Agricultural Waste Produce: Utilization and Management

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Abstract

Agricultural waste is the term used to denote the extensive range of waste produced as a result of several agricultural operations. Rapidly intensifying agricultural production has unsurprisingly resulted in augmented quantities of agricultural wastes that comprise crop waste, food processing waste, animal waste, and toxic agricultural waste. Presently used methods for disposal of these agricultural residues have caused prevalent concerns related to environment. Therefore, for their sustainable utilization, various approaches with respect to their utilization, reuse, and processing need to be developed. It is the need of an hour to manage these agricultural wastes in a sustainable manner so as to maintain a healthy environment and withstand the sources of energy. The chapter will discuss about the agricultural waste generation, methods of agriculture waste utilization, and agricultural waste management system.

Keywords

Agriculture waste · Sustainable utilization · Waste management

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13.1 Introduction

For many countries, agriculture and its associated industries are one of the most premeditated sectors. Abreast to the agricultural and related activities and operations, large volumes of solid and liquid residues are generated that is referred to as Agricultural waste (Hodaifa et al. 2019). Gontard et al. (2018) has defined agricultural waste, by-products, and co-products as plant or animal residues that are not either food or feed and that poses an additional burden to environmental and economic sectors of farming and primary processing. The term agricultural wastes encompasses crop wastes such as stalks, bagasse, fruits drops and culls, vegetables, prunings; manure, food processing waste, hazardous agricultural waste comprising of toxic chemicals such as insecticides, pesticides, and herbicides; agro-industrial waste generated from agricultural processing industries of crops, fruits, vegetables, meat, poultry, and dairy products. Agricultural waste otherwise called agro-waste can be in the form of liquids, slurries, or solids. The composition of such agro-waste depends on the system and the type of agricultural activities leading to its generation.

Increase of agricultural production resulted in increase in quantities of waste from livestock, farm activities, and from agro-industries. This increase in agricultural wastes is likely to be on a rise if all over the world, developing countries continue to exaggerate their farming systems. According to Agamuthu (2009), approximately 998 million tons of agricultural waste is produced every year. Agricultural residues generally termed as agro-wastes are produced in huge quantities every year in Indian farm fields. To an approximation, the amount of crop residues produced every year exceeds 620 million tons in India (Singh and Sidhu 2014) of which, almost 50% finds applications in various agricultural and industrial purposes like animal feedstock, paper industry, roofing material, and energy generation. This agriculture waste presents a serious environmental problem in the case of not being well treated or managed (Hodaifa et al. 2019). Major quantities of the agricultural residues generated on-farm, which is generally treated as wastes by the farmers, are burnt in the field itself or are allowed to decay in the open air creating environmental pollution. Although this is a cheap, non-labor-intensive and comparatively easy mean of agro-waste disposal, but in return this has great negative impact on the agro-ecosystem as it generates a significant amount of particulate matter in environment to create air pollution through smoke and smog and disturbs physical, chemical, and biological structure including and microflora and fauna of the soil (NMSA 2016). The disposal methods for the untreated and underutilized agricultural residues that are being followed today (burning, dumping or unplanned land filling have caused prevalent environmental concerns (Sadh et al. 2018). Jain (2014) reported that burning of agricultural crop residue contributes to the emission of greenhouse gases (CO_2, N_2O, CH_4), air pollutants (CO, NH_3, NOx, SO_2, NMHC, volatile organic compounds), particulate matter, and smoke, thereby posing risk to humans. It is therefore, imperative to make competent use of crop residues generated in the agriculture production system to help improve crop productivity, soil conditions, and environmental sustainability.

Taking into consideration the burden that the current disposal methods add to the environment and economy, approaches with respect to their utilization, reuse, and processing need to be developed to enable the sustainable utilization of feedstock and reduce pollution (Rao and Rathod 2018). There is a need to manage these crop wastes through a sustainable approach majorly through following three R technique of reducing, reusing, and recycling. Different categories of agriculture waste can be utilized efficiently for specific purposes such as energy, nutrient feed, soil amendments, adsorbents, etc., to list a few. It is imperative to use agriculture waste in a well-planned manner so that we can maintain a healthy environment for ourselves and all other living creatures.

13.2 Agricultural Waste Generation

At present, every year in India, around 960 million tons of solid waste is being generated as by-products during various industrial, mining, municipal, agricultural, and other processes. Out of this approximately 350 million tons are organic wastes from agricultural sources (Pappu et al. 2007). The nature of waste is reliant on the type of agricultural activities or processing carried out for its generation. The agricultural waste can be classified into the sources of waste generation.

The first category is the waste generated from cultivation activities. These are majorly the crop residues that encompass all agricultural wastes such as leaves, stem, straw, stalk, husk, shell, pulp, peel, stubble, etc. which originate from cereals, cotton, jute, groundnut, legumes, tea, coffee, cacao, fruits, palm oil, and all other organic materials which are produced as by-products from harvesting. Another type of waste generated is during the control of weeds and insects, i.e., the use of pesticides in order to destroy the insects and pests. Imbalanced use of these pesticides often leads to the pesticides abuse by the farmers. Majority of the bottles and packaging material containing these pesticides are discarded inefficiently into either the fields or the local water bodies. This can be threatening as it is claimed by the Plant Protection Department (PPD), that approximately 1.8% of the chemicals persist in the packaging material even after use (Dien and Vong 2006). Another serious environmental consequence is posed by the unused pesticides and pesticide packages with residue if they are either stored or buried in the erroneous way as their contents may leak into the environment via osmosis and thereby negatively impacting the environment (Obi et al. 2016). In addition, other waste generated from agricultural activities is through excess fertilizers. From this excess fertilizer, a part persists in the soil, some excess part runs off, depending upon irrigation system adopted, enters the water bodies such as ponds, lakes, rivers, another part enters the ground water, and rest of the portion either gets evaporated or de-nitrated, adding to the air pollution (Obi et al. 2016).

The second category of agricultural waste is that generated from Livestock Production. Global livestock and poultry industry producing meat, milk, and egg is growing continuously and is also generating large volumes of wastes. Livestock waste includes solid waste (manure and organic materials) produced via slaughterhouse; fluid waste (water from the animal bathing, cage washing, urination and water from slaughterhouses); pollution of air (methane and hydrogen sulfide); and odors. Also, the livestock enterprises around residential areas pose a serious threat to humans health. As reported by Ifeanyi (2012), 75 to 95% of total volume of livestock waste is water, while the rest consists of organic and inorganic matter, different species of microbes, and even parasite eggs. However, the disposal of these livestock wastes lingers to be a challenge from the stances of cost, environmental safety, and biosecurity.

The third category of agricultural waste is that generated from waste from Aquaculture. The expansion of aquaculture industry led to generation of metabolic waste that could either be dissolved or remain suspended. Approximately 30% of the feed even in a well-managed aquafarm get converted into the solid waste. Waste management in these production units can be maintained by the patterns of water flow as a proper water flow can minimize the disintegration of the fish feces and allow the speedy settling and concentration of the settleable solids (Mathieu and Timmons 1995).

The fourth category of agricultural waste is that generated from processing, i.e., process residues. Agriculture or food processing wastes are the water discharged from these operations: vegetable processing (wash water, skins, rinds, pulp, and other organic waste from fruit and vegetable cleaning, processing, cooking, and canning), Meat (Grease, fat, oils, wash water, cooking waste, dripping, hair, and feathers from slaughtering, butchering, cooking and packaging of fish, chicken, beef, and all other meat products), Dairy and Egg (Wash water and process waste from egg and milk processing, drying, bottling, and packaging), Miscellaneous food processing (grain processing and animal food production).

The types and quantities of waste production in agriculture vary between farms. Apart from the above-mentioned categories some other common agricultural wastes include packaging, redundant machinery, silage plastics, net-wrap, oils, tires, old fencing, batteries, veterinary medicines, horticultural plastics, scrap metal, and other building waste. Other uncommon wastes include spent and unused sheep dip.

13.3 Sustainable Approaches for Agriculture Waste Utilization

Recycle and reuse have emerged as major pillars for the sustainable agriculture waste utilization and for the management of resources by preventing the generation of waste and if generated then reuse, recycling, and recovery of the same is used to fulfill the objectives of sustainable developmental goals (Shulman 2011). There are many ways in which the different categories of agriculture waste can be utilized (Fig. 13.1).

13.3.1 Energy

Application of agricultural waste for energy development and utilization is becoming increasingly important due to the depletion of petroleum resources and the

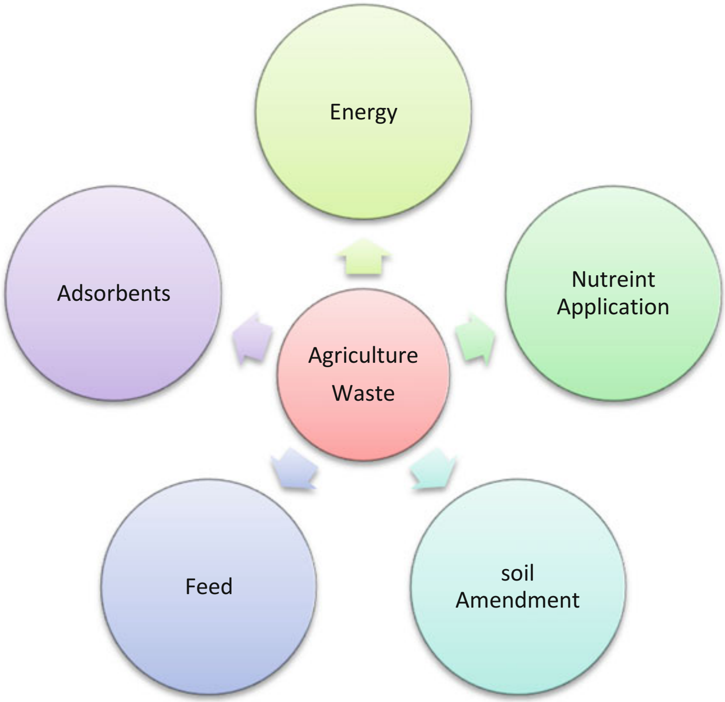

Fig. 13.1 Agriculture waste utilization

unceasing deterioration of the ecological environment (Wei et al. 2020). One of the most imperative is the utilization for the production of green energy. Due to the abundant availability of biomass throughout the world, it is essential to use it as an alternate energy resource to satisfy our needs of energy consumption. Earlier, the agricultural waste and biomass were naturally converted into organic fertilizer under favorable condition or were burnt, but at present their potential as energy source has been recognized and is thus being explored. Upadhaya and Harshvardhan (2017) have reported energy conversion as a good and effective utilization of agricultural waste.

Today, agricultural energy also known as green energy is the prime contributor in economic development of many developing countries. Variety of agricultural residues (straws, nut and fruit shells, fruit tree residues, seeds, grain dust, plant stalks and stovers, green leaves, and molasses) hold a high potential as renewable energy resource (Demirbas 2009). Energy generation from biomass holds innovative prospects for today's farmer with new possibilities to diversify agricultural activities.

The technologies such as liquefaction, pyrolysis, direct combustion, gasification are some of the technologies for conversion of biomass into energy that have potential for commercial-scale use (Demirbas 2009). In addition to the residues of the crop harvest, now forestry products are also being stressed as a substantial energy source. There is a huge list of crops and residues that are suitable for the contemporary bioenergy chains (Reijnders 2004; Pimentel et al. 2005). Apparently, power plants are using agricultural residues for generation of energy in a very cost-effective way. For power generation agricultural residues like Maize Cobs, Wheat Straw, and Rice Husks are collected at a place, from where they can easily be used for energy generation. Argo-waste feedstock contains energy in the chemical bonds of its constituent varieties of hydrocarbon (such as cellulose, hemi-cellulose, lignin, and proteins) (Mahawar et al. 2015). Wilson (2011) reported that biomass must have a high H: C ratio and a relatively low O: C ratio for thermal characterization. While analyzing the suitability of agriculture waste as energy resource, a study conducted by Nagle (2011) showed that fruit residuals have high energy content.

Biofuels are renewable energy source that are now being produced from variety of agricultural biomass. Residues from cereal crops, olive tree, tomato, and grape have been reported to provide abundant lignocellulosic waste in a study by Faraco and Hadar (2011), which can be considered as potential raw material for large-scale ethanol production. Lal (2005) estimated that the amount of crop residue generated throughout the world on yearly basis is around 2802×10^6 Mg for cereal crops, 3107×10^6 Mg for 17 cereals and legumes, and 3758×10^6 Mg for 27 food crops. The fuel value of the total annual residue produced is estimated at 1.5×10^{15} kcal, about 1 billion barrels (bbl) of diesel equivalent, or about 8 quads for the USA; and 11.3×10^{15} kcal, about 7.5 billion bbl of diesel or 60 quads for the world. Bioethanol, biomethanol, biodiesel, methane, and bio-oil are some examples of the agriculture-based biofuels. In a study by Qureshi (2010) fermentation of dilute H_2SO_4 barley straw hydrolysate by *Clostridium beijerinckii* P260 resulted in the generation of 7.09 gL^{-1} ABE (acetone, butanol, ethanol). Various agricultural waste materials like sugarcane molasses, beet molasses, corn cobs and hulls, cellulosic materials like sugarcane waste, and coffee husk hydrolyzing fermenting strains have been used for bioethanol production (Beall et al. 1992; Arni et al. 1999; Othman et al. 1992; Franca et al. 2008). Physical, chemical, and spectroscopic characteristics of the residues of an endemic marine plant, *Posidonia oceanica* were investigated by Cocozza et al. (2011). They concluded that the fibrous portion of *P. oceanica* can be utilized as a biofuel, due to its lesser heating values ranging from 13.6 to 15.7 Mg/kg.

Another technology that can treat agriculture waste is pyrolysis where agricultural waste is heated up to a temperature of 400–600 °C, in anaerobic conditions by which the material vaporizes, leaving behind a char also sometimes known as biochar. The product output of Pyrolysis of agricultural waste is oil, char, and gas (Obi et al. 2016). Others are hydro-gasification, and hydrolysis which are generally used for energy recovery and the preparation of chemicals such as preparation of alcohols for fuel, ammonia for fertilizers, glucose for food and feed.

Biogas technology provides an alternate source of energy in rural as well as urban areas as a substitute for fossil fuels. Biogas is a biofuel that is naturally produced as a by-product during the decomposition of organic waste. The agricultural waste can be used in the generation of biogas. The agricultural resources such as energy crops, grasses, agricultural residues, and aquatic weeds can be used for the production of biogas resulting in effective utilization of agri-wastes and reducing emissions from the storage of animal waste. Biogas is highly combustible, has high content of methane (50–75%), which renders it combustible, and has a good provision as an energy source.

Methane gas that has specific applications for heating purposes such as in broilers, water heating, drying of grains, etc., can be produced from agricultural wastes particularly manures. The conversion of agricultural waste to form methane-rich gas is a two-step microbial fermentation that undergoes in anaerobic conditions. The typical gas produced by this fermentation process is composed primarily of methane i.e. 50–70%, followed by 25–45% CO_2, 0.5–3% nitrogen, 1–10% hydrogen, and traces of hydrogen sulfide. The heating value of this generated gas ranges from 18–25 MJ/m^3 (Timbers and Downing 1977). There are some major disadvantages associated with the digestion system such as high capital costs and the explosive properties of the methane gas. However, these disadvantages are outweighed and overshadowed by the aforementioned advantages. This method of anaerobic digestion also makes the treatment and disposal of huge livestock waste feasible, thereby curtailing the odor problem and abreast of that produces relatively odor free sludge that still retains the fertilizer value (Obi et al. 2016).

13.3.2 Nutrient Application

After the crop is harvested, some of the crop nutrients are retained in the farm residues which are either burnt or dumped improperly. These residues if utilized efficiently, holds the potential to be the source of nutrients. The recycling of these organic agri-wastes enables the essential plant nutrients to be recovered and replenished so as to maintain organic matter, physicochemical properties of the soil, and agronomic productivity. The residual agriculture waste from the farm is rich in nutrients such as N, P, and K and can be utilized for nutrient application after conversion into composts. Numerous non-economic parts and residues of the crops are left in the field after the harvest, such as straws, stover, stubble, and haulms of various crops and even the processing wastes like groundnut shells, oil cakes, rice husks, and cobs of maize and sorghum discarded during crop processing have nutrient providing potential. However, the crop residues need composting before being used as manure (Mahimairaja et al. 2008). Composting is basically a microbiological process accomplished by the combined activity of bacteria, actinomycetes, fungi, and protozoa which are either present in the composting material or are introduced externally to speed up composting and enrich the compost. As a result, the substrate is broken down to form an amorphous brown to dark brown mixture known as compost. Compost is considered a valuable organic fertilizer, supplying nutrients for the crop and hence saving substantial amounts of mineral fertilizers (Erhart et al. 2005). It is estimated that almost 50% of the total agricultural residues are produced majorly by wheat, rice, and oilseed crops. The residues from these crops are estimated to contain almost 0.5% N, 0.2% P_2O_5, and 1.5% K_2O (Singh and Sidhu 2014). It depicts that approximately 6.5 million tons which equals to almost 30% of the total NPK mineral consumption in India, is contained in the form of these farm residues. Therefore, recycling of the agricultural farm residues or agro-wastes becomes a subject of not only major agro-ecological concern but is also well connected with the improved soil and plant health. The recycled waste products could be bio-composts, which may be fortified with microbial consortia and organic material (like amino acids, humic acid, phytostimulants and minerals, etc.) to produce bio-organic farm inputs at commercial scale which could ultimately generate economic livelihood to the rural society also (Singh and Prabha 2017).

The animal manures are the major waste generated from Livestock Production, which can be utilized for fertilizer use at the farm level. According to a report by Council for Agricultural Science and Technology, manure has the capacity to supply 19, 38, and 61% of N, P, and K in chemical fertilizer. Many studies have reported that manures contain high nutrients which can be utilized to supply nutrients to the plants (Lustosa et al. 2017). Obi et al. (2016) reported that adding manure to soil increases its fertility via improving the physical condition of the soil, increasing the nutrient retention or cation exchange capacity, enhancing the water-holding capacity and also the structure stability of the soil.

13.3.3 Adsorbents

The application of adsorbents made from agricultural waste supports the 3 Rs, i.e., reduce, reuse, and recycle rule of waste management strategy and can prove to be an efficient and revenue generating management practice for agricultural sector (Tandon and Sai 2019). Massive urbanization and industrialization have resulted in excessive release of heavy metals into the environment such as mercury, copper, zinc, cadmium, chromium, and lead. These metal ions are not susceptible to biological degradation, unlike organic pollutants. In the past decades, the contaminated effluents are being treated by the agricultural wastes through absorption, as it has been proven to be the low-cost alternative, for the treatment of heavy metals and other compounds. The low value agricultural waste such as rice husk, sugarcane bagasse, coconut husk, sawdust, neem bark, oil palm shell (Mohan and Singh 2002; Ayub et al. 2002; Tan et al. 1993; Khan et al. 2003 and Ayub et al. 2001), etc., can be adsorbents in the elimination of heavy metals as reported in many studies. Results published by Hegazi (2019) showed that low-cost adsorbents can be efficiently used for the removal of heavy metals with a concentration range of 20–60 mg/l also, rice husk was effective in the simultaneous removal of Fe, Pb, and Ni, whereas fly ash was effective in the removal of Cd and Cu from the wastewater. Kuan et al. (2011) investigated the physicochemical characteristics of residues and soluble fibrous residues produced from alkali-treated raw cereal materials (corncob and wheat straw) with high dietary-fiber content (49.87–68.65%). Cereal materials and insoluble fibrous residues were found to contain essential minerals (in contrast to soluble fibrous residues), and showed 2,2-diphenyl-1-picrylhydrazyl radical scavenging ability, good emulsification ability and emulsion stability, mineral binding capacity, water capacity, and oil holding capacity. The production of nanofibers from SF by electrospinning proved successful.

13.3.4 Feed

In most developing countries like India, the animal feed is usually deficient in nutrient sources. Agro-residues being rich in various bioactive and nutraceutical compounds, viz. carotenoids, polyphenolics, and dietary fiber, to list a few, present a potential solution to the problem of lack of nutrition in animal feed and the worldwide supply of protein and calories. The traditional method of increasing livestock production by supplementing forage and pasture with grains and protein concentrate may not meet future meat protein needs. Appropriate technologies can be used for their valorization of animal feed by nutrient enrichment. Technologies available for protein enrichment of these wastes include solid substrate fermentation, ensiling, and high solid or slurry processes. Technologies to be developed for the reprocessing of these wastes need to take account of the peculiarities of individual wastes and the environment in which they are generated, reprocessed, and used (Ajila et al. 2012).

Apart from the above-mentioned methods of utilization, there are many other methods of sustainable utilizations as well. Agriculture process residues including husks, seeds, molasses, bagasse, and plant roots have potential to be used as animal fodder. It can also be used as a soil amendment, fertilizers, and in manufacturing of various products. In a study by Lim and Matu (2015), a biofertilizer was developed using agro-wastes. Organic waste from agriculture can also be utilized for Natural fiber-polymer composites (NFPCs) (Väisänen et al. 2016). Various studies reported that different kinds of waste such as pomegranate peels, lemon peels, and green walnut husks can be used as natural antimicrobials (Adámez et al. 2017; Katalinic et al. 2013). Agro-industrial wastes are used for manufacturing of biofuels, enzymes, vitamins, antioxidants, animal feed, antibiotics, and other chemicals through solid state fermentation (SSF) (Sadh et al. 2018).

13.4 Agricultural Waste Management System

United States Department of Agriculture has defined agricultural waste management system (AWMS), as a "planned system in which all necessary components are installed and managed to control and use by-products of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, and animal resources." Agricultural waste management is part of the ecological cycle in which everything is cycled and recycled such that an interdependent relationship is maintained in the eco-system. By waste management, all the plant wastes are placed at the right place and right time for the best utilization in order to convert into useful products and pollution control. The Total Solids (TS) concentration of agricultural wastes is the main characteristic that determines the handling of the material. For

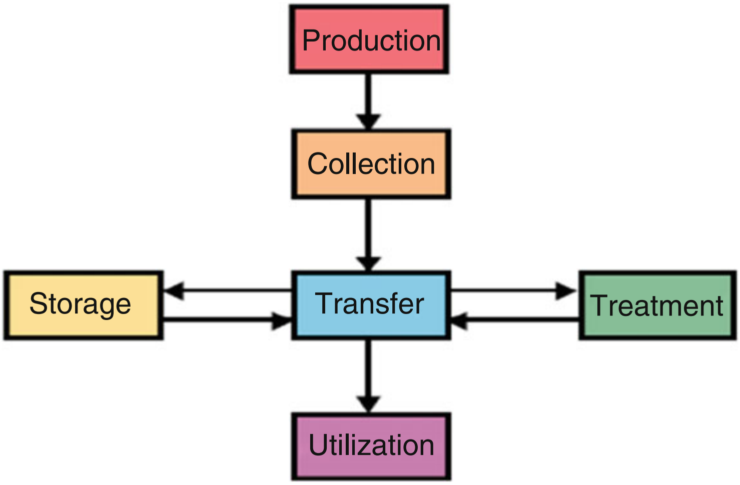

Fig. 13.2 Functions of agricultural waste management (Obi et al. 2016)

excreted manure, for example, the following factors affect the TS concentration and they include the climate, type of animal, amount of water consumed by the animal, and the feed type.

As noted by USDA, AWMS consists of following six basic functions, also depicted in Fig. 13.2:

- **Production**: Amount and nature of agricultural waste generated.
- **Collection**: Initial capture and gathering of the generated waste from the point of origin or deposition.
- **Storage**: Temporary containment or waste holding.
- **Treatment**: Function designed to reduce the pollution or toxic potential of the waste, including physical, biological, and chemical treatment and increases its potential beneficial use.
- **Transfer**: Movement and transportation of the waste throughout the system from the collection to the utilization stage either as a solid, liquid, or slurry, depending on the total solids concentration.
- **Utilization**: Application of the waste for beneficial use and it includes recycling reusable waste products and reintroducing non-reusable waste products into the environment.

Obi et al. (2016), described the "3R" Approach to agricultural waste management (AWM). The "3R" Approach to agricultural waste management (AWM) is the concept of minimizing the ill-effects of waste generation by reducing the waste quantity, reusing the wastes via using simple treatments and recycling the wastes by using it as resource for further production. The three R principle, i.e., reducing,

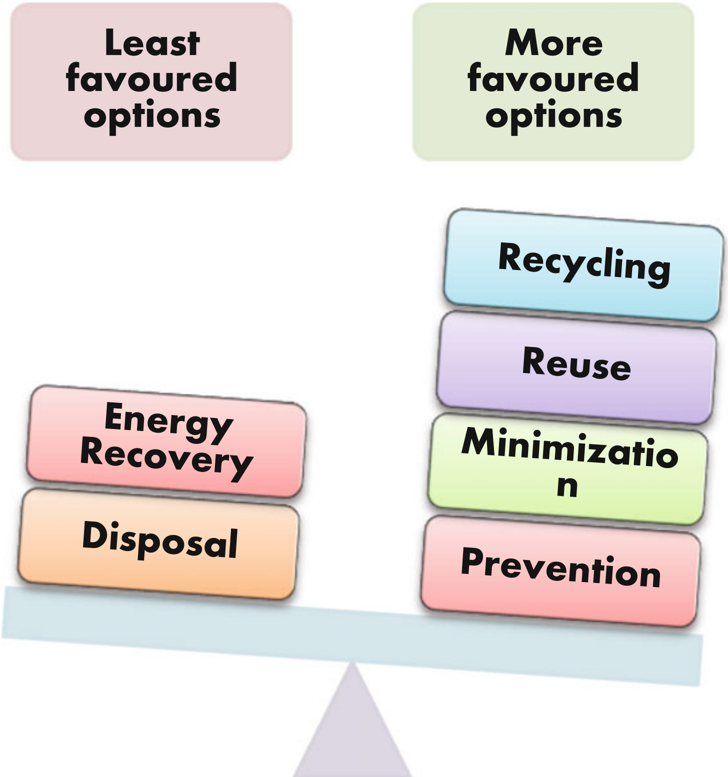

Fig. 13.3 The least and more favoured options of Agriculture waste management

reusing, and recycling of wastes, aims at achieving efficient minimization and utilization of waste generation by (Fig. 13.3)

- Reducing the quantity of waste generated by effectively utilizing the items.
- Reusing the items or parts of items which still have usable aspects.
- Recycling via use of waste itself as a resource.

13.5 Hazardous/Special Agricultural Waste

As defined by SEPA (Scottish Environment Protection Agency), special waste is defined as a hazardous waste that requires to be handled with additional care and controls for well being of humans and environment. Few examples of such waste are residual pesticides, chemicals and their containers, waste oils generated from farm machinery, asbestos roofing material, infectious waste produced during healthcare of animals, and electrical equipment containing cathode ray tubes. Many agricultural enterprises use large amounts of agricultural chemicals. With this increased usage comes the potential for surface and groundwater contamination as a result of improper storage of chemical residue, rinse water, and unused chemicals and the improper disposal of empty containers (USDA 2012). The hazardous agricultural waste can be treated via thermal, physical, chemical, or biological sorting and processing that can reduce the volume and hazardous nature of agricultural waste. The treatment also makes it easier to handle and recover (http://www.netregs.gov.uk). Disposing of hazardous/special waste should be done only in authorized sites. The transportation of hazardous waste should be strictly by a registered waste carrier. The hazardous/special waste can be disposed to an authorized landfill site. USDA has also specified the waste management system for agriculture chemicals (USDA 2012).

13.6 Conclusion

Extensive range of waste is produced as a result of several agricultural operations such as crop waste, food processing waste, animal waste, and toxic agricultural waste. Effective utilization of such waste has the potential to benefit man due to its high strength, environmentally benign nature, low cost, and ease of availability and reusability. Whereas, if this waste is not managed properly, it can result in prevalent concerns related to environment. Energy production, nutrient application, chemical adsorbents, animal feed, biofertilizer production are some of the strategies of effective waste utilization and management. The application of the knowledge of agricultural waste management systems such as the "3Rs" can be useful in transforming the waste into beneficial materials for human and agricultural usage. Appropriate waste utilization will help in promotion of world's developing agricultural sector and also the management of environment pollution.

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