husbandry system, light, temperature and the aerial environment (Sainsbury, 1992). The high stocking density in modern animal house may lead to reduced air quality with high concentration of aerial pollutants (Curtis and Drummond, 1982; Maghirang *et al*., 1991; Feddes and Lickso, 1993).

4.5. Climate change

Livestock farming causes considerable emissions of the greenhouse gases (CO_2, CH_4 and N_2O) via combustion of fossil fuels, digestion or decomposition of organic matter, stored manure and soils. Large scale production of animal waste and surface application of the waste to soils has been shown to cause more gas emissions and contribute about 9 - 12% of the total global warming effect and acid rain. These emissions received much attention in recent years because of the alleged contribution of these gases to global climate change. Methane and nitrous oxide are considered significant green house gases due to their efficiency in absorbing infrared radiations. Sommer and Moller, (2000) observed that methane and nitrous oxide absorb 26 to 200 times more infrared radiation, respectively than carbon dioxide. In addition, CH_4 is emitted by animals, and as the end-product of anaerobic decomposition of organic matter. Nitrous oxide is produced during nitrification or denitrification in stored manure and soils. The decomposition of animal waste may also results to emission of volatile organic compounds and reactive organic compounds into the air. Currently, there is much concern about the release of reactive organic compounds and their effect on the ozone layer. Sunlight causes the nitrogen dioxide to be converted back to nitrous oxide, release oxygen ions which react with oxygen to form ozone. This raised ozone concentration at ground level are detrimental and can cause increase in the incidence of respiratory problems in young children. A high atmospheric concentration of ammonia can results in acidification of land and water surface causing damage to plants and reducing plant biodiversity in natural system.

4.6 Human and animal health

Recent, reviews on the current status of parasitic diseases, including food-borne trematode, zoonoses and cysticercosis have highlighted the risks of disease transmission through animal waste and human excreta (De *et al*., 2003). Solid manure and liquid manure effluent may contain pathogens that poses significant health hazard to both humans and animals. Direct discharge of manure to waterways and percolation to groundwater, usually in by-pass flow *via* cracks and fissures, is a great risk to human and animal health because livestock manure contains numerous pathogens (bacteria, viruses, parasites). Transmission of these pathogens *e.g. Escherichia coli*, *Campylobacter*, *Salmonella, Leptospira, Listeria, Shigella, Cryptosporidum, Hepatitis A, Rotavirus, Nipah virus and Avian Influenza* (Davies, 1997; Stanley *et al*., 1998; Cameron *et al*., 2000; Fischer *et al*., 2000) is enhanced by inappropriate management of animal manure and may be reduced by proper manure handling and use. Insanitary handling of manure may also promote the spreading of parasites to man by introduction of larval stages of organisms into the food chain that can cause systemic or local infections.

The annual occurrence of typhoid fever has been estimated at 17 million cases with approximately 600,000 deaths, and diarrhoeal diseases cause death of 951,000 people annually in South East Asia. A number of waterborne bacteria, protozoa, viruses and, in particular, parasites are the source of these diseases. Highly contagious and pathogenic diseases, such as Foot and Mouth Disease, Swine Fever and Aujezsky's Disease may also spread with animal effluent through waterways (Cameron *et al*., 2000). It has not been completely proven, but poor manure management, the mixing of human and animal excreta, and the close contact between domestic and animal housing may propagate Avian Influenza and Severe Acute Respiratory Syndrome. There are also a number of animal diseases associated with increasing intensity of production and concentration of animals on limited space; many of them pose a threat to human health (Donhann *et al*., 1995; Reynolds *et al*, 1996; Borgers *et al*., 1997). Discharging pig slurry from infected premises to rivers represents a great risk for the spreading of the pathogens. Industrial and intensive system of animal production may be a breeding ground for emerging diseases (Nippah, Bovine Spongiform Encephalopathy, Avian Flu), with public health consequences.

Finally, animal products from intensive production systems tend to have higher residual contents with public health hazards (Nardone and Valfre, 1999). Known side effects of high levels of NO_3 are blue baby syndrome, cancer and respiratory illness in human as well as foetal abortions in livestock (Kelleher *et al*., 2002; Sommer and Hutching, 2001). Ground water levels in excess of 50mg NO_3/L are potentially harmful for infants and children (Rotz, 2004). Furthermore, nitrogen contamination of water systems can increase eutrophication in the formation and growth of sea grass beds, changes in algae community composition, increased algae blooms, hypoxic or anoxic events and death of fishes (Richardso, *et al*., 2001).

5. Sustainable environmental management

Measures to mitigate nutrient losses from livestock farms should be based on clear public objectives for environmental quality. Formulation of these objectives is difficult because it requires a political process of weighing and compromising conflicting objectives. On the one hand, there is an urgent need in many countries to increase livestock production and to improve income of livestock farmers. It is extremely important to protect the natural resources and biodiversity to ensure a good environmental quality, healthy ecosystem and attractive landscapes. Protection of soils is necessary for food security of future generations. Pollution of the atmosphere should be reduced because it threatens human and animal health and contributes to climate change. Biodiversity has an economic aspect (genes for the future) as well as an ecological function (health of ecosystems). Sustainable environmental management should be taken into account in an early stage of intensification of crop and livestock production and should be considerations in the development of environmental policy.

6. Animal waste handling methods

In some countries especially developing countries, little information is available about livestock waste production and management. The quantity and composition of animal waste is dependent on breed, species, production level and feeding practices. At present, data on these determinants appear to be based on various assumptions (Gerber *et al*., 2005). The loss of nutrients from agricultural operations will become a critical issue in areas that are exposed to eutrophication (Burton and Turner, 2003). There is need to develop a collection, handling, storage and transport systems that are compatible with the requirements of current production systems that are environmentally friendly. The following livestock waste handling techniques have been used to ensure timely application of manure to the crops, improved nutritive value and reduced viability of pathogens.

6.1. Pit disposal

Disposal of animal wastes in dogged pits has been the method of choice for years because of its low cost and convenience. A deep pit with inside framing and a tight-fitting cover, or an open trench prepared by a backhoe has been used for the disposal of death birds. Some farmers use a transplanting auger to dig smaller round holes for disposal. In order to control odors and flies, and discourage scavengers, a covering of at least two feet of earth must be maintained. The disposal cost associated with pits has been estimated to be 3.68 cents per pound for a broiler flock of 100,000 (Crew *et al.,* 1995). Disposal in a municipal or commercial landfill is also an option when the operators will permit carcass burial. This route is usually reserved for larger or emergency disposal needs because of transportation costs.

6.2. Composting

During composting of solid manure, aerobic decomposition of organic matter and impeded heat transport cause heating of the material, often to 60–70^{O}C (Van Der Meer, 2006). This heating has positive effects by killing pathogens and weed seeds. At low temperatures, the reduction rate of pathogens is slow, thus, after a lagoon treatment period of more than 120 days, the concentrations of micro-organisms remaining in the effluent from lagoons in Europe were high, *viz*. 105 per 100 ml for faecal *coliforms* and *streptococci* and 104 per 100 ml for *Clostridia* (Burton, 1997). Due to higher ambient temperatures, storage of liquid effluents may be a more efficient and reliable treatment in Asia than in Europe, but the efficiency of storage on pathogen reduction should be assessed before using storage as the sole treatment measure. Composting may facilitate production of hygienic solid manure that may be applied to land with minimal risk from pathogens. During composting, the temperature of the material should exceed 55–65^{O}C for at least one week to give a good reduction in pathogens and weed seeds (Strauch, 1986; Ten Have and Van Voorneburg, 1994; Nicholson, *et al*., 2005). This method enables on-farm conversion of dead birds into a humus-like soil amendment. Adding water to alternating layers of straw, carcasses and manure in bins placed on a roofed concrete slab starts the process. The suggested by-weight ratios of these various components are: 1 part carcass, 2 parts poultry litter, 0.1 part straw and 0.25 part water (Donald and Blake, 1990; Donald *et al*. 1990; Donald *et al*., 1994). The thermophilic bacteria then go to work using the nitrogen, carbon and fat from litter and dead birds, to digest them at temperatures of 54.44 - 65.56°C.

Most large farms use a two stage process, wherein, after a couple of weeks when the temperature has decreased, the material is turned into a second bin to aerate the compost. Heating and further decomposition occurs over the next week to produce compost that can be applied to crops or pastures. As many units as are needed to accommodate a flock are placed in a concrete-floored shed and filled using the proportions previously mentioned. In small-scale composting, achieving the desired 50 - 60% moisture level in the bin is much more important than in larger two-stage operations. After the temperature has peaked above 54.44°C and begins to decrease, the compost can be moved to storage or applied to the soil. While composting is effective, it requires a loader (two-stage), time and attention to detail. The average composition of broiler compost has been found to be: 28% moisture, 1.9% nitrogen, 2.3% P_2O_5, and 1.6% K_2O (Christmas, *et al*., 1996; FDACS, 1999).

6.3. Rendering

The rendering option allows the removal of carcasses from the farm to eliminate environmental pollution possibilities while recycling waste material into a good feed ingredient. Rendering involves heating, hydrolyzing and pressing processing plant wastes into by-product meal. The three major concerns related to this method of disposal are biosecurity, proper feather breakdown and a suitable on-farm storage method to reduce transportation cost. Brown (1996) offered some recommendations in this area, starting with a farm having a written biosecurity plan that is reviewed often to emphasize its importance. The storage and pick-up container should be secured against animal invasion and located at least 100 yards from houses. Carcasses should be taken to the storage site at the end of the day by an employee not returning to farm buildings that day. Brown (1996) also suggests that money spent on biosecurity should be viewed as an investment in future profitability.

A rendered carcass meal has been produced and tested in feeding trials with broilers at the University of Florida. The full-fat processing yield was 41% and the use of the material at up to 12% in the diet supported equal or improved feed efficiency. Neither meat flavor nor texture was affected by the inclusion of the meal in the diet. Feather hydrolization did not appear to be a problem and the meal contain 55.7% protein, 2.03% sulfur amino acids, 3.15% lysine, 3.73% calcium, 1.47% total phosphorus and 0.41% fiber (Christmas, *et al*., 1996).

6.4. Lactic acid fermentation

Lactic acid fermentation has also been widely tested as a preservation method for holding carcasses up to three months before rendering (Bui Xuan, *et al*., 1997). Carcasses need to be ground, thoroughly mixed with the correct amount of a fermentable carbohydrate such as molasses, corn meal or dried whey, and brought to 60-70% moisture. The lactic acid bacteria present in the gut then start to convert the energy source to lactic acid. As the conversion proceeds anaerobically, the pH is naturally lowered after five to seven days to between 3.0 and 4.5 where spoilage bacteria cannot survive. This process does take some attention to detail in terms of accurate measurements of raw materials and thorough mixing. Either the renderer or the producer must also have equipment for transporting the tanks of fermented product.

7. Utilization of livestock wastes

It is obvious that there is an urgent need for a sustainable use of livestock waste manures in animal and crop production. Some of the approaches that might be used within this research have also been proposed. Therefore, reducing waste from animal agriculture is important to maintain clean environment. Livestock waste management via recycling is an important step in sustainable livestock waste management as well as to reduce the negative environmental impact associated with its mismanagement.

7.1 Bio-fuel production

Biogas production from animals by anaerobic digestion has been traditionally a common practice in Asia, particularly in tropical areas such as Indonesia, India and Vietnam (Henuk, 2001). This is particularly true in very densely populated areas where trees have been cut and used as fuel or other purposes thereby distorting the ecosystem. Currently, the increased cost of fossil fuel used in manufacturing commercial fertilizer, and the realization that the supply of petroleum is limited with increased emphasis on improvement of the environment, has resulted in an increased interest in utilization of animal waste (Fontenot, 1979; Cheeke, 1999; Damro, 2000) as shown in Table 4.

Table 4

Guideline quantities and heat values of biofuel from animal waste

Waste	Total body weight (kg)	Methane	Heat value (Kcal/d)
Human	50	70	225
Laying hen	2	70	62
Fattening pigs	50	65	900
Dairy cow	500	70	6,850

Source: Taiganides (1983).

7.2. Organic fertilizer

Animal manures have been used effectively as organic fertilizers for centuries. According to Bell (2002) animal dropping contain all essential plant nutrients and have been well documented to be an excellent fertilizer. Poultry manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content (Sloan *et al.* 2008). Experiences in Europe and the USA have shown that land application of livestock manures for the fertilization of crops and grasslands and for improvement or maintenance of soil fertility is the most suitable method of manure utilization. In addition, manures supply other essential plant nutrients and serve as a soil amendment by adding organic matter. Organic matter persistence will vary with temperature, drainage, rainfall, and other environmental factors. Organic matter in soil improves moisture and nutrient retention. The utilization of animal manure is an integral part of sustainable agriculture and a valuable source of nutrients and organic matter for use in the maintenance of soil fertility and crop production. However, for reliable fertilizer planning and to allow confidence amongst farmers in the use of manures as nutrient sources, it is necessary to know the nutrient content of the manures (Table 2 and 5). A moderate application of livestock wastes is highly beneficial depending on storage and climate condition and can reduce soil acidity especially in highly weathered and leached soils of the world (Van Wambeke, 1976).

Table 5

Chemical composition of animal (chicken) manure.

Composition	**Chicken manure**
Macro nutrient (%)	
Total N	4.30
Phosphorus	2.85
Potassium	1.53
Calcium	7.53
Magnesium	1.19
Sodium	0.18
Micro nutrient	
Boron	29
cobalt	67
Manganese	1736
Zinc	1151
Chemical properties	
Alkaline (cmo_ckg^{-1})	225
EC (msm^{-1})	1494
pH (H_20)	8.03
Moisture content	6.42
$CaC0_3$	25.8

Source: Materechera and Mkhabela (2002).

7.3. Vermicast production

Vermiculture can be defined as the non-thermophilic biodegradation and stabilization of organic materials (Arancon *et al.*, 2003) resulting from interaction between earthworms and micro-organism living in both the worm's intestine and organic materials (Pizl and Novakova, 2003). Vermiculture system world wide uses two epigeic earthworm species *Eisenia Andrei and Eisenia foetida* (Elvira *et al*., 1996; Dominguez *et al*., 2005). Animal dropping can be potentially converted into vermin-cast and vermin-meal (protein meal) via low cost vermiculture system. Vermin-cast is an industrially recognized product that contains a proportion of cast mixed with portions of stabilized undigested humic residue. Casts are digested organic remains, mucus and nitrogenous excretory substances from the worm intestinal tract (Tripathi and Bhardwaj, 2003). The gizzard of worms allows them to produce casts that have a much finer texture than both raw and composted waste (Bajsa *et al*., 2003). Vermicast is becoming increasingly valuable due to its soil like texture and pleasant odour (Ndegwa and Thompson, 2000). Vermi-cast derived from animal manure have been shown to supply growth benefit to plants which out perform conventional inorganic fertilizers when compared on nutrient basis, and are sold as a biologically enhanced organic fertilizer (Buckerfield *et al*., 1999). They also provide microbial biomass, plant growth hormones, enzymes and humic acid (Arancon *et al*., 2003).

7.4. Alternative animal feed

Animal wastes when properly handled and dried will contribute to reduction of feed cost in areas where feedstuffs are scarce and expensive thus increasing the profit margin accruable to the farmer (Daghir, 1995). This will increase the profit margin and at the same time lower the cost of poultry meat and eggs reduce hunger and lower the competition between humans and poultry for food (El Boushy and Vander Poel, 2000). Depending on the production system used, 60 - 70% of cost of production goes to feed under intensive system of livestock management. Due to this high cost of conventional feeds and feed ingredients, nutritionist and other related workers in developing countries have seriously advocated the use of non conventional feeds and feed ingredients such as processed animal waste, leaf meals and agro industrial waste in animal nutrition. This will lead to a reduction in the use in animal feeds of traditional feed ingredients such as maize, wheat and soybean that can be consumed by human (El Boushy and Vander Poel, 2000). Poultry and swine manure collected in confinement feeding facilities can be recovered for re-feeding to beef cattle, dairy cattle and sheep. This practice has been shown through research to be an effective system of recovering, processing, and re-feeding such waste as source of energy, protein, and mineral nutrients in ruminant animal production (Bell, 2002).

Dried animal waste such as poultry dung is broadly equivalent to cereal such as barley in terms of protein and essential amino acids (Mcllroy and Martz, 1978). In UK, for example, when properly processed, dried poultry waste present no serious hazards to ruminants and poultry and had no negative effects on meat, egg or milk quality (Mcllroy and Martz, 1978).). This by-product of animal waste has been generally proven by a number of workers to be economically marginal because of the relatively low percentage of proximate compositions and amino acid profiles of poultry waste as reported by several researchers (Table 6) and high ash contents.

Table 6

Chemical analysis and amino acids composition of dried poultry waste on the basis (%).

Nutrient	a	b	c	d	e
Moisture	7.36	9.40	11.40	4.50	7.40
Crude protein	24.21	31.08	28.70	24.28	23.80
True protein	10.84	23.18	10.50	14.73	10.60
Non protein N	13.37	7.90	18.20	9.55	-
Ether extract	2.13	1.62	1.76	4.07	2.10
Crude fibre	13.72	10.70	13.84	10.11	13.70
Ash	26.90	23.76	26.50	35.79	26.90
Ca	7.78	8.27	7.80	10.61	7.80
P	2.56	2.00	2.45	2.71	-
K	1.91	-	-	2.34	-
ME (MJ/Kg)	-	8.09	2.76	2.34	-
Amino acids					
Lysine	0.49	0.48	0.39	0.56	-
Histidine	0.20	0.21	0.23	0.19	-
Arginine	0.47	0.45	0.38	0.53	-
Aspartic acid	1.06	1.10	0.71	1.22	-
Threonine	0.50	0.44	0.35	0.60	-
Serine	0.52	0.47	0.38	0.72	-
Glutamic acid	1.54	1.36	1.12	1.69	-
Glycine	0.82	1.61	1.33	0.93	-
Alanine	1.62	-	0.61	1.07	-
Valine	0.62	0.78	0.46	0.83	-
Methionine	0.09	0.20	0.12	0.29	-
Isoleucine	0.50	0.42	0.36	0.66	-
Leucine	0.80	0.69	0.55	0.94	-
Tyrosine	0.26	0.31	0.27	0.40	-
Phenylalanine	0.45	0.40	0.35	0.53	-
Cystine	1.09	-	0.15	0.21	-

Source: Henuk & Dingle (2002).

However, a precise determination of the benefit to an animal of animal manure is very difficult since manure is a dynamic organic material continually undergoing biological and chemical transformation. The benefit therefore, depends upon the composition and nutrient forms present as at the time of feeding. The manure nutrient content is affected by the overall manure handling system.

8. Conclusion

Poor handling of animal waste generated from livestock industries over the years had posed serious public concern on environmental quality and biosecurity issues and had made direct disposal of livestock wastes on land socially less acceptable. The conversion of livestock waste to useful products that are environmentally friendly turn out to be the only alternative to the emerging environmental issues associated with indiscriminate livestock waste disposal.

References

Anonymous, 2002. The Composition of Foods (Sixth Summary Edition), 537 pp, Royal Society of Chemistry and the Food Standards Agency, Cambridge, UK.

Apsimon, H.M., Kruse, M., Bell, J.N.B., 1987. Ammonia emissions and their role in acid deposition, Atmosph. Environ., 21, 1939–1946. http://dx.doi.org/10.1016/0004-6981(87)90154-5

Arancon, N.O., Edward, C.A., Bierman, P., Motzquar, J.O., Lee, S., Welch, C., 2003. Effects of vermicompost on growth and marketable fruits of field grown tomatoes, peppers and strawberries. Pediobiol., 47, 731-735. http://dx.doi.org/10.1016/S0031-4056(04)70260-7 , http://dx.doi.org/10.1078/0031-4056-00251

Bajsa, O., Nair, J., Mathew, K. & Ho, G.E. (2003).Vermiculture as a tool for domestic waste water management. Water Sci. and Tech., 48, 124-132.

Bell, D.D. (2002). Waste Management. In: Chicken meat and egg production, 5th edition (Bell, D.D. and Weaver, Jr., W.D., eds). Kluwer Academic publisher. Massachusetts. http://dx.doi.org/10.1007/978-1-4615-0811-3_11 , http://dx.doi.org/10.1007/978-1-4615-0811-3

Berendse, F., 1990. Organic matter accumulation and nitrogen mineralization during secondary succession in heathland ecosystems. J. Ecol. 78, 413 – 427. http://dx.doi.org/10.2307/2261121

Borgers, P., Huothuijs, D., Remijn, B., Brouner B. & Blersker, K. (1997). Lung function and respiratory symptoms in pig farmers. British J. Industrial Med., 44, 819 - 823.

Bouwman, A.F., Booij, H., 1998. Global use and trade of foodstuffs and consequences for the nitrogen cycle, Nutr. Cycl. Agroecosys. 52, 261 – 267. http://dx.doi.org/10.1023/A:1009763706114

Brown, J., 1996. All involved in poultry are responsible for biosecurity. Poultry Times, Gainesville, GA, p. 17.

Buckerfield, J.C., Flavel, T.C., Lee, K.E., Webster, K.A., 1999. Vermicompost in solid and liquid form as a plant growth promoter. Pedobiol. 43, 753 - 759.

Bui Xuan, A.N., Preston, T.R. & Dolberg, F. (1997). The introduction of low-cost polyethylene tube bio-digesters on small scale farms in Vietnam, Livestock Res. Rural Development. 9, 6 - 7. http://www.cipav.org.co/lrrd.

Burton, C.H., 1997. Manure Management – Treatment strategies for sustainable agriculture, Silsoe Research Institute, Bedford, UK.

Burton, C.H., Turner, C., 2003. Manure Management: Treatment Strategies for Sustainable Agriculture, 2nd edition, Silsoe Research Institute, Bedford, UK.

Cameron, R., Mohammed, H., Ward, D., 2000. Area-wide integration (AWI) and its implications for animal and human health. Discussion Keynote Paper, Session 3 of Electronic Conference on Area Wide Integration of Specialized Crop and Livestock Production, 5pp.
http://www.virtualcentre.org/en/ele/awi_2000/3session/3paper.htm
http://www.virtualcentre.org/en/ele/awi_2000/3session/3plenary.txt.

CEC, 1991. Commission of The European Communities, Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/CEC). Official J. Europ. Commun. Nr. L. 375(31.12.91), 1 – 8.

CEC, 2003. Commission of The European Communities, Commission Regulation (EC) No 1334/2003 of 25 July 2003 amending the conditions for authorization of a number of additives in feeding stuffs belonging to the group of trace elements, Official J. Europ. Uni. Nr. L. 187/11 (26.7.2003).

Chavez, C., Coufal, C.D., Lacey, R.E., Carey, J.B., Beier, R.C., Zhan, J.A., 2004. The impact of supplemented dietary methionine source on volatiles compound concentrations in broiler excreta. Poult. Sci. 83, 901 - 910.

Cheeke, P.R., 1999. Applied Animal Nutrition-Feed and feeding, second edition, Macmillan Publishing Company. New York.

Cole, D.J.A., Tuck, K., 2002. European approaches to reducing ammonia emission. In: Proceedings of 2002 National Poultry Waste Management Symposium. PP. 59 - 66.

Correll, D.L., 1999. Phosphorus: a rate limiting nutrient in surface waters. Poultry Science 78 (5), 675 – 682.

Crews, J. R., Donald, J. O. & Blake, J.P., 1995. An economic evaluation of dead-bird disposal systems. Circular ANR-914, Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Christmas, R. B., Damron, B.L. & Ouart, M.D. (1996). The performance of commercial broilers when fed various levels of rendered whole-hen meal. Poultry Sci., 75, 536 - 539.
http://dx.doi.org/10.3382/ps.0750536

Curtis, S.E. & Drummond, J.G., 1982. Air environment and animal performance. In: Handbook of Agricultural Productivity, vol.2, Animal Productivity (Rechcigi, M.Jr., ed.), CRC Press Inc, Florida, USA.

Daghir, N.J. (1995). Poultry production in hot climates. CABI, Wallingford.

Damron, W.S., 2000. Introduction to animal science. Global biological, social and industry perspective. Prentice Hall. New Jersey.

Davies, R.H., 1997. A two year study of Salmonella typhimurium DT104 infection and contamination on cattle farms, Cattle Practice, 5, 189 – 194.

De, N.V., Murrell, K.D., Cong, P.D., Cam, P.D., Chau, L.V., Toan, N.D. & Dalsgaard, A., 2003. The food borne trematode diseases and zoonoses of Vietnam, Southeast Asian J. Trop. Med. Pub. Health, 34, 12 – 34.

Delahaye, R., Fong, P.K.N., Van Eerdt, M.M., Van Der Hoek, K.W. & Olsthoorn, C.S.M., 2003. Emissie van zeven zware metalen naar landbouwgrond [Emission of seven heavy metals to agricultural soils]. Report, Central Statistical Office (CBS), Voorburg/Heerlen, The Netherlands. Available at: http://www.cbs.nl/nl-NL/default.htm

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. & Courbois, C., 1999. Livestock to 2020 – The next food revolution, Food, Agriculture, and the Environment Discussion Paper 28, 72 pp. International Food Policy Research Institute (IFPRI), Food and Agriculture Organization of the United Nations (FAO), International Livestock Research Institute (ILRI). IFPRI, Washington, USA.

Dominguez, J., Velando, A. & Ferreiro, A., 2005. Are Eisenia fetida and Eisenia andrei (Oligochaete lumbricidae) different biological species? Pedobiol., 49, 81 - 87.
http://dx.doi.org/10.1016/j.pedobi.2004.08.005

Dizer, H., Nasser, A. & Lopez, J.M., 1984. Penetration of different human pathogenic viruses into sand columns percolated with distilled water, groundwater or liquid manure, Appl. Environ. Microbiol., 47, 409 – 415.

Donald, J. O. & Blake, J.P., 1990. Dead bird composter construction. DPT Circular 10/90-001. Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Donald, J. O., Blake, J.P., Tucker, K. & Harkins, D., 1994. Mini-Composters in Poultry Production. Circular AND-804, Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Donald, J. O., Mitchell, C. & Payne, V., 1990. Dead Bird Composting. Circular AND-558, Alabama Cooperative Extension Service, Auburn University, Auburn, AL.

Donhann, K., Reynolds, S., Whitten, P., Merchant, J., Burmeister, L. & Popendort, W., 1995. Respiratory dysfunction in swine production facility workers, dose- response Relationships of environmental exposures and pulmonary function. Am. J. Industrial Med., 27, 405 - 418.
http://dx.doi.org/10.1002/ajim.4700270309
PMid:7747746

EEC, 1980. European Economic Community, Council Directive 80/778/EEC of 15 July relating to the quality of water intended for human consumption. Official Journal of the European Communities No L 229, (30.8.1980), p. 11.

EL Boushy, A.R.Y. & Vander poel, A.F.B., 2000. Handbook of poultry feed from waste: Processing and use. 2nd edition. Kluwer Academic Publishers, Dordecht.

Elvira, C., Dominguez, J. & Mato, S., 1996. The growth and reproduction of Lumbricus rubella and Dendrobaena rudida in cow manure mixed culture with Eisenia andrei. Appl. Soil Ecol., 15, 97 - 103.

Faostat data (2006). Food and Agriculture Organization of the United Nations, Rome, Italy. http://faostat.fao.org/site/336/default.aspx. fao.org/site/336/default.aspx.

Feddes, I.J.R. & Lickso, Z. J., 1993. Air quality in commercial turkey housing. Canadian Agricultural Engineering, 35, 147-150.

Fischer, T.K., Steinsland, H., Mølbak, K., CA, R., Gentsch, J.R., Valentiner-branth, P., Aaby, P. & Sommerfelt, H., 2000. Genotype profiles of Rotavirus strains from children in a suburban community in Guinea-Bissau, Western Africa, J. Clin. Microbiol., 38, 264 – 267. PMid:10618098 PMCid:88706

FDACS (1999). Florida Department of Agriculture and Consumer Services, Florida Agricultural Statistics Service-Livestock, Dairy and Poultry Summary. Tallahassee, FL.

Fontenot, J.P., 1979. Alternative in animal waste management. Introductory comments. J.Anim. Sci., 48, 111-112.

Gerber, P., Chilonda, P., Franceschini, G. & Menzi, H. (2005). Geographical determinants and environmental implications of livestock production intensification in Asia, Bioresource Technol., 96, 263 – 276. http://dx.doi.org/10.1016/j.biortech.2004.05.016
PMid:15381225

Harry, E. G., 1978. Air pollution in farm buildings and methods of control: a review.

Heij, G.J. & Schneider, T., 1995. Eindrapport Additioneel Programma Verzuringsonderzoek, derde fase (1991–1994) [Final Report Dutch Priority Programme on Acidification, third phase (1991–1994)], Rapport nr. 300-05, Dutch Priority Programme on Acidification, National Institute for Public Health and Environment, Bilthoven, The Netherlands (in Dutch).

Henuk, Y.L., 2001. Nutrient adjustments of the diets fed to cage and barn laying hens to decrease waste. PhD Thesis, University of Queensland.

Henuk, Y.L. & Dingle, J.G., 2002. Poultry waste: Current problems and solutions, In: Global Perspective in Livestock waste management; proceedings of the 4th International Livestock Waste Management Symposium and Technology Expo, Penang, Malaysia. 19-23 May 2002 Malaysia Society of Animal Production, Penang, pp.101-111.

Hogan, K.B., Hoffman, J.S. & Thompson, A.M., 1991. Methane on the greenhouse agenda, Nature, 354, 181–182. http://dx.doi.org/10.1038/354181a0

Hutchings, N.J., Sommer, S.G., Andersen, J.M. & Asman, W.A.H., 2001. A detailed ammonia emission inventory for Denmark, Atmosph. Environ., 35, 1959 – 1968. http://dx.doi.org/10.1016/S1352-2310(00)00542-2

IAEA/FAO, 2008. International Atomic Energy Agency/ Food and Agriculture Organisation Guidelines for Sustainable Manure Management in Asian Livestock Production Systems. A publication prepared under the framework of the RCA project on Integrated Approach for Improving Livestock Production Using Indigenous Resources and Conserving the Environment.

Jarvis, S.C., Sherwood, M. & Steenvoorden, J.H.A.M., 1987. Nitrogen losses from animal manures: from grazed pastures and from applied slurry, Animal Manure on Grassland and Fodder Crops: Fertilizer or Waste? (H.G. Van Der Meer, R.J. Unwin, T.A. Van Dijk, G.C. Ennik, Eds.), Development Plant Soil Sci., 30, 195–212, Martinus Nijhoff Publishers, Dordrecht, The Netherlands.

Kelleher, B.P., Leahy, J.J., Henihan, A.M., O'Dwyer, T.F., Sutton, D. & Leahy, M.J., 2002. Advances in poultry litter disposal technology-a review. Biores. Tech., 83, 27-36. http://dx.doi.org/10.1016/S0960-8524(01)00133-X

Ketelaars, J.J.M.H. & Van Der Meer, H.G., 2000. Establishment of criteria for the assessment of the nitrogen content of animal manures, Final Report to DG XI of the European Commission, Report 14, 64 pp. + Annexes, Plant Research International, Wageningen, The Netherlands.

Khalil, M.A.K. & Rasmussen, R.A., 1992. The global sources of nitrous oxide, J. Geophys. Res., 97: 14651–14660. http://dx.doi.org/10.1029/92JD01222

Krupa, S.V., 2003. Effects of atmospheric ammonia (NH3) on terrestrial vegetation: review, Environ. Pollution, 124,179–221.http://dx.doi.org/10.1016/S0269-7491(02)00434-7

Leha, C., 1998. Biodigester effluent versus manure, from pigs or cattle, as fertilizer for duckweed (Lemna spp.), Livestock Res. & Rural Dev., pp: 5. http://www.cipav.org.co/lrrd.

Lekkerkerk, L.J.A., Heij, G.J. & Hootsmans, M.J.M., 1995. Ammoniak: de feiten. [Ammonia: the facts], Rapport nr. 300-06, Dutch Priority Programme on Acidification, State Institute for Public Health and Environment, Bilthoven, The Netherlands.

Lelieveld, J., Crutzen, P.J. & Dentener, F.J., 1998. Changing concentration, lifetime and climate forcing of atmospheric methane, Tellus, 50B, 128–150.

Mackenzie, W.R., Hoxie, N.J., Proctor, M.E., Grad us, M.S., Blair, K.A., Peterson, D.E., Kazmierzak, J.J., Addis, D.G., Fox, K.R., Rose, J.B. & Davies, J.P., 1994. A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the public water supply, New England J. Med., 331, 161 – 167. http://dx.doi.org/10.1056/NEJM199407213310304,PMid:7818640

Maghirang, R.G., Manbeck, H.B., Roush, W.B. & Muir, E.V., 1991. Air contaminant distributions in a commercial laying house. Transactions of the Ame. Soc. of Agricultural Eng., 34, 2171-2180.

Materechera, S.A. & Mkhabela, T.S., 2002. The effectiveness of lime, chicken manure and leaf litter ash in ameliorating acidity in a soil previously under black wattle (Acacia mearnsii) plantation. Biores. Tech., 85, 9-16 http://dx.doi.org/10.1016/S0960-8524(02)00065-2

Mcllroy, W. & Martz, F.A., 1978. Cattle feed from solid waste components. In: Animal feed from waste materials, (Gillies, M.T., ed.), Noyes Data Corporation, Park, Ridge, New Jersey, pp., 263-303.

Merrill, L. & Halverson, L.J., 2002. Seasonal variation in microbial communities and organic mal-odour indicator compound concentrations in various types of swine manure storage systems. Environmental quality. 31, 2074-2085.

Moolenaar, S.W., 1999. Heavy-metal balances, part II. Management of cadmium, copper, lead, and zinc in European agro-ecosystems, J. Industrial Ecol., 3, 41–53. http://dx.doi.org/10.1162/108819899569386

Moolenaar, S.W. & Lexmond, T. M., 1998. Heavy metal balances, part I. General aspects of cadmium, copper, zinc, and lead balance studies in agro-ecosystems, J. Industrial Ecol., 2, 45 – 60. http://dx.doi.org/10.1162/jiec.1998.2.4.45

Moore, P.A., 1998. Best management practices for poultry manure utilization that enhances agricultural productivity and reduce pollution. In: Animal waste utilization: Effective use of manure as a soil resource. J.L. Hatfield and B.A. Stewart, eds. Ann Arbor press, Chelsea, ML, pp. 89-123.

Nardone, A. & Valfrè, E., 1999. Effects of changing production methods on quality of meat milk and eggs. Livestock Prod. Sci., 59, 165 – 182. http://dx.doi.org/10.1016/S0301-6226(99)00025-1

Ndegwa, P.M. & Thomas, S.A., 2000. Integrating composting and vermi-composting in the treatment and biological conversion of biosolids. Biores. Tech., 76, 13 - 23.

Nguyen, X.T., 1998. The need for improved utilisation of rice straw as feed for ruminants in Vietnam: an overview, Livestock Res. Rural Development, 10, 13 pp. http://www.cipav.org.co/lrrd

Nicholson, F.A., Groves, S.J. & Chambers, B.J., 2005. Pathogen survival during livestock manure storage and following land application, Biores. Technol., 96, 135 – 143. http://dx.doi.org/10.1016/j.biortech.2004.02.030 PMid:15381209

Okoli, IC., Alaehie, D.A., Okoli, C.G., Akanno, E.C., Ogundu, U.E., Akujobi, C.T., Onyicha, I.D. & Chinweze, C.C.E., 2006. Aerial pollutant gases concentrations in tropical pig pen environment in Nigeria. Nature and Science, 4, 1-5.

O'Neill, D.H. & Phillips, V.R. (1992). A review of the control of odour nuisance from livestock buildings. Part 3, properties of the odorous substances, which have been identified in livestock wastes or in the air around them. Journal of Agricultural Engineering Research, 53, 23 - 50. http://dx.doi.org/10.1016/0021-8634(92)80072-Z

Pizl, V. & Novakova, A., 2003. Interaction between micro fungi and Eisenia andrei (Oligochaete) during cattle manure vermi-compositing. Pedobiol., 47, 895 - 899. http://dx.doi.org/10.1016/S0031-4056(04)70286-3 http://dx.doi.org/10.1078/0031-4056-00277

Reynolds, S., Donham, K., Whitten, P., Merchant, J., Murmeister, L. & Popendorf, W., 1996. Longitudinal evaluation of Doze- response relationships for environmental exposures and pulmonary function in swine production workers. Am. J. Indus. Med., 29, 33 - 40. http://dx.doi.org/10.1002/(SICI)1097-0274(199601)29:1<33::AID-AJIM5>3.0.CO;2-#

Richardson, T., Pinckney, J. & Paerl, H., 2001. Responses of estuarine phytoplankton communities to nitrogen form and mixing using microsm bioassays, Estuaries, 24, 828 - 839. http://dx.doi.org/10.2307/1353174

Rotz, C.A., 2004. Management to reduce nitrogen losses in animal production. Journal of Animal Science, 82: E119-E137.PMid:15471791

Ryser, J.P., Walther, U. & Flisch, R., 2001. Données de bases pour la fumure des grandes cultures et des herbages en Suisse, Engrais de Ferme Revue Suisse d'Agriculture. 33: 1–80.

Sainsbury, D., 1992. Poultry health and management-chickens, turkey, geese, quail. 3rd edn. Blackwell Scientific Ltd, Oxford, UK.

Sloan, D.R., Kidder, G. & Jacobs, R.D., 2008. Poultry Manure as a Fertilizer. http://edis.ifas.ufl.edu.

Smith, K.A., Jackson, D.R. & Pepper, T.J., 2001. Nutrient losses by surface run-off following the application of organic manures to arable land. 1. Nitrogen, Environ. Pollution, 112, 41–51. http://dx.doi.org/10.1016/S0269-7491(00)00098-1 http://dx.doi.org/10.1016/S0269-7491(00)00097-X

Smith, K.A. & Van Duk, T.A., 1987. Utilisation of phosphorus and potassium from animal manures on grassland and forage crops, Animal Manure on Grassland and Fodder Crops: Fertilizer or Waste? (H.G. VAN DER MEER, R.J. UNWIN, T.A. VAN DIJK, G.C. ENNIK, Eds.), Martinus Nijhoff Publishers, Dordrecht, The Netherlands.Development Plant Soil Sci., 30, 87–102,

Sommer, S.G. (2000). Area-wide integrated recycling of pig effluent in Thailand. Effluent treatment and handling, DIAS Report no.17 DIAS, Denmark.

Sommer, S.G., Génermont, S., Cellier, P., Hutchings, N.J., Olesen, J.E. & Morvan, T., 2003. Processes controlling ammonia emission from livestock slurry in the field, Europ. J. Agron., 19, 465 – 486. http://dx.doi.org/10.1016/S1161-0301(03)00037-6

Sommer, S.G. & Moller, H.B., 2000. Emission of green house gases during composting of deep litter from pig production-effect of straw content. J. Agric. Sci., 134, 327 - 335. http://dx.doi.org/10.1017/S0021859699007625

Sommer, S.G. & Hutching, N.J., 2001. Ammonia emission from field applied manure and its reduction- invited paper. European Journal of Agronomy. 15, 1 - 15. http://dx.doi.org/10.1016/S1161-0301(01)00112-5

Stanley, K.N., Wallace, J.S., Currie, J.E., Diggle, P.J. & Jones, K., 1998. The seasonal variation of thermophilic campylobacters in beef cattle, dairy cattle and calves, J. Appl. Microbiol., 85, 472–480. http://dx.doi.org/10.1046/j.1365-2672.1998.853511.x PMid:9750278

Steinfeld, H. & Chilonda, P., 2006. Old players, new players, Livestock Report 2006, 3–14, Animal Production and Health Division, Food and Agriculture Organization of the United Nations, Rome, Italy.

Strauch, D. (1986). Hygienic aspects of land use of municipal sewage sludge and animal manure, Efficient land use of sludge and manure (A.D. Kofoed, J.H. Williams, P. L'hermite, Eds.), CEC Seminar, Elsevier Applied Science Publishers, London, UK. Pp: 224–237.

Taiganides, E.P., 1992. Pig waste management and recycling – The Singapore experience, 345 pp, International Development Research Centre, Ottawa, Canada.

Taiganides, E.P., 2002. The solution to pollution. In: Global perspective in livestock waste management symposium and technology expo, Penang; Malaysia, 19 - 23 May 2002, (Cong, H.K., Zulkifle, I., Tee, T.P. and Liang, J.B. eds.). Malaysia Society of Animal Production, Penang, pp. 1-10.

Tamminga, S., Jongbloed, A.W., Van Eerdt, M.M., Aarts, H.F.M., Mandersloot, F., Hoogervorst, N.J.P. & Westhoek, H., 2000. The forfaitaire excretie van stikstof door landbouwhuisdieren [Standards for the excretion of nitrogen by farm animals], Rapport ID-Lelystad no. 00-2040R, Instituut voor Dierhouderij en Diergezondheid, Lelystad, The Netherlands. Pp: 71.

Ten Have, P.J.W. & Van Voorneburg, F. (1994). Mestverwerking (Manure processing), (J.H. Van Middelkoop, Ed.), Naar veehouderij en milieu in balans, 10 jaar FOMA onderzoek. Onderzoek inzake de mest- en ammoniakproblematiek in de veehouderij 19 (Pluimvee). Dienst Landbouwkundig Onderzoek (DLO), Wageningen, The Netherlands. pp: 51–59.

Tripathi, G. & Bhardwaj, P., 2003. Decomposition of chicken waste amended with cow manure using an epigeic species (Eisenia foetida) and an anecic species (Lampito mauritii), Biores. Tech., 92, 215 - 218. http://dx.doi.org/10.1016/j.biortech.2003.08.013 PMid:14693456

UKTERG., 1988. United Kingdom Terrestrial Effects Review Group, The effects of acid deposition on the terrestrial environment in the United Kingdom, First Report, HMSO Publications Centre, London, United Kingdom.

Van Breemen, N., Burrough, P.A., Velthorst, E.J., Van Dobben, H.F., De Wit, T., Ridder, T.B. & Reijnders, H.F.R., 1982. Soil acidification from atmospheric ammonium sulphate in forest canopy throughfall, Nature, 299, 548–550.http://dx.doi.org/10.1038/299548a0

Van Riemsdijk, W.H., Lexmond, Th.M., Enfield, C.G. & Van Der Zee, S.E.A.T.M., 1987. Phosphorus and heavy metals accumulation and consequences. Animal Manure on Grassland and Fodder Crops: Fertilizer or Waste? (H.G.

Van Der Meer, R.J. Unwin, T.A. Van Dijk, G.C. Ennik, Eds.), Development Plant Soil Sci., 30, 213–227, Martinus Nijhoff Publishers, Dordrecht, The Netherlands.

Van Der Meer, H.G., 2006. Reduction of Agricultural and rural Pollution by Innovative aDditives (RAPID), Final Scientific Report of CRAFT Contract QLK5-CT-2001- 70429, Note 415, Plant Research International, Wageningen University and Research, Wageningen, The Netherlands. pp: 282.

Van Der Meer, H.G. & Wedin, W.F., 1989. Present and future role of grasslands and fodder crops in temperate countries with special reference to over-production and environment. Proceedings of the XVI International Grassland Congress. Nice, France. 3, 1711–1718.

Van Wambeke, A., 1976. Formation, distribution and consequences of acid soils in agricultural development. In: Plant adaptation to mineral stress in problem soils, (Wright, M.J. ED.), Cornell University Press, New York, pp.15-24.