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Potential Health Risk Associated with Application of Organic Amendments

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ABSTRACT: Application of organic-amendments in soil is an age-old practice for supplying nutrients to the crops. Organic amendments (animal slurry, manure, compost, and sewage sludge) provide vital nutrients to the soil besides increasing its organic matter content, improved soil structure, better physical condition and promotes microbial populations. Along with the benefits, use of organic amendments can result in possible risks and threats to human health due to presence of several contaminants. These organic amendments may contain organic pollutants, heavy metal (oids), pathogens and other contaminants. These contaminants impose risks to human health which can be reduced by treatment of these amendments before application. Apart from sewage and sludge, other sources like manures are ensured to be applied to the soils at right rate, time and place. But still, there is a need to develop effective measures to reduce the hazards involved with the application of organic amendments while getting all the benefits. Therefore, the main objective of this paper is to review all the possible health hazards due to application of organic amendments to the soil and recommending improved management practices which ensure least contamination of food or water resources.

Keywords: Organic amendments, sewage, contaminants, human health.

INTRODUCTION

Conventionally, the organic amendments have been the primary source of plant nutrients. There are records of use of organic amendments like manuring, composting, and crop rotations in agriculture by Romans advocated from 500 BC to 500 AD (Parr and Hornick 1992) and it was widely accepted that in the late medieval times organic amendments were used to restore nutrients lost due to agricultural cultivation (Wild, 1988). With the establishment of first fertilizer manufacturing plant (super phosphate) in 1842, use of synthetic fertilizers in agriculture increased (Allison, 1944; Dyke, 1993). However, in resource-poor areas, organic amendments remained the only way to add nutrients to soils (Thomas *et al*., 2006). Again, with the development of civilization, people started giving more emphasis on organic amendments to fulfil the nutrient requirement of crops while maintaining soil quality.

Organic amendments are composed of organic parts that are derived from biomass and living beings. Examples of organic amendments include compost, green manures, food waste, animal dung, geotextile, and sewage manure. Organic amendments help to improve soil structure and aggregation, increase soil organic matter and (Macro and micro) nutrient content (Urra *et al*., 2019), reduce soil erosion and soil degradation (Ros *et al*., 2003), promote soil microbial activity (Chakraborty *et al*., 2021; Patra *et al*., 2021;) and plant growth attributes (Bana *et al*., 2012; Bana *et al*., 2016; Bana *et al*., 2022; Ranva *et al*., 2022), and increase water holding capacity (Bulluck *et al*., 2002). Along with the benefits of organic amendments, particularly animal manure, compost, waste food and sewage biosolids can result in possible risks and threats to human health, due to presence of several contaminants (Table 1). Organic pollutants, heavy metal(loid)s, human pathogens and other emerging contaminants can be found in organic amendments (Mattana *et al*., 2014; Park *et al*., 2011; Petrie *et al*., 2014; Mohapatra *et al*., 2016). Moreover, the negative side effects such as eutrophication, immobilization of nutrients, contamination of ground water, greenhouse gas emissions, and soil acidification and/or salinization caused by improper and overuse of organic amendments,

possess a big threat to environmental and human health and thus restrict their safe use in agriculture (Larney *et al*., 2012; Thangarajan *et al*., 2013; Alvarenga *et al*., 2015; Goss *et al*., 2013). Even though many of these issues have been studied and data is frequently published in academic publications and textbooks but is not always available to the wide-ranging population of the globe and the comparative data on risks, benefits, advantages, and downsides for all soil amendments is not always accessible. These hazards must be carefully evaluated against the significant advantages provided by organic amendments to the soil. Thus, our emphasis in this review is on the risk associated with human health as well as contamination of soil, water and food crops resulted from the direct use of organic amendments.

Table 1: Advantages and concerns associated with the application of organic amendments in agriculture.

Advantages	Concerns
Key source of macronutrients for plant growth and development	Uneven distribution of nutrients in soil; increased losses of N and P through leaching and runoff water; greenhouse gases emission and leading to acid rain
Source of micronutrients	Increase heavy metals in soil
Increase soil carbon content	Release of antibiotics into the soil and environment
Improve soil microbial population	Release of zoonotic pathogens into soil and environment
Enhanced soil aggregation, reduced topsoil bulk density and compaction, better- soil quality and permeability	Increased risk of the preferential flow of contaminants and pathogen in water
Greater root exposure to soil, increased water-holding capacity of soil, resilience against water and wind erosion	

(Modified from Goss *et al*., 2013; Meena *et al*., 2014)

VARIOUS ORGANIC AMENDMENTS

There are six major categories of organic amendments (Table 2) that can be added to soil for crop production.

Farmyard manure. Farmyard manure (FYM) and farm slurry are two common types of animal manure. The FYM includes plant materials that has been used as animal bedding and has absorbed faeces and urine. Farmyard manure supply a significant amount of N, P, and K after mineralization (Chakraborty *et al*., 2021). Animal slurry is made up of a variety of elements, including sand, water from cleaning, small branches, and straw from bedding materials, in addition to most faeces and urine (Triolo *et al*., 2013).

Table 2: Different sources of organic amendments.

Sr. No.	Organic amendments
1.	Farmyard Manure
2.	Green Manure and Crop Residues
3.	Municipal Biosolids
4.	Food Residues and Waste
5.	Garbage from Manufacturing Processes
6.	Compost

Manure prepared from various sources has varying characteristics and requires different application rates. For example, the excreta of horses, cattle, pigs, lambs, chickens, turkeys, rabbits, and seabird, all have different properties. Sheep dung, for example, is high in nitrogen and potash, but pig manure is low in both. Because horses consume mostly grass and a few weeds, horse dung may contain grass and weed seeds, as horses do not digest seeds as well as cattle. Cattle dung is an excellent source of both nitrogen and organic carbon (Gross *et al*., 2021). Approximately 42% animal manure is contributed from confined animals, 44% from grazing animals, and 14% is used for purposes other than agriculture such as animal feed or heating fuel (Goss *et al*., 2013).

Green manure and crop residues. Green manuring is the process of incorporating any field or forage crop into the soil when it is still green or shortly after flowering in order to improve the chemical and physical fertility of the soil (Fu *et al*., 2021). Other agricultural by-products such as harvest residues, whether pretreated or not, have been spread over land, in addition to manure from animal production systems. Examples are grain straw and ploughed-in stubbles after harvest. Roughly 5000 Mt of dry matter are produced from cereals worldwide out of which about 2600 Mt is straw (Wirsenius *et al*., 2010), which can be utilized as animal feedstuff, incorporated into the soil, or used as bedding material for housed animals. Cowpeas, soybeans, annual sweet clover, Sesbania sp. Scop., and guar may be used as full-grown summer green manure crops to provide nitrogen and organic matter. To provide biomass, smother weeds, and improve soil tilth, non-legumes such as millet, forage sorghum, annual ryegrass, brassicas, and buckwheat are grown. The desired benefits of green manuring are achieved by incorporating the shoots in soil, although the root system of the crop grown, can also provide some benefit by recycling the nutrients in soil (Meena *et al*., 2018). Thus, crop residue retention is a potential strategy for improving soil physical and chemical properties and the microbial population in the soil (Kumawat *et al*., 2017).

Fig. 1. Incorporating green manure crops at Carman, MB. August 20, 2005.

Municipal biosolids. Sludge from municipal wastewater treatment is often used in agricultural land; however, this needs regulatory control. After general screening and grit removal, the suspended organic material is sorted out by primary treatment (sedimentation), and the readily metabolized fraction is consumed by the bacteria in the secondary treatment. Final treatment stage includes alkali stabilization to raise the pH, heating and drying combined with digestion (aerobic or anaerobic) and composting (Vilardi *et al*., 2020). Either in liquid form after land application or as cake after dewatering, the stabilization procedure is designed to remove pathogens and to make the material less appealing to scavengers. Municipal or sewage biosolids are the common names for these products.

Food residues and waste. Extra sources of material such as unsold or unsalable fresh vegetables from supermarkets of urban areas have been put to agricultural land, sometimes after composting. In the Western countries, food waste is a major issue. Increased food waste generation has a direct impact on pollution and environmental changes, such as greenhouse gas emissions and contamination with packaging. To reduce consumer food waste, it is important to understand the factors that lead to food waste (Jungowska *et al*., 2021).

Fig. 2. Food residues and waste from different industries (Sadh *et al*., 2018).

Garbage produced from manufacturing system. Food production involves several complex processes that result in massive amounts of food waste. Animal feeding, anaerobic digestion, composting, incineration land filling are all examples of rudimentary ways for dealing with these materials that have poor economic and environmental value (Garcia-Garcia *et al*., 2019). Annually, large volumes of biosolids are produced because of the papermaking process, but only a tiny portion of this material gets applied to the soil (Goss *et al*., 2013). Leftovers from sugar beet, sugar extraction, olive oil extraction, and distillery waste have also been applied to agricultural land for their ability to enhance the crop productivity (Hachicha *et al*., 2012).

Compost. Composting is the process wherein degradable organic products and wastes are converted into stable products using microbes. Composting has been around for quite long time, but it has big drawbacks that have limited its widespread use and efficiency. Pathogen detection, low nutritional status, long composting time, extended mineralization time, and odour creation are few problems associated with composting. Compost incorporation can have a big impact on soil physical characteristics, nutrient dynamics, and vegetation establishment. Patra *et al*., (2021) observed that application of manure and fertilizer for ten years, increased the organic carbon and mineral nitrogen content in soil and providing food and

nourishment to soil microorganisms, resulting in increased enzymatic activity and microbial biomass. Application of enriched compost with a lower dose than recommended dose of N and P in rice, lowered the toxic Al fractions, resulting in increased N, P, and K content in rice grain, husk, and straw (Patra *et al*., 2020).

CONTAMINANTS OF RISING CONCERN IN SOILS TREATED WITH ORGANIC AMENDMENTS

Since Rachel Carson's "Silent Spring" (1962) was available during the Green Revolution which increased political and community concern about the environmental side effects of pollutants and resulted in improved legislation and regulations regarding chemical approval and usage (Kastner and Miltner, 2016).

Steady application of biosolids and animal manures to soils has usually been believed to be a main source of metal and metalloids (Semblante *et al*., 2015), and different pathogenic bacteria such as Campylobacter, *Escherichia coli, Salmonella,* and *Yersinia* (Macori *et al*., 2017). Before application of these organic wastes as soil amendments, the identification, description, and ordering of possibly dangerous biological agents and chemical is important. Biosolids collected from urbansewer water treatment plants have latterly been recognized as one of the main causes of microplastics in soils. According to Nizzetto *et al*. (2016), between 125 and 850 tons of microplastics per million people are introduced to European soils each year. Because roughly 99 percent of microplastics in the waste watercourse are probable to be reserved in sludge, they may include considerable concentrations of microplastics even after treatment prior to land-spreading (Mahon *et al*., 2017). Several studies (Lares *et al*., 2018) have highlighted the critical need for enhanced final-stage wastewater treatment methods that are more effective in removing microplastics from wastewater effluents and sludges. Their growing abundance in soils, as well as in unknowns surrounding, their possible exposure paths and unexpected ecotoxicological consequences, have made them a focus of recent research.

POTENTIAL CONTAMINANTS ASSOCIATED WITH ORGANIC AMENDMENTS

Organic amendments provide a natural supply of carbon for soil microbial population, including harmful microbes. Inorganic nitrogen and sulphur molecules are produced when proteinaceous substances and nucleic acids are destroyed, whereas trace metals like copper and zinc might be released when enzymes are damaged. Metals, microbes, industrial organic and inorganic contaminants, and runoff from rooftops, streets, and parking spaces are all potential pollutants in municipal waste. Metallic element not adsorbed from water and food, antibiotics used to cure disease, as well as growth and sex hormones, can all be found in faeces-based additions.

Pathogens. A quantitative risk assessment for the application of organic soil amendments must include the number of pathogens discharged into the ecosystem. Animal faeces are a major source of enteric and other organisms, like helminthic worms, protozoa and viruses, some of which are injurious to humans (Pang *et al*., 2019). Through contaminated feed, water sources, and excrement, enteric pathogens can infect both farm animals and humans (Shere *et al*., 1998). Many of the organisms present in animal manure can also be found in sewage biosolids (Gerba and Smith 2005). Some viruses infect just one type of farm animal, whereas others are widespread in all livestock, but they may not express signs of having infective strains in their system. Even though they may infect all main agricultural animals, the microbes found in cow, pig, and poultry dung are all different (Olson *et al*., Meena 2004), for example, *Giardia duodenalis* strains that causes diarrhea in cattle is not the same as the one that causes diarrhea in humans. Liquid manure is more uniformly polluted than solid manure due to the increased movement of bacteria in this system compared to the solid phase (Wang *et al*., 2019). *Escherichia coli* is a faecal, coliform bacterium that is facultative an aerobiotic. It is mainly found in animal feces, and most of the strains are harmless. Some strains of *E. coli* can be a source of disease. In addition to bacterial pathogens, manure, particularly that from cattle, may include two protozoan parasites. *Cryptosporidium* spp. and *Giardia* spp. are the microorganisms of concern to cause sickness in humans. Viruses are another common manure contaminant. Humans and a number of other species are infected with rotaviruses, which cause diarrhea (Estes and Cohen, 1989). Hepatitis E can also be transmitted by consumption of polluted water. The influenza virus is highly common, and poultry and pigs are possible reservoirs for human strains. Contagious avian influenza virus may persist in water for 207 days at 17 degrees Celsius (Swayne and Swayne, 2008). However, there is a scarcity of data on incidence and longevity of viruses in animal dung.

Macro and micronutrients threats to public. The nitrate and nitrite are the forms of nitrogen in soil amendments that pose a threat to human and animal health. The products of mineralization and nitrification of carbon-based compounds pose a threat to human and animal health from various forms of N in soil amendments. Nitrate has been a problem once it enters a potable water source because it can be converted to NO_2^- at the back of the tongue after it reaches the mouth (Forman *et al*., 1985). Residents living near an organic amendments storage facility that releases NH_3 may encounter health problems such as increased irritation in the eyes, vomiting, weakness, and other psychological difficulties (Thu *et al*., 1997). Augmented NH_3

emissions from organic amendments can have a detrimental influence on environment, posing a risk to animal and human health, by contributing to eutrophication of superficial waters, nitrate pollution of subsurface waters and soil acidity (Spiehs *et al*., 2010). $PM_{2.5}$ is hazardous to human health because it causes irritation of the bronchial tubes, reduced lung function, difficulty breathing, worsening asthma, chronic bronchitis, coughing, irregular heartbeat, nonfatal heart attacks, and early mortality in people with lung or heart disease (WHO, 2006). Under anoxic environments, the breakdown of carbon molecules in organic amendments can produce methane. This odorless gas has the potential to asphyxiate anyone who enters the close confines of tanks used to spread liquid amendments. Organic additions may not pose a direct hazard to human health, but the loss of phosphorus to surface water can be challenging. Eutrophication occurs when phosphorus enters freshwater, making them more capable of supporting the growth of algae. The death of a bloom of these algae and the subsequent breakdown of the algae by microbes reduces the O_2 content in the water, reducing its accessibility to fish and other species, and fish can be asphyxiated in severe cases (Falconer, 2001). Copper, zinc, arsenic and cadmium are common trace-element pollutants detected in organic amendments, particularly sewage biosolids but many additional trace elements can be present depending on the source. Long-term exposure to arsenic in drinking water and food, which comes from organic amendments, fertilizers, and geogenic sources, leads food-chain contamination. Continuous application of manure and fertilizers increase micronutrient accumulation (Zn, Fe, Cu, Mn, and Ni) in rice (Patra *et al*., 2022; Meena *et al*., 2022). The level of aluminium toxicity in rice plants grown in acidic conditions could be lowered by using enriched compost (Patra *et al*., 2018). Plant growth and development are inhibited by cadmium toxicity, which affects physiological mechanisms such as germination, photosynthesis, ion transport, and mineral feeding, resulting in lower biomass and yield in many crops (Bansal *et al*., 2021). Trace elements like Cu and Zn are commonly added in the diets of grower and finisher pigs as a simple way of minimizing illness and enhancing weight gain in confined animals. A significant amount of the trace element in food is excreted in the manure of animals. Increased use of recycled paper in paper mills has resulted in greater levels of many trace elements, such as Cu and Zn, in paper mill biosolids. The median yearly input of Pb, Cd, and Se in sewage and sludge is at least an order of magnitude greater than in animal manure. Metals tend to increase after carbon-based additions have been mixed into the soil because overall removal is small. Metal bioavailability to plants in newly applied organic amendments, particularly organic manure, does not always remain constant over time period but tends to decrease, by a factor of about two in case of Cu (Smolders *et al*., 2012), possibly due to an increase in the dimensions of the carbon-based ligands to which they are attached (Del Castilho *et al*., 1993a), orby creating bonds with other metal oxides (Kukier *et al*., 2010).

Antibiotics and other medical waste. Antibiotics are inoculated into animals to treat a specific illness, as a preventive measure. Mixtures with bactericidal characteristics, such as triclosan and triclocarban, are found in a wide range of personal care items and can enter in sewage systems. Only a portion of the antibiotics delivered, whether by subcutaneous injection or in feed, gets metabolized in farm animals or humans. It was anticipated that these metabolites would be swiftly converted back to the original antibiotics. As a result, massive amounts of antibiotics can be released into the environment each year through excretion and applied to soils as manure and sewage biosolids for crop production. Antibiotic concentrations in manure vary widely depending on the source species and the kind of activity (Holzel and Bauer 2008; Holzel *et al*., 2010).

FARMING METHODS TO REDUCE THE RISK OF ORGANIC AMENDMENTS ON HEALTH

A variety of agronomic methods can assist to reduce the risk of organic amendments posing a health concern to humans. Not all methods, however, are appropriate in all countries. Typically, management practices are chosen based on their economic viability, which is influenced by labour availability, availability of equipment, and weather conditions of the location. The fertilizer manufacturing's guiding principles for fertilizer usage emphasis on applying the correct product at the right location, right rate, and right time in the soil (Roberts, 2010).

Bruulsema and Ketterings (2008) observed that in what way the 4R nutrient stewardship idea may be used to find the optimum nutrient management techniques for dairy farms. They comprised calculating the nutrient credits to be given for the manure used, as well as prior grass crops and legume crop used for hay or grazing, as part of the "Right Source" concept. Nevertheless, they emphasized the need of rapid incorporation of volatile N sources and the advantages of injecting rather than broadcasting manure. Industry has highlighted the need of investor participation, including customers and the public, in defining the good management techniques while developing the 4R concept (Bruulsema *et al*., 2009). A huge amount of NH_3 is lost to the environment during storage or unconfined treatment, such as open-field composting. Release of H_2S and NH_3 from kept liquid manure can be minimized by the use of coverings. Aeration and acidification are two strategies used to control unstable organic compounds, NH_3, and greenhouse gas emissions from composts and animal manure stored in lagoons (Smith *et al*., 2008).

Surface banding or shallow incorporation beneath grass, as well as injection of liquid supplements (organic), minimizes NH_3 loss throughout the application to agricultural crops. Broadcast or fertigation of amendments that are quickly incorporated have comparable favorable effects. When wastewater from storage lagoons is sprayed to irrigated land, it can cause a substantial load of particles in the soil, which can hamper plant growth and development. More amount of chemical fertilizers provided in wastewater can lead to the development of salts, which can further hamper crop yield in areas with high levels of evaporation (Cabrera *et al*., 2009).

Long-term research based on soil test crop response (STCR) convincingly proved that STCR-based integrated fertilizer use for yield targeting may achieve targeted crop output while saving fertilizer without compromising soil fertility (Sharma *et al*., 2016). The improvement in available nitrogen, phosphorus and potassium was noticed under targeted yield-based fertilizer management approach in post-harvest soil over farmer's practice (Chobhe *et al*., 2022). Luthra *et al.* (2022) found that the response of hybrid maize to N, P, and K fertilizers was higher when combined with FYM treatment than when N, P, and K were applied alone.

Another crucial consideration is that organic amendments typically contain a mixture of organic and mineral forms of N and P. Before they can be used by plants, the organic forms must be converted into mineral forms. Our capacity to generate precise field-specific predictions about how much and when enough nutrition will become available is extremely limited. Likewise, because the quantity of N and P available differs from what plants require, the optimum rate of application must be precisely controlled to avoid nutrient oversupply and associated health implications. Crop rotations that limit nutrient leaching during the drainage season have been developed, aimed at limiting nitrogen availability to periods when the crop needs nutrients, preventing amendment application near water courses if the ground is slopy, snow covered or frozen, and developing crop rotations that limit nutrient leaching during the drainage season.

Organic amendments may also include trace elements in quantities much beyond the crop's requirements. Pathogen transfer to water resources is hampered by soil, particularly sandy soil, which presents crucial but ineffective barriers. Many strategies that decrease nutrient loss following amendment application, such as rapid incorporation, may help bacteria and other disease groups survive. Soil amendments should not be applied before to rain events. Grass filter strips can remove particulate P and bacteria from runoff that flows over the soil surface. Other ways to reduce the danger of surface water pollution include controlling runoff and establishing a buffer zone between water bodies and organically amended soil. Most producers' options for controlling the leak of pollutants into the environment from the land application of amendments currently depend on the ability to use pre application treatments to reduce pathogen, endocrine disrupting compound, and antibiotic loadings while maintaining mineral nutrient levels. The amount of nutrients, pollutants type, application techniques, weather, soil and geological background, as well as the location of field in landscape, all have an impact on the timing and amount of amendments that should be applied to a field.

CONCLUSIONS

Organic amendments not only make good use of often-limited nutrient supplies, but they may also mitigate the adverse changes in soil conditions caused by faulty crop production techniques. Essential nutrients, as well as useful organic compounds, may be found in materials that are commonly thought of as waste. However, the most of organic amendments, sewage biosolids and animal manures, have contaminants that make it hazardous for human and animal health. While nutrients are necessary for healthy agricultural development, they can also pose a direct or indirect harm to human health if present in excessive quantity. Heavy metal and metalloids, organic pollutants, antibiotics, pathogenic bacteria and viruses are the major contaminants in organic amendments. Enteric pathogens such as helminthic worms, protozoa, and viruses are commonly found in animal faeces, and these pathogens can infect both farm animals and humans through contaminated feed, water supplies, and waste. There are few of improved management practices which ensure that these harmful substances cannot contaminate food or water resources. But still, there is a need to develop effective techniques to reduce the hazards involved with application of organic amendments to agricultural soil.

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