National policies on manure utilization and GHG mitigation in other countries

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Animal manure is a useful resource when handled carefully, but it can also be a source of significant problems and public health issues when handled incorrectly. Animal manure handling may provide risks to the quality of the land, water, and air. Despite this, some areas continue to use non-sustainable animal waste management techniques. Sustainable animal manure management necessitates multifaceted techniques and provides several benefits to both farmers and the general population. The significance placed on manure handling and management in various nations has resulted in the implementation of necessary legislation, rules, standards, and policies to encourage sustainable animal manure handling. Some of these are put in place at the local, state, national, regional, and international levels. For effective treatment of animal manure, a variety of approaches are available, ranging from basic, low-cost procedures to sophisticated strategies.

1. Significance of manure management

Animal husbandry is critical to global food security, nutrition, and economic security. Domestic animal husbandry in many nations is dominated by ruminants, non-ruminants, and aquatic animals (Malomo et al. 2018). Cattle, swine, poultry, and companion animals are among examples. The livestock sector is one of agriculture's fastest expanding subsectors. It has been estimated that there are currently around 1.4 billion cattle, 2.1 billion sheep and goats, and approximately 350 million other domestic herbivores on the planet, which equates to more than one domestic herbivore for every two humans on the globe (Mottet et al. 2018). Animal agriculture contributes to a nutritious food supply, employment development, income production and household earnings, asset saving, economic output and taxation, agricultural diversity, animal traction, soil fertility, and transportation (Teenstra et al. 2014). However, ample divergent types of wastes also being produced during animal production. Leftover feed, wastewater, hatchery wastes, slaughterhouse wastes, and manure are all examples of possible wastes created during animal production processes (Teenstra et al. 2014). Among them, manure is of utmost importance owing to its diverse and versatile benefits. Manure is rich in nutrients, organic materials, and renewable energy. Despite the importance of organic fertilizers in agricultural productivity, manure continues to be an essential fertilizer resource, particularly in places where organic fertilizers are not widely available or accessible to farmers (Teenstra et al. 2014). Nonetheless, it also contributes significantly to many environmental issues and perturbations including anthropogenic greenhouse gas (GHG) emissions. According to IPCC accounting, animal agriculture is responsible for 8–10.8 percent of global greenhouse gas (GHG) emissions, and based on lifecycle analysis, livestock contributes up to 18 percent of global emissions (O'Mara, 2010, Teenstra et al.

2014, Pratt et al. 2015). As the world's population and food demand expand, livestock-related emissions will rise; enteric CH_4 emissions are expected to rise by more than 30% from 2000 to 2020 (O'Mara, 2010). It has been estimated that manure management mitigation potential to reduce the GHG is huge, only due to improved grazing land management the estimated potential is about ~800 million tonnes CO_2-equiv./yr (O'Mara, 2010, Pratt et al. 2015). Conversely, inadequate manure management, resulting in the loss of nutrients and organic matter, producing environmental and climatic concerns and endangering human health. Therefore, manure management is of great significance and needs serious and immediate attention and concrete actions.

2. Challenges of manure management

Manure management is a major source of agricultural GHG emissions, with the majority of manure GHG emissions reported to occur in management systems such as lagoons, feed pads, and animal housing (Pratt et al. 2015). The manure storage and handling system influences manure-related emissions of CH_4 and N_2O. In 2005, global GHG emissions from manure management totaled 446 million tonnes of CO_2-equivalent (EPA, 2006), with CH_4 accounting for 53% and N_2O accounting for 47% (O'Mara, 2011). According to FAO (2003), worldwide CH_4 emissions from enteric fermentation and manure management will increase by 60% by 2030 compared to 1997–1999, and agricultural N_2O emissions would increase by 50% (UNFCCC, 2008, Smith et al. 2007). It has been discovered that 50-55% of the C content of manures lost during management/storage, whilst N losses have been found to range between 1% (Hao et al. 2001) and 40% (Eghball et al. 1997). There are many challenges and hurdles for the sustainable and upright management of manure. The most important challenges/constraints are discussed below:

(i) Lack of understanding of the potential of manure

The first and most important issue is a lack of understanding about the importance of integrated manure management in contributing to food security and lowering short-lived climate pollutant (SLCP) emissions. Farmers, local extension personnel, and policymakers frequently fail to recognize the significance of manure.

(ii) Lack of information and supporting knowledge infrastructure

Many small-scale farmers' level of education is very low, this low literacy remains an impediment. Further, a lack of a knowledge infrastructure to assist farmers in better manure management or integrated manure management is also a gigantic obstacle.

(iii) Inefficient legislations/policies

Manure (or related) laws and legislation that are ineffectual frequently do not promote appropriate manure management. The primary motivations of manure policy are energy production or concerns with the environment or public health. The usefulness of manure as a fertilizer and soil improver, as well as the advantages to food security, are not always policy drivers. Improved coordination across key ministries (for example, the Ministries of Agriculture, Energy, Public Health, and Environment) is critical for the creation of coherent and holistic policies.

(vi) Lack of resources and investments.

Secure to financial credit and other incentives remains a significant obstacle, particularly for small-scale farmers who lack security to access finance for investment. Proper integrated manure management necessitates significant expenditures in capital, labor, and expertise, which raises output costs in the near run.

3. Policies on manure management in major developed countries

3.1. Japan

The "Act on Appropriate Treatment and Promotion of Utilization of Livestock Manure" was passed in 1999 and came into force in 2004. The legislation requires animal business operators (except small-scale farmers, fewer than 10 cattle or horses, 100 pigs, and 2000 poultry) to satisfy Japanese government manure management requirements for livestock management facilities and waste management procedures. Facilities for recycling animal manure are funded by national and municipal governments. It is necessary to conduct yearly monitoring of the quantities of animal waste generated, waste treatment techniques, and the quantity of waste treated under each treatment method (MAFF, 2018).

To implement the ACT on the Appropriate Treatment and Promotion of Utilization of Livestock Manure, the Minister of MAFF develops a basic policy in 2015 to promote livestock waste utilization and address livestock-related environmental issues, such as composting through coordination between the crop and livestock agricultural industries, generating energy when processing of manure into compost is difficult.

Other important rules and regulations for cattle industry owners include the Water Pollution Prevention Act. Under this Act, livestock business operators must monitor levels of nitrate-nitrogen, pH, biochemical oxygen demand (BOD), COD, SS, and coliform group bacteria, nitrogen, and phosphorus in effluent based on the workplaces equipped with specified facilities, the amount of wastewater discharged per day, and the location of the livestock farms. In addition to the requirements of the Water Pollution Prevention Act, specific establishments associated with designated lakes must comply with permitted pollutant loads and structural criteria for small livestock barns under the Act on Special Measures Concerning Lake Water Quality. Livestock waste that is not intended for a specific use must be disposed of appropriately in line with the Waste Management Law.

In Japan, the cattle industry accounts for around one-third of all CH_4 emissions and 20% of all N2O emissions (MoE, 2020). Manure treatment can reduce CH_4 and N_2O emissions, enhance soil carbon storage capacity through the application of composted livestock manure, promote compost usage, and substitute fossil fuels through biogas generation. The MAFF offers assistance in following areas: 1) to improve composting sheds and machines through subsidy programs, leasing of facilities and machines, tax benefits, and financing; and 2) to support renewable energy production using livestock manure by setting unit prices for electricity generated using livestock manure to compensate for the additional cost of improving, operating, and maintaining facilities and machines; 3) to create new technology to help with composting, sewage treatment, and odor control, among other things; 4) to provide on-site farm technical consultants; and 5) to promote excellent examples and new technologies (MAFF, 2018).

The regulations and methods for manure treatment are thorough and consistent. The roles of various stakeholders under various Acts are very clear and consistent. The national government is responsible for developing fundamental policies to encourage manure usage and establishing management standards for appropriate manure management. The prefectures are responsible for providing training, guidance, and suggestions to livestock company operators, as well as on-site inspections to ensure compliance with management requirements and the development of prefectural programs to promote manure usage.

3.2. Germany

Manure management and manure land application are governed by a number of statutes and rules. The Fertilizer Ordinance was modified and came into effect at the end of May 2017, primarily to implement the EU Nitrates Directive (91/676/EEC) (BMUB, 2017). The Fertilizer Ordinance specifies the land application method, application volume, and livestock manure storage capacity. The requirements for manure application include: equipment for spreading fertilizer and livestock manure must comply with recognized technological rules, livestock manure must be spread close to the soil, and livestock manure must be immediately incorporated after application; ammonia emissions from animal manure and sewage sludge must be avoided during application; and ammonia emissions from animal manure and sewage sludge must be avoided. The amount of nitrogen in livestock manure must be determined by testing or calculated using approved government agency recommendations. The amount of animal manure put to the soil cannot exceed 170 kg N/ha for arable crops and 230 kg N/ha for intensively managed grassland. Blocking times for grassland and arable land are well specified. After harvest, a maximum of 30 kg NH_4-N/ha or 60 kilogram N/ha in liquid fertilizer or manure should be applied. The allowable gross nitrogen balance surplus is lowered from 60 kg N/ha to 50 kg N/ha on a three-year average beginning in 2020 (Kuhn, 2017). The Fertilizer Ordinance provides no specifications for the capacity of animal manure storage containers. However, these might be subtracted indirectly from the time when manure application is stopped/banned. According to the Technical Instructions on Air Pollution Prevention, livestock farms with

250 or more cows, 1500 fattening pigs, or 15000 laying hens are obliged to have a storage volume for manure or slurry of 6 months (TA-Luft7).

On April 1, 2000, the Renewable Energy Sources Act (EEG) came into effect, establishing a feed-in tariff (FIT) program to stimulate the development of renewable power. It has been changed numerous times since then. The biomass objective is set at 0.1 GW per year in the 2014 amendment. Only biogas facilities that employ bio-waste and liquid manure will be paid more than the regular rate, based on their capacity. Tariffs for new installations will be decreased by 0.5 percent every three months. The most recent changes came into effect on January 1, 2021. The new EEG envisions a biomass capacity of 8.4 GW. The growth of the German biogas sector has been primarily initiated and pushed by successive versions of the EEG as well as supporting legislation, particularly after 2004.

These legislations have provided favorable circumstances for biogas access to energy markets and grids, as well as steps to ensure investment in and financing of biogas plants through compensation. Between 2000 and 2016, the number of biogas systems increased from approximately 1000 to more than 9000. The installed capacity in 2015 was 4200 MW. Manure is one of the feedstocks used in anaerobic digesters to create methane, and good manure management may reduce CH_4 emissions by up to 90%. A 2014 amendment to the Renewable Energy Act sought to decrease overall policy costs by limiting development in renewable energy technology through feed-in tariff reductions, as well as to stimulate the use of organic and agricultural waste as feedstocks (Fekete et al. 2021). In addition to the EEG, additional legislation affecting the biogas industry includes the Farm Manure Regulation, Circular Economy Act, Combined Heat and Power Generation Act, Biomass Order etc (Thrän et al. 2020).

The new NEC Directive (EU) 2016/2284 on national obligations to reduce emissions of certain atmospheric pollutants, enacted in December 2016, calls for a 29% reduction in NH_3 emissions by 2030, compared to 2005 levels. This may be accomplished by taking a number of steps to minimize and limit NH_3 emissions from agriculture. Covering liquid manure storage facilities and integrating or injecting agricultural manure as soon as possible are among them. Some of these measures are already mandated by law, including the current Fertilizer Application Regulation (low-emission manure application) and Air-Quality Control Legislation (built-in covers on liquid manure and digestion residue storage units in installations subject to licensing, as well as Land-level decrees on exhaust air scrubbers in large-scale pig-fattening units). Certain emission-reducing plants and machinery can still be supported through investment aid. Furthermore, execution of the other actions listed in the National Air Pollution Control Programme is necessary in order to meet the new NEC Directive's ammonia reduction obligation. These ammonia-reduction methods also have an indirect effect on N_2O (BMUB, 2019).

3.3. Netherland

Animal manure rules must be followed by entrepreneurs in the agricultural, horticultural, and livestock sectors in the Netherlands, including the amounts of nitrogen and phosphate in all animal manure, the method of application and spreading periods, the conditions for transporting and storing it, and production must not exceed the available land area for animal manure application. You can reach an arrangement with a manure processing factory or comparable facility to treat or recycle any remaining excess.

In terms of the quantity of nitrogen in all animal manure, the EU Nitrates Directive establishes a rigorous limit threshold of 170 kilograms of nitrogen per hectare for its usage.

Derogation is used in the Netherlands, allowing for a conditional 250 kilograms of nitrogen per hectare on farms with grazing cattle. In the Netherlands, current derogation regulations enable farms with at least 80% grassland to apply 250 kg of nitrogen from animal dung per hectare to all of their land, depending on soil type and area (Klootwijk et al. 2016).

In Europe, milk quotas were implemented in 1984 to manage market excess. The quota system limited the amount of milk produced by each member state and, as a result, by individual producers. The European Union (EU) milk quota system was eliminated in April 2015 in response to rising global milk demand and trade agreements (Klootwijk et al. 2016). Cattle numbers in the Netherlands rose after it was abolished. Since then, limitations on manure management and mineral emissions such as phosphates have had a significant impact on dairy herd limits and, as a result, agricultural methane and nitrous oxide emissions. To reduce phosphate emissions, it was planned to implement a market system for phosphate emission permits beginning in 2018. The amount of allowances was established based on the scenario in July 2015, which resulted in a dairy herd decrease.

Since 2008, the Covenant for Clean and Efficient Agricultural Sectors has been in force. It is a voluntary agreement on clean and efficient agricultural industries, including agricultural energy efficiency and renewable energy. Measures planned include manure storage to minimize CH_4 emissions, energy conservation and renewable energy initiatives, and so forth (Donat et al., 2012; MEACP, 2019). The agricultural, horticultural, and livestock sectors have set a goal of producing 1,500 million m3 of natural gas equivalents from biogas (from approximately 400 installations). This renewable energy will be produced by anaerobic digestion and co-digestion of manure and digestible biomass fluxes. The biogas may be utilized to provide sustainable power and heat, as well as a transportation fuel. The usage of biogas will allow for the generation of about 48 PJ of sustainable energy per year in 2020. In 2020, the incineration of two-thirds of the amount of chicken dung in the Netherlands will result in about 2 PJ of sustainable energy generation (Policy information, 2021). Because manure is kept for a limited amount of time and produces biogas that may be utilized to create heat and/or power, the fermentation of manure (with or without co-substrates such as maize) for biogas generation decreases emissions from manure storage. The current level of fermented manure is about 5%. This proportion is anticipated to rise to about 8% by 2025 under the SDE + Sustainable Energy Production Subsidy Scheme. However, new discoveries about methane leakage have resulted in increased methane emissions, particularly for co-fermentation facilities (MEACP, 2017).

3.4. United States

In the United States, confined dairy and swine farms that employ anaerobic lagoon, deep pit, or liquid/slurry systems accounted for about 85 percent of all CH_4 emissions from animal waste management. Farms that use one of these systems may considerably reduce their CH_4 emissions by reducing the amount of volatile materials entering waste treatment and storage buildings, or by collecting and converting the CH_4 produced by the system to CO_2 through burning.

Agricultural producers are encouraged to grow biofuel feedstocks or provide land for wind or solar power generation by a variety of policies, such as the Renewable Fuel Standard, which ensures that transportation fuel sold in the United States contains a minimum volume of renewable fuel, or proposed Renewable Portfolio Standards, which would apply similarly to electricity production. The Energy Policy Act of 2005 includes credit guarantees for businesses that generate or use renewable energy, such as biomass energy. Policies might encourage biogas recovery and usage in order to minimize methane emissions from animal manure.

The United States Department of Agriculture (USDA) and the United States Environmental Protection Agency (USEPA) together established the Unified National Strategy for Animal Feeding Operations (AFOs) in 1999 to address the water quality and public health concerns associated with AFOs. The Strategy is based on a national performance expectation that all AFO owners and operators establish and implement voluntary site-specific Comprehensive Nutrient Management Plans (CNMPs) that are technically sound and economically feasible (USDA & USEPA, 1999). The CNMP includes 1) feed management to minimize nutrient levels in manure; 2) manure processing and storage to prevent water pollution from AFOs; 3) land application to guarantee that the correct quantities of all nutrients are applied in a way that is safe for the environment and public health; and 4) AFO operators should keep records that show how much manure was generated and how it was used, including where, when, and how much nutrients were supplied. Testing of soil and manure should be included in the record-keeping system. When manure exits the AFO, records should be preserved (USDA & USEPA, 1999).

3.5. Canada

Several provincial legislations in Canada attempt to reduce agricultural diffuse pollution. The Nutrient Management Act (2002) in Ontario establishes regulatory standards for some nutrient management techniques, such as manure storage and application. To prevent water pollution from cattle in Manitoba, the Animal Manure Mortalities Management Regulation (1998) establishes numerous regulations for the usage, management, and storage of livestock manure. On crown property, permits are necessary for the building, alteration, or extension of manure storage facilities, and particular restrictions, such as maximum animal population, fence limits, drainage restrictions, and water work restrictions, apply. The Agricultural Operations Regulation (2002) in Quebec aims to solve the problem of diffuse pollution produced by agricultural activity by maintaining an efficient phosphorus balance in the soil in order to preserve soil fertility and prevent losses from excessive manure usage. It contains standards for livestock structures and manure management, as well as land use regulations to limit water contamination (OECD, 2017).

4. Gaps in China compared to developed countries

Gaps in China regarding manure management policies in comparison to developed countries i.e., Japan, Germany, Netherland, United States and Canada are given below:

4.1 Gaps compared to Japan

1. Lack of leasing of facilities and machines, tax benefits and financing from large to medium and small livestock farmers/farms.
2. Lack of on-site farm technical advisors and proper and strict monitoring of disposing of surplus manure and other farm wastes.

4.2 Gaps compared to Germany

1. Lack of a nutrient (N, P, K and micronutrients etc) monitoring in manures from different animal farms (pig, cattle, and poultry etc) via official agency.
2. A lack of attention, encouragement, and subsidy on renewable power production from manure and its supply to markets and grids, as well as measures to fix unit pricing for electricity generated from manure and

secure investors' investments in this sector.

4. 3 Gaps compared to Netherland

1. Incineration of poultry manure its renewable energy/fuel is common applied .
2. There is a need to reduce overall costs in Renewable Energy Technologies through a reduction of feed-in tariffs

4.4 Gaps compared to United States

1. Lack of a technically sound and economically feasible site-specific Comprehensive Nutrient Management Plans across China, lack of a thorough monitoring and record keeping for the amount of manure generated and how the manure was used, including where, when, and how much nutrients were applied.
2. Lack of a carbon profiling of farms, online tools that can allow farmers to compare their farm-level performance with similar farms, modern, accurate and easy to implement technologies, assembly of stockholders, policy makers, and government, improving cattle breeding genetics (i.e., herds towards low emissions stock), knowledge transfer programs to promote on-farm climate mitigation management practices through farmer participation in discussion groups.

4.5. Gaps compared to Canada

1. There is a need to keep a tight rein on the excessive usage of manure and its management.

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