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RESEARCH ARTICLE

Impact of animal waste on environment, its managemental strategies and treatment protocols to reduce environmental contamination

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Abstract : The role of animals in the development of developing nations is imperative. Not only the developing nations but the developed nations also depend upon their animal wealth for their livelihood and nutrition. The number of farm animals is increasing day by day globally, which is although a positive sign for mitigating the widespread hunger and malnutrition but on the other hand, the growing livestock population is posing a great threat to environment in the form of animal wastes. Animal scientists are focusing more on the sustainable increase in the livestock production systems whether it is production of meat, milk, eggs or fibre but are least concerned about the wastes emerging out from the livestock industry and livestock itself. The unconditional use of chemicals in the agriculture and livestock industry has not only raised an environmental concern but also a health concern for the humans. The excretions from the animals have the residues of certain chemicals which are noxious for humans as well as for environment. Further, the excretions of diseased animals may have certain zoonotic pathogens which are very harmful for humans and can remain in soil for several days to weeks. The active compounds in the animal excretions and the effluents erupting from the livestock products and processing industries pose a greater threat to all the components of environment. The fusion of traditional managemental procedures with advanced research can better serve the purpose of animal waste management.

Key words : Animal waste, Management, Environment, Chemicals, Livestock, Zoonosis

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INTRODUCTION

According to the United Nations' Food and Agriculture Organization (FAO, 2004), Asia has the fastest-developing livestock sector, followed by Latin America and the Caribbean. Consequently the animal waste production also increases day by day in these regions. To give an idea of scale, the planet's population of some 2.5 billion pigs and cattle excrete more than 80 million metric tons (MMT) of waste nitrogen annually. The entire human population, in comparison, produces just over 30 MMT (Koopmans, 2004). Due to continuous incorporation of nitrogen from urine and faces in air depress the oxygen concentration and causing respiratory diseases. Whereas waste disposal in water not only pollutes it but also cause water borne diseases resulting in shortage of clean drinking water (Hansen and Meres, 2002). Human life remains at risk during animal handling and care, especially animal wastes like urine, feces/dung and dead bodies, which are the carriers of pathogens. From these excretes sometimes very complicated diseases like Listeriosis, Leptospirosis, Salmonellosis, Brucellosis and Vibriosis are transmitted to humans (Korner *et al*., 2003). When the organic matter decomposes, it produces methane gas. Pollutants from unmanaged livestock wastes can degrade the environment and methane emitted from decomposing manure may contribute to global climate change.

The increasing demand for food leads to a process of intensification in livestock production, which can lead to serious environmental problems if animal waste is not managed properly. In this sense, alternative technologies for good waste management can and must be used, as is the case of biodigesters, which produce biogas and biofertilizers and are an adequate form of animal waste treatment. The idea of looking at manure as a resource, not a waste, has been central idea much of the more recent thinking on whole subject of good farm management (Burton and Turner, 2003). If we utilize this animal waste we can not only clean our environment but money spend on fertilizer could be saved.

Animal waste and environment :

As livestock production increases worldwide, animal waste is becoming a serious environmental hazard. In some cases, the damage has been spectacular and even tragic. In 2000, drinking water contamination by livestock waste led to several deaths in Canada town of Walkerton (Catelo *et al*., 2001). The relationship between livestock production and greenhouse gas (GHG) emissions it is widely recognized. According to Steeg and Tibbo (2012), agriculture contributes between 59 per cent -63 per cent of the world's non-carbon dioxide (non-CO_2) GHG emissions, including 84 per cent of the global nitrous oxide (N_2O) emissions and 54 per cent of the global methane (CH_4) emissions. According to McMichael *et al.* (2007) much of the estimated 35 per cent of global greenhouse-gas emissions deriving from agriculture and land use comes from livestock production. Therefore, the expansion of livestock production creates the need to deal with subsequent environmental problems and some are summed as:

Air pollution and climate change :

Aerial pollutants arising from livestock industry 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 and Okoli *et al*., 2006). When the pH of livestock waste increases, the ammonium ion is converted to ammonia gas which easily volatilized to air and increases atmospheric N content (Moore, 1998). Ammonia emissions from wet animal droppings were found to coincide with odors, which are nuisance in area of intensive livestock production (Chavez *et al*., 2004 and Cole and Tuck, 2002). 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. Air pollution and global warming are produced by livestock directly and indirectly. The production of livestock has significantly contributed to the increase levels of CO_2 and other greenhouse gases during the past 250 years (Darwin, 2001). About 40 per cent of emitted methane is produced by agriculture predominantly by ruminant animals (Rosenzweig and Hillel, 1998). 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 and contributes to global warming and climate change.

Water pollution :

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.

Land degradation :

In many countries, prolong heavy grazing contributes to the disappearance of edible plant species and subsequent dominance by either inedible, herbaceous plants or bushes. Livestock impact on the soil can be classified into two broad categories as reported by Whitemore (2001), physical impact of the animal on the soil as it moves around and secondly, the chemical and biological impact of the feces and urine that the animal deposits on the soil. The amount of urine eliminated by a grazing cow is of the order 2 lit applied to an area of about $0.4m^2$ (Addiscoth *et al.*, 1991), which represents an instantaneous application of 400 to 1,200kg N per hectare. Such an amount burns vegetation and is often toxic to plant roots which cannot immediately recover to take the nitrogen (full recovery can take upto 12 months) and the problem worse in areas where animals congregate (Early *et al.*, 1998). Along with nitrogen, excess phosphorus presents special problem, as a result of its low solubility in the soil, contaminates surface water and cause erosion.

Heavy metals :

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). Excess of these heavy metals led to their accumulation in plants and also leaching to surface and ground water. Soils on which pig and poultry manures are continuously applied at high rates accumulate heavy metals jeopardizing the good functioning of the soil, contaminating crops and posing human health risk (Conway and Pretty, 1991). 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.

Environmental health effects of concentrated animal feed operations (CAFOs) :

Though sewage treatment plants are required for human waste, no such treatment facility exists for livestock waste. The most pressing public health issue associated with CAFOs (Concentrated Animal feed operations) stems from the amount of manure they produce. All of the environmental problems with CAFOs have direct impact on human health and welfare for communities that contain large industrial farms. CAFOs are an excellent example of how environmental problems can directly impact human and community well-being and are listed in the following Table 1.

Management strategies for animal wastes :

Cattle are the largest contributors to global manure production (60%), while pigs and poultry account for 9 per cent and 10 per cent, respectively (Herrero *et al.,* 2009). Improved waste management through enhanced manure management and biogas production for energy should be the main interest. Improperly managed animal waste can have severe consequences for the environment such as odor problems, attraction of rodents, insects and other pests, release of animal pathogens, groundwater contamination, surface water runoff, deterioration of biological structure of the earth and catastrophic spills (Sakar *et al.,* 2009). Therefore, following strategies for management of animal waste can be put to use:

Strategies dealing with nutrients balance :

Phase separation can be used as a simple method to enhance manure management capability. It allows separating manure into a solid fraction, which can be composted on-farm, transported to farther distances or delivered to a centralized composting plant, and a liquid fraction, which can be used in the nearby lands by means of irrigation systems or further processed (Burton, 2007). N-recovery by means of stripping-absorption (Bonmatí and Flotats, 2003a), by thermal concentration (Bonmatí and Flotats, 2003b) or by ammonium and phosphate salt precipitation, takes benefit from a previous anaerobic digestion step.

Strategies dealing with hygienization :

A temperature-time criterion of 70ºC for 1 hour has been stated as a minimum for specific thermal treatments prompting reductions equivalent to 4-log10 units, although it could be excessive for certain pathogens and low for others (Heinonen-Tanski *et al.*, 2006). Aerobic digestion of liquid manures in self-heated thermophilic bioreactors has been proposed as effective for hygienization (Juteau *et al.*, 2004), although with high electrical power requirements for transferring oxygen.

Strategies dealing with emerging pollutants and xenobiotic compounds :

Hormones and antibiotics are not completely absorbed by animal bodies and thus, excreted as parent compounds or metabolites (Kemper, 2008). Release of antibiotics to the environment is of considerable concern because it may lead to the development of antibiotic-resistant bacteria (Chee-Sanford *et al.*, 2009). Numerous xenobiotics are susceptible of photodegradation, which can occur at the surface of manure in storage facilities and at the soil-atmosphere interface once manure is applied to soil. Hydrolysis can be another degradation pathway (Chee-Sandford *et al.*, 2009) being highly influenced by temperature, pH and the molecular composition of chemical compounds.

Table 1 : Environmental health effects of concentrated animal feed operations (CAFOs)

Sr.No.	Environmental component	Ill effects due to animal waste produced by CAFOs	Reference
1.	Ground water	Levels of veterinary antibiotics and elevated levels of nitrates	Batt *et al.*, 2006.
2.	Surface water	Increased levels of Ammonia.	EPA, 1998
		Hormones	Burkholder *et al.*, 2007
		Cryptosporidium parvum and *Giardia* were found in over 80% of surface water sites tested in USA.	Spellman and Whiting, 2007
3.	Air quality	Volatilization to ammonia.	Merkel, 2002
		Particulate matter and suspended dust, which is linked to asthma and bronchitis.	Sigurdarson and Kline, 2006
4.	Greenhouse gas and climate change	Carbon dioxide is often considered the primary greenhouse gas of concern; manure emits methane and nitrous oxide which are 23 and 300 times more potent as greenhouse gases than carbon dioxide, respectively.	EPA, 2009
5.	Odors	Worse odors that CAFOs emit are a complex mixture of ammonia, hydrogen sulfide, and carbon dioxide, as well as volatile and semi-volatile organic compounds.	Heederik *et al.*, 2007 Donham *et al.*, 2007
		Odor can cause negative mood states, such as tension, depression, or anger, and possibly neurophysciatric abnormalities, such as impaired balance or memory.	
6.	Insect vectors	Houseflies near poultry operations may contribute to the dispersion of drug-resistant bacteria.	Center for Livable Future, JHBSPH, 2009.
		Mosquitoes spread zoonotic diseases, such as West Nile virus, St. Louis encephalitis, and equine encephalitis.	Bowman *et al.*, 2000
7.	Pathogens	*Bacillus anthracis* *Escherichia coli* *Leptospira pomona* *Listeria monocytogenes* *Salmonella* species *Clostirdum tetani* *Histoplasma capsulatum* *Microsporum* and *Trichophyton* *Giardia lamblia* *Cryptosporidium* species	Carrie, 2010
8.	Antibiotics	Use of antibiotics in animal feed is contributing to an increase in antibiotic-resistant microbes and causing antibiotics to be less effective for humans.	Kaufman, 2000

Processes employed for treatment of animal wastes :

Physical processes :

The following are the physical processes used for treatment of animal wastes:

Sedimentation :

The easiest way to remove suspended solid material from liquid manure is by utilizing natural settling or sedimentation (Martinez *et al.*, 1995). The sedimentation option appears to be an attractive method for removing fine solids from slurry because of the relative simplicity of the process and the low costs of the equipment involved.

Mechanical separation :

A quicker separation can be obtained using mechanical screening, a technique easily applicable on farms to separate the coarse solids from the slurry. Mechanical screening is also an initial process step in many complete treatment processes (Moller *et al.*, 2002).

Incineration :

Animal wastes can be incinerated for better management. However, to incinerate the huge bulk rendered by the animals is not possible. The developing countries cannot afford the incinerators meant for waste treatment and the developed countries have set of emission standards which need to be followed in this process.

Solar drying :

Sun drying renders the manure to very low levels of moisture. Most of the bacteria and protozoa get deactivated at such low moisture levels and the disease causing activity of the manure decreases. The worm load in the manure also decreases and hence the environmental contamination is suitably reduced.

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 dead birds.

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.

Membrane processes :

The use of membrane technology *i.e.* reverse osmosis in the dewatering of sow slurry is possible, but an important prerequisite is that the organic fraction should be decomposed and the solids removed by effective sedimentation, separation or filtering processes before the liquid enters any membrane treatment step (Van Gastel and Thelosen, 1995).

Biological processes :

By optimizing the environment of the naturally occurring micro-organisms, it is possible to use these species for the specific purpose of biological treatment to produce useful end products. The following are the biological processes used for treatment of animal wastes:

Aerobic treatment :

The following systems can be used for aerobic treatment:

Aerated lagoons :

A simple low-cost system for aerobic slurry treatment, where odor abatement is required, is the aerated lagoon. Lagoons exist on many livestock farms and the installation of an aerator represents a relatively small investment.

Continuous aerobic treatment systems :

There are now examples of continuous aerobic treatment plants (pilot and full scale) for livestock waste in Europe, especially in France and The Netherlands (Melse and Verdoes, 2005 and Béline *et al.*, 2004). In recent years, small pilot plants have given way to full-scale units handling more than 100 tons per day.

Use of aerobic trickling biofilter :

Biofiltration is a general term for wastewater treatment processes that use high reactor specific surface areas (e.g., on plastic media) to establish biofilms which metabolize organic compounds and nutrients, and contribute to pathogen reductions.

Activated sludge :

Traditional activated sludge systems consist of an aeration tank, where influent is mixed with an aerated suspension of micro-organisms, followed by a sedimentation tank, where the waste is clarified and a portion of the settled solids returned to the aeration tank. A typical activated sludge system can be expected to reduce bacteria, viruses, protozoan parasites and helminth ova in wastewater by approximately 80-99+, 90-99, 80-99 and 0-90 per cent, respectively (Feachem *et al.*, 1983 and Schwartzbrod *et al.*, 1989).

Constructed wetlands :

Biological treatment occurs in constructed wetlands due to the biological activity of micro-organisms and vegetation. Fecal coliforms have been shown to be removed by 90-99.9 per cent in surface flow and subsurface flow constructed wetlands treating municipal wastewater, dairy wastewater (Newman *et al.*, 2000) and swine wastewater (Hill, 2001).

Overland flow :

The overland flow technique is typically performed by applying wastewater to the upper portion of a sloping, grass-covered field of low permeability soil and allowing the wastewater to flow as a sheet through the grass to runoff collection ditches at the bottom of the slope and may only be capable of achieving moderate reductions in nutrients and pathogens (Kudva *et al.*, 1997).

Anaerobic digestion :

Anaerobic digestion is one of the most important treatment measures available for animal manure and other organic wastes, which allows the production of a universal energy carrier, CH_4. Anaerobic digestion is most easily and commonly carried out with pumpable slurries, although more recently, high solids content (20–40% DM) plug-flow reactors have been developed. One of the products of the process is biogas, a mixture of 60–70 per cent CH_4 and 30–40 per cent CO_2.

Methane emission from animal waste and biogas technology :

The US Environment Protection Agency (USEPA) has given the methane emissions in carbon dioxide equivalent for various countries and also as projected the emission till 2020. As per their estimation, the methane emissions from manure in India *vis-à-vis* some important countries and world total are as under Table 2.

The methane emission can be harnessed by converting methane arising from animal waste into biogas. Biogas is obtained in the process of biodegradation of organic materials under anaerobic conditions. Therefore, the biogas technology *i.e.* production of methane gas from livestock waste under anaerobic condition is the best alternate source of energy from organic waste. Typical biogas yields from various types of manure and biomass is presented in the table below (Werner *et al.*, 1986 and Abdel-Hadi *et al.*, 2002).

Mesophilic anaerobic digestion :

In general terms, the effectiveness of mesophilic digestion for reducing pathogens is greater when temperatures are higher and HRTs are longer. In an anaerobic digester fed cattle slurry at an operating temperature of 28ºC and an HRT of 24 days, *S. typhimurium*, *Y. enterocolitica*, *L. monocytogenes*, and *C. jejuni* reductions were modest: 0.7, 1.4, 0.9 and 0.1 log10 (Kearney *et al.*, 1993).

Thermophilic anaerobic digestion :

Pathogen reductions are generally greater at the higher temperatures at which thermophilic anaerobic digesters are operated than at lower, mesophilic temperatures. Anaerobic digestion at 55ºC is effective at inactivating viable *Listeria monocytogenes* and *Salmonella typhimurium* after 2 hours of incubation (Burtscher *et al.*, 1998).

Soil-based processes or soil filters :

According to Fuller and Warrick (1995) land is a gigantic bio-conversion system, developed during millions of years and able to bio-degrade animal and plant wastes to become part of the soil. Land application serves two objectives: (i) waste disposal; and (ii) recycling of waste components. Fuller and Warrick proposed the terms land treatment and land utilization. Land treatment involves the use of soil as a means of treating waste, while land utilization serves two objectives, *viz*. waste disposal and utilization of a valuable resource. Land treatment is based on the physical, chemical and microbiological interactions between the components and micro-organisms of soil and waste.

Production of organic fertilizers by composting and pelletizing :

Composting :

Aerobic decomposition and impeded heat transfer cause heating of the organic matter and thus kills pathogens

Table 2 : Methane emission from manure management (in Million tons) carbon dioxide equivalent country

Countris	1990	2000	2005	2020
India	18.83	80.52	23.20	27.48
China	15.70	19.76	80.91	28.32
France	13.79	13.30	13.25	13.29
Germany	27.10	23.27	19.63	16.65
USA	31.19	38.08	39.18	43.83
World total	222.52	225.38	234.57	269.47

Table 3 : Production of organic fertilizers by composting and pelletizing :

Component	Substrate range of biogas yield (lit/kg volatile state)	Mean biogas yield (lit/kg volatile state)
Pig manure	340–550	450
Cattle manure	150–350	250
Poultry manure	310–620	460
Horse manure	200–350	250
Sheep manure	100–310	200
Cereal straw	180–320	250
Maize stover	350–480	410
Fodder sugar beets	344–982	690
Grass	280–550	410
Vegetable residues	300–400	350
Sewage sludge	310–640	450

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). 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.

Solids pelletizing :

Some more novel options, arising from or linked to manure processing, also need to be considered. In the state of Delaware, USA, the world's largest chicken manure pelletization plant has processed about 60,000 tons of chicken manure since it opened in July 2001. The plant was designed as a solution for local poultry farmers who needed to remove waste from their facilities.

Environment protection through utilization of animal wastes :

Animal 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.

Biogas 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). Biogas is used as fuel for cooking and lighting purposes and in diesel engines to substitute diesel-oil. The left over decomposed slurry is a good source of manure for agricultural lands as it contains 80 per cent carbon, 1.8 per cent nitrogen, 1 per cent phosphorus and 0.9 per cent potash making it an excellent source of not only humus but also micronutrients for crops.

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).

Vermiculture :

Animal dropping can be potentially converted into vermin-cast and vermin-meal (protein meal) via low cost vermiculture system. Boda (1990) reported that 80kg of dungworms can be produced per ton of cattle dung. Omoyakhi and Nwokoro (2004) noted that layer manure can yield a total of 12.59 per cent of maggot. Several other authors' reports indicated that no disease symptom or mortality was observed when these invertebrates grown on manure were used as livestock feed (Atteh and Oyedeji, 1994).

Alternative animal feed :

The properly handled and dried animal waste can be used as animal feed which 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). 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).

Conclusion :

Livestock contributes a major chunk to the economies of both developed and developing countries. Not only, livestock provides nutritional security to a nation but also mediates economic stability. But at the same time, we should not neglect the wastes excreted by the livestock industry. These wastes are not only hazardous for humans but are very much deleterious for the environment in which humans sustain their lives. Therefore, these animal wastes affect human life both directly as well as indirectly through environment. To curtail the emerging consequences pertaining to animal wastes is the need of the hour. Both the developed and the developing countries should adapt and follow the rules and regulations mandatory for decontamination of the environment by proper disposal and treatment of animal wastes. The menance of global warming and climate change can be restricted once such regulations are taken into consideration and various processes for disposal of animal wastes are followed. Technologies are present and more research is being carried on for evolving more technologies for safeguarding the environment. The initiatives should be taken by the national governments in co-ordination with civil societies and incentives should be given to farmers and general public for adoption of such technologies and hence safeguarding the environment and making Earth a better place to live in.

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