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Bioremediation of Temple Waste Using Earthworms for Production of Compost and Value Added Products

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Abstract: Management of organic waste is a main concern worldwide, as unscientific disposal of waste is adversely affecting the environment by causing various types of ill effects/health issues. For the management of various types of wastes such as agricultural waste, commercial wastes domestic waste and industrial waste some modern decomposition or degradation methods (aerobic and an-aerobic) are in practice in different parts of globe. Out of all the organic waste, temple floral waste management is yet to be explored. Flower waste is a semi-solid waste produced from temples and rituals like marriages, puja etc. In India, utilization of flowers occurs at different places and for different purposes. Floral waste gets decomposed aerobically as well as an-aerobically. It produces bad smell and toxic gases which leads to health problems in humans. About half by mass floral waste is made up of biodegradable waste. There are many methods which can be used to treat flower waste, but they are slow and very costly and the natural processes are slightly tough to manage. To solve all the problems related to temple waste, Government agencies are also suggesting various techniques such as vermicomposting which is considered to be the most eco-friendly method for the treatment of organic waste. Vermicomposting is a biological process involving interactions between microorganisms and earthworms which efficiently convert different type of organic wastes into nutrient rich manure "black gold". Thus, it may be implemented on commercial scale to eradicate the problem of temple waste, minimise health impacts and would help to promote the concept of "Green Temples".

Keywords: Temple waste, Earthworms, Vermicomposting, Bioremediation, Pollution, Black gold

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Introduction

Waste means trash, garbage junk, litter or unuseful material, which is of no use and dumped by the people. Hazardous waste and medical waste is formed from well-known inception, which is managed by the administrative unit. The birth rate is rising rapidly leading to overpopulation on earth, causing rapid accumulation of waste every single minute further creating problems for administrative authorities to collect and manage it. Improper disposal of organic waste is the primary cause of environmental pollution. Recently, organic waste management is primary concern in whole world because its unscientific disposal can harmfully affect the environment by causing many ill effects such as offensive odour, groundwater contamination, communicable diseases (malaria, tuberculosis (TB), cholera etc.) vector-borne disease (dengue, typhus etc.) in humans (Sharholy *et al.*, 2005; Ray *et al.*, 2005; Rathi, 2006; Garg *et al.*, 2006; Sharholy *et al.*, 2008). There are many physical, chemical and micro-biological methods of disposal but they are time-consuming and very costly. Agricultural residues, domestic waste and non-edible oil cakes waste is enriched with carbon content. Generally, the land lifting remediation approach is used for the disposal of organic waste. Increase in global population, modernization and technological advancement generated growing demand for food and other essential products. This has been resulted into rise in the amount of waste being generated daily by each household (Hamer and Zwiefelhofer, 1986; Dernbach and Henning, 1987). Various studies have evaluated the direct link between the quantity of waste generation and the economic population explosion, growth of the nation including urbanization and industrialization. In developing countries, the urban population is growing very rapidly and it is estimated that by the year 2025 the two-third part of the world's people living in cities (Sharma and Jain, 2020).). It has been reported that in 2016 the municipal solid waste (MSW) generation in the world was around 2,010 million tons (MT) per year and it may estimate that it may increase up to 3,400 MT by year 2050. It indicates nearly 70% increase in production of MSW within 34 years (Khandelwal *et al.*, 2019). According to the reports, around the world 242 MT of plastic waste has generated in 2016, which constituted 12% of MSW. Plastics consists of organic and inorganic raw materials such as hydrogen, silicon, nitrogen, carbon and oxygen, which are generally take out from natural gas, oil, and coal (Saminathan *et al.*, 2014). In the past, natural polymers are replaced by synthetic polymers and consequently it has now become an important part of our day to day life (Wei and Zeimmermman, 2017). Progressively, with the increase in the robustness, durability, stability, and strength, plastics have become unaffected to many environmental factors. About 10% of the household waste consists of plastic waste, most of which is disposed in landfill (Barnes *et al.*, 2009; Hopewell *et al.*, 2009). Nonetheless, 60-80% of the waste found on beaches, floating on ocean or sealed in plastic (Derraik, 2002; Barnes *et al.*, 2005). Around 2.3 billion pieces of plastic, which weighed 30,500 kg were recovered from Southern California beach over 72 h. Mostly plastics are non-biodegradable and as a result have accumulated into the environment in extensive quantities due to the inappropriate management of waste. The increasing consumption of plastic waste is polluting oceans because most of the developing countries do not have proper plastic waste management systems (Spranghers *et al.*, 2017). The wildlife species are adversely affected by the huge quantities of synthetic plastics as young animals occasionally get intertwined in the plastic which results in major injury to them. Additionally, in birds and animals, ingestion of plastic debris which persists in their digestive system causes several problems including decreased feeding stimulus, reduced level of steroid hormones, gastric enzymes, and also leads to gastrointestinal blockage (Ahmed *et al.*, 2018). Moreover, the non-biodegradable nature of the synthetic plastics and their long-term accumulation in the soil leads to soil fertility loss which results in decreased growth and development of plant. These synthetic plastics also causing danger to aquatic flora and fauna as their amount has increased six times more than the planktons present in the water bodies. Synthetic plastics when consumed by aquatic animals can undertake bio-magnifications which can later produce significant harm to human health.

Improper disposal and management of municipal solid waste (MSW) causes all types of pollutions including air, water, and soil. Non-selective dumping of wastes pollutes surface as well as ground water supplies. In urban areas, municipal solid waste (MSW) blocks drains, generating stagnant water for floods and insect breeding during rainy seasons. Uncontrolled burning and improper incineration of municipal solid waste (MSW) leads to urban air pollution. Decomposition of organic wastes in landfills generated Greenhouse gases while untreated leachate pollutes surrounding area mainly soil and water bodies. Improper municipal solid waste management (MSWM) creates serious health (cholera, diarrhea, typhoid fever) and safety issues. According to Gajalakshmi and Abbasi (2008) the waste materials can be categorized in various ways such as, on the basis of their source of origin (domestic, kitchen, market, agricultural, industrial, municipal, temple waste); on the basis of their consistency (gaseous, liquid or solid) or on the basis of their chemical nature (organic or inorganic). By using polluted water for drinking, bathing, food irrigation etc., it can also introduce individuals to various disease organisms and other contaminants. About 50 million tons of municipal waste is produced every year in many cities of India (Sharholy *et al.*, 2008; Hazra and Goel, 2009; Saha *et al.*, 2010). Such huge quantities of waste being produced has created the challenging issues to its proper disposal (Idris *et al.*, 2004). It has been reported that in India about 960 million tons of solid waste is generated per annum, from different sources which include industrialization by-products, municipal, mining, agricultural and other processes (Pappu *et al.*, 2007). Moreover, nearly 350 MT waste generated directly from agricultural practices (Pappu *et al.*, 2007). Also, more than 90% of these wastes were directed for unscientific disposal or land fillings that generates various problems to environment and public health (Sharholy *et al.*, 2008). However, strategies for management of various waste types have been shown in Figure 1.

Temple Waste:

In India, worshiping of God is performed in temples, mosques and gurudwaras. People offers floral garlands, agarbatti, fruits, milk, prasaad, dhatura, dhoopbati, coconut, sweets and havan material etc. to the God which is generated in the temple and converted into wastes called as temple waste (Fig. 2). Waste produced from temples is mostly organic in nature and form about 70% of entire solid waste (Singh *et al.*, 2018). In India, the amount of floral waste production is 300 million ton per day (Kumar *et al.*, 2020). Temple waste is a heterogeneous mixture of different materials offered to God and its composition varies in each temple. The waste materials are mostly organic (degradable and non-degradable). The composition of temple waste depends upon the offerings of visitors such as floral garland, milk, agarbatti, dhatura, belpatra and coconut etc. Consequent groups of temple waste components can be recognized including (i) decaying waste refuge (floral, fruits, agarbatti and coconut) (ii) non-biodegradable substances (cloths, Chola, plastic bag, glass frame, diya and plastic strip etc.) (iii) Organic pollutants (cadmium (Cd), chromium (Cr), arsenic (As), lead (Pb), mercury (Hg) etc. which may exert adverse impacts on plant growth (United States Environmental Protection Agency, 1992). During the festive season, people mainly offer flowers and agarbatti to God for better survival of life. Chrysanthemum, China Rose, Jasmine, Marigold and Rose are some chief florets which are mainly offered by people to God. Flower waste is thought to be holy residue, which is different from other wastes and is thrown away in water bodies. Generally, flower waste is ignored and constantly damaging the environment and different water channels. These waste materials produce unbearable foul smell and spread lots of gases which causes various infectious diseases among human beings. However, it was found that temple wastes are the major source of environmental pollution and causes various harmful health diseases. Burning of incense is esteemed as a customary spiritual tradition to adore divinities and also a part of daily routine all over the sphere among all the religions (Jhala, 2000). India has more than two million temples. Burning of incense account as an abundant source of large number of particulate matters and cancerous Polycyclic Aromatic Hydrocarbons

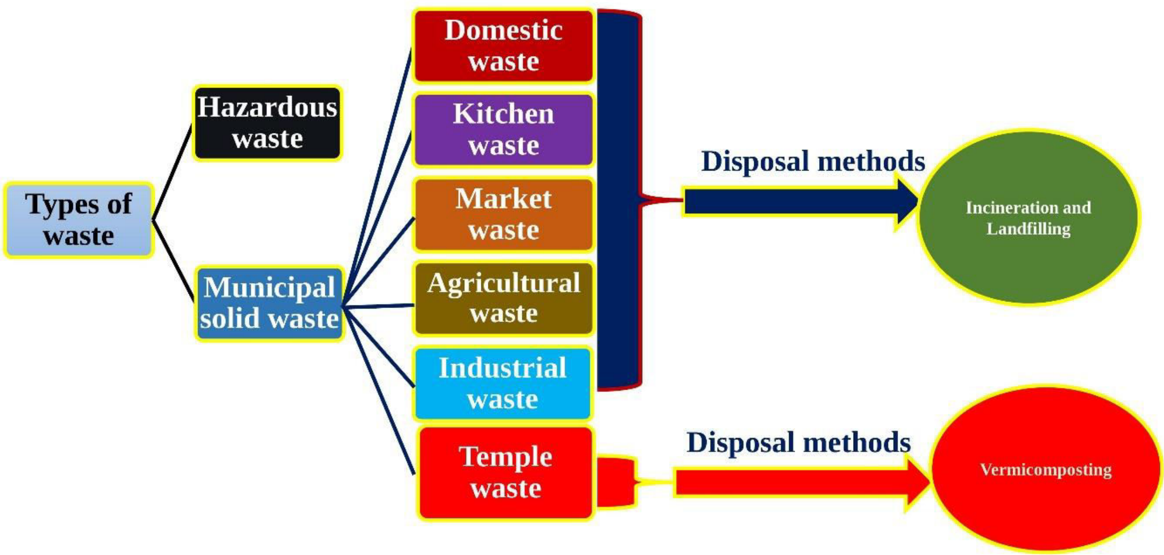

Fig. 1: Waste Management Strategies.

Fig. 2: Temple Waste.

(PAHs). This practice produces non-stop smoke because of its long, slow and incomplete combustion. Various studies demonstrated that people subject to such smoke established substantial potential risk for the existence of acute throat and upper respiratory tract irritation (Smith *et al.*, 2000). According to a report of WHO (World Health Organization, 2005), it is estimated that about 36% of chemicals used by Floraverde plantations as highly toxic. Transportation of flowers from one place to another place produce enormous pollution and vehicular movements release many harmful gases into the atmosphere. Floral waste is said to account for 16% of the total pollution of the rivers (Joshi *et al.*, 2009). Excess organic content present in the flowers leads to increased algal blooms production and eutrophication in water bodies when floral waste starts decomposing. Additionally, it may disturb amount of oxygen in the water bodies and cause deaths in aquatic systems. However, floral waste generating at temples is evolving a severe threat to environment and human beings. The organic nature of the temple flower waste makes it available to various biological management options such as vermicomposting as a substitute of disposal to landfill sites, open dumping or any other environmentally risky and costly waste management alternatives (Aalok *et al.*, 2008; Adhikary, 2012).

Floral waste is one of the primary concerns, utilized in various industries viz; perfumes, cosmetics, food, and textile industries. The disposal of flowers in water bodies (rivers and oceans etc.) can affect the organisms present in water, which is a significant cause of water pollution. In India, the utilization of flowers occurs at different places and for another purpose (in religious places for worship, in bouquets and garland preparation, in ceremonies etc.). Various festivals are celebrated every year. In all holy places, the flowers are offered, which afterwards are discarded and become waste (Yadav *et al.*, 2015). In Navratri, different forms of Durga are worshipped by the people. Temples are decorated with different kinds of flowers and offered to Goddess Durga at the time of puja (Yadav *et al.*, 2018). Flower considered a spiritual entity that can be provided by devotees to God. After offering flowers to God, they become useless and then converted into volatile solid waste. All the dumped flower waste is dispersed at temples, Gurudwaras and Mosques. Andhra Pradesh, Karnataka and Tamil Nadu, West Bengal, are fourth in supplying flowers in India. Different types of flowers are offered in temples, dargahs, gurudwaras etc. In dargahs, mostly jasmine flowers, in gurudwaras, marigold flowers are delivered most of the time. In different temples, varieties of flowers like marigolds, lotus, roses and many other are offered to God (Elango and Govindasamy, 2018). These flowers contain different essential components. In Marigold (*Tegetus erecta)* flowers, essential oils, Flavonoids patuletin, quercetagetin and quercetin are present. In Chrysanthemum flowers, flavonoids, volatiles, myricetin, and quercetin are present (Wu *et al.*, 2010), while Jasmine flowers are a good source of essential oils flavonoids, phenolic, saponins, and steroids (Kunchachan *et al.*, 2012). Rose flowers are the primary source of riboflavin, sugar, tannins, pectin, mineral salts, salt of tartaric acid and *Hibiscus rosa-sinensis* contains essential oils, flavonoids, tannins, quinines, phenols, alkaloids, protein, carbohydrates and steroids (Al-Snafi, 2018). Proper use of flower waste could be beneficial if managed properly.

Significance of Earthworms in Waste Management:

From pre-historical times, earthworms have been found helpful in agriculture and human health, and they have drawn the attention of philosophers and naturalists worldwide. Earthworms are called "Intestine of Earth" by Aristotle in 384-322 B.C. They are helpful for the maintenance and enhancement of soil fertility. In the Indian subcontinent, the earthworm origin was traced in 1844, and Robert Templeton provided a detailed study on earthworms of India. In 1758, Carolus Linnaeus reported in his book "Systema Naturae" zoological nomenclature for earthworms that earthworms contribute to soil fertility by their burrowing and feeding activities. Savigny (1826) reported the diversity of earthworms and about 20 species of Lumbricidae from Paris. In 1881, Charles Darwin gave due credit to earthworms for their fantastic work activities in the waste decomposition process, and Dr Thomas J. Barrett (1959) was very impressed by his work on earthworms. Dr Thomas J. Barrett tried to utilize them in barren, dry land to form fertile, lush farms. Moreover, earthworms are referred to as "Earth master Systems", and the introduction of selected earthworm species to the poor agricultural land was recommended by him. Earthworms also considered as "Humus Factories of Manure". In 1959, Dr Thomas J. Barrett wrote a book, i.e. "Harnessing the Earthworm", and maintain the potential of earthworms in compost (shaping dark-colored fertile soil) and considered as "Greatest Servant of Nature". The earthworms have great importance in waste management, in organic farming and sustainable agriculture reported by different workers (Edwards, 1985; Edwards and Neuhauser, 1988; Senapati, 1992; Rosset and Benjamin, 1993; Bhawalkar, 1994; Mitchell, 1994; Ismail, 1997; Eijasackers, 1998; Ghatnekar *et al.*, 1998; Talashikar and Powar, 1998; Agrawal, 2005; Agrawal and Agrawal, 2006). According to Agrawal (2005), vermitechnology helps to control sustainable development in human society. Professor Radha D. Kale, also famous as "Earthworm Lady", published her book "Earthworms: Cinderella of Organic Farming", and later book was entitled "Vermicompost- The Crown Jewel of Organic Farming".

Earthworms are the natural invertebrates belonging to the Lumbricidae family, primarily present in temperate soil and tropical soils. Earthworms are hermaphrodites in nature. But in general, self-fertilization does not occur in them. The cocoon production starts from the age of 6^{th} weeks to 6 months, and an earthworm produces approximately 100 cocoons in this time under favorable conditions (Ismail, 1997). Generally, cocoon incubation period is about 3-5 weeks, but it differs according to the region. In temperate earthworms, it is 3-30 weeks. However, 1-8 weeks in tropical earthworms. Earthworms have the power to regenerate lost segments. The life cycle of earthworms is well known, and understanding the effect of earthworms in various organic waste requires a detailed study about the biological potential of earthworm species (Edward, 1998). Multiple studies have been conducted on their lifecycle in different species i.e. temperate species, Indian species and tropical species (Lavelle, 1979). Gunathilagraj (1996) described the biology of earthworm species for composting. Several workers have studied the uses of biological agents for decomposition (also consist of earthworms in organic waste disposal). Generally, three types of earthworms are there, i.e. Epigeic earthworms, endogeic earthworms and anecic earthworms. In these species, epigeic worms are surface dwellers. Endogeic worms are found in soil minerals, and anecic earthworm species *Lumbricus terretris* form vertical burrows. Among these earthworm species, epigeic and anecic are used in vermicomposting. According to Kale (1993), *E. fetida, Edurilus eugeniae* and *Perionyx excavatus* decompose wastes.

Among them, *E. fetida* (brandling worm) is an earthworm species that can be used commonly worldwide (Haimi, 1990). They can adapt to semi-natural conditions in culture. However, other earthworm species are seasonal breeders, with low food requirements, low metabolic rate, low reproductive potential and low population density. Hence, they cannot be used for waste management and composting purpose. Organic waste can be converted into vermicompost (Kale, 1998) during ingestion of these biodegradable materials, and five-ten per cent of this material is responsible for growth and development of the earthworm material which is excreted as cast. The cast gets mixed with mucus secretion from the earthworm's gut wall and some microbes. The decomposition process continues even after the release of the cast. The nutritional value of compost depends upon the organic waste used as earthworm food.

It has already been proved that earthworms eat high quality of fungus and Ca and higher sugar content and N_2 (Cooke and Luxton, 1980; Lee, 1983; Edwards and Bohlen, 1996; Parthasarthi and Ranganathan, 2000). Earthworms are heterothermic organisms (metabolism and other vital activities are dependent on the ambient temperature). *P. excavatus* (local species) is adapted to normal local conditions. Charles Darwin (1809-1882) studied earthworms for 40 years. He estimated that British farmland contained about 50,000 worms that formed worm cast about 18 tons/year.

In organic matter (leaf litter) recycling, the role of earthworms has been demonstrated (Edwards and Heath, 1963; Heungens, 1969). Macfadyen (1963) analyzed and discussed soil organisms like earthworms to process vast amounts of waste with an enormous scope of vermi-stabilization of organic waste. Shanthi *et al.*

(1993) demonstrates earthworm species ability, namely *Eudrilus eugeniae, Eisenia species*, and *Perionyx excavatus*, to degrade vegetable waste. Reinecke *et al.* (1992) reported that *E. fetida* could tolerate high temperatures than *Eudrilus eugeniae* and *P. excavatus*. It handles about 42°C as well as soil temperature below 50^{0}C. The food quality and quantity enhance the size of earthworms and affect the growth and development of earthworms (Dominguez *et al.*, 2000; Chaudhari and Battacharjee, 2002). Stockli (1928, 1949) reported that earthworms have a significant role in increasing plant productivity, soil fertility and growth of microorganisms.

In vermicomposting, *E. foetida* is commonly used earthworm species for vegetable waste due to ability to tolerate high environmental condition (pH, temperature and moisture content) (Kaviraj and Sharma, 2003; Garg *et al.*, 2006; Suthar, 2009). *E. fetida* is also utilized in sludge management. Partially decomposed waste have good quality and composition of humus having high phosphorus (P) and potassium (K) content (Delgado *et al*., 1995). Albanell *et al.* (1988) reported that *Eisenia fetida* accelerate mineralization and degree of humification. Kaviraj and Sharma (2003) reported comparative study of *E. fetida* (exotic) and *P. excavatus* (local) species of earthworms in vermicomposting of municipal solid waste (MSW) and Singh and Sharma (2002) studied the role of bio-inoculants i.e. "*Pleurotus sajor-caju*, *Trichoderma harzianum*, *Aspergillus niger* and *Azotobacter chroococcum"*, in pre-decomposition of a mixed solid waste i.e. municipal solid waste (MSW) and horticulture waste (70:30) vermicomposting then observed that it improves its quality of compost and reduces its stability time period.

Earthworms are used in liquid waste and about 4500 kg earthworms consume 900 kg waste in a day and increase in population was showed reported by Prince (1981). Haimi and Huhta (1986) reported that *E. fetida* has ability to decompose different types of wastes or mixture of wastes in one month. The population growth of *Eisenia fetida* and *Eudrilus eugeniae* was found to depend on the quality and quantity of the available food, culture media, temperature and moisture levels (Hartenstein *et al.*, 1984; Reinecke and Venter, 1987). Aoka Sanagyo Co. Ltd. of Japan has a capacity to handle 3000 tons of garbage by converting it by vermicomposting per month (including the wastes from paper pulp and food industry), that leads to production of 400 tons casting along with 10 tons of earthworms. Earthworms are considered as engineers of the ecosystem because of their ability of cycling of various nutrients in soil and shaping its structure (Blouin *et al.*, 2013). Due to continuous feeding and burrowing habits of earthworms, they promote litter decomposition, mineralization of nitrogen (N) and water infiltration which deeply influence soil properties (Hättenschwiler and Gasser, 2005). These worms play a vital role in the establishment of soil ecosystem services (Lavelle *et al.*, 2016). The soil volume which directly affected by earthworms is called as the drilosphere (Lavelle, 2002). It is significant functional domain of the soil, made by the earthworm community and creates the different structures such as: middens, burrows, tunnels, and casts. In addition to this, these building activities establish an input of organic matter to the soil and a pathway for the stabilization of soil organic carbon through the formation of organo-minerals (Deeb *et al.*, 2017). Therefore, along with shaping soil structure, earthworms also have a significant influence on soil organic matter and micro-organisms in their gut, casts and drilosphere (Andriuzzi *et al.*, 2016) and are also recognized as biochemical engineers (Lavelle *et al.*, 2016). From pre-historical times earthworms have been found useful in agriculture and human health and they have drawn the attention of philosophers and naturalists all over the world. About 3200 species of earthworms are known to occur throughout the world while in the Indian subcontinent, they are represented by 500 species belonging to 67 genera. Of these, about 374 species have been reported from India, from different habitats (Senapati and Sahu, 1993). Barrett (1959) was highly impressed by extensive works of Sir Charles Darwin on earthworms and he tried to use them to improve his barren dry lands into fertile lush farms. He referred earthworms as "Earth Master Systems" and he recommended introduction of selected species of earthworms to the poor agricultural land. He also considered earthworms as "Humus Factories of Manure". Barrett (1959) wrote a book "Harnessing the Earthworms" and emphasized the potential of earthworms in shaping dark colored fertile soil (compost) and considered them to be the "Greatest Servant of Nature". He was the first person to suggest raising of some of the species of earthworms on large scale. Later on the role of earthworms in organic matter (leaf litter) recycling has been demonstrated by other workers (Heungens, 1969). The concept of using soil organisms including earthworms to process large quantities of waste biomass and possibilities and the scope of vermin-stabilization of organic waste have been discussed and analyzed by Macfadyen (1963). Stockli (1949) reported that earthworms cast play an important role in increasing plant productivity, soil fertility and enhancing growth of microorganism. For the breakdown of organic matter there should be symbiotic relationship between the earthworms and microorganisms and helps in realizing mineral nutrients in the soil. Due to this reason cast have more microbial flora than the surrounding soil (Barley and Jennings, 1959; Parle, 1963). Nitrogen fixing bacteria are found in the gut and casts of earthworms (French, 1976; Satchell, 1983). Yeates (1981) reported that certain species of microorganism are killed when passed through gut, while others proliferate. Earthworms and some types of bacteria work "Hand-in-Hand" to decompose waste into compost. Biology of earthworm species suitable for composting has been described by Pandit *et al.* (2012). Several workers have investigated the utilization of natural decomposition process including earthworm in organic waste disposal. There are numerous species of earthworms including *Eisenia foetida*, *Perionyx excavates, Eudrilus eugeniae*, and *Lumbricus rubellus* (Suthar, 2009; Mainoo *et al.*, 2009) which are generally used in vermicomposting process. It has been demonstrated that earthworms can process household garbage, city, refuge, sewage sludge and industrial (paper, wool, food) wastes (Hartenstein, 1979; Appelhof, 1980; Senapati and Dash, 1982). A number of researchers have investigated the capability of earthworms as a treatment or management factor for numerous organic waste streams (Chauhan *et al.*, 2010; Kalamdhad and Khwairakpam, 2012; Mehta and Karnwal, 2013; Dandotiya and Agrawal, 2014; Degefe *et al.*, 2016). Earthworms work upon sewage sludge and solids from water wastes (Sinha *et al.*, 2010), processed paper industry waste (Butt, 1993), brewery waste (Butt, 1993), and coffee pulp. A number of researchers have reported the potential utilization of epigeic earthworms for effective degradation of organic wastes, generated from different industries for example dairy industry (Gratelly *et al.*, 1996), wood and chips industry (Maboeta and Rensburg, 2003), winery and distillery industry (Nogales *et al.*, 2005); paper and pulp industry (Elvira *et al.*, 1997; Kumar and Jagadeesan, 2010), textile mill waste (Kaushik and Garg, 2004; Garg and Kaushik, 2005) and flower waste (Kumar and Anbuganapathy, 2010). Even so, *Eisenia fetida* is the most common and favorable earthworm species used for vermicomposting of vegetables waste because of their high tolerance to ecological variables such as temperature, pH and moisture content (Suthar, 2009). Various researchers have tried and tested the breakdown of different types of organic wastes employing earthworms (Allevi, *et al.*, 1987; Shanthi *et al.*, 1993; Alok *et al.*, 2009). Kumar *et al.* (2013) observed that the *Eisenia fetida* attained maximum weight and it survived best at temperature ranges between 20ºC to 29ºC and moisture between 70%-85% in medium having horse manure and activated sludge. It has been reported that the digestive epithelium of the simple and straight tubular gut of earthworms secrete various enzymes such as cellulase, amylase, invertase, protease, and phosphatase (Ranganathan and Vinotha, 1998). There are certain species which have been identified to be very helpful in degradation of the organic wastes, such as *Eisenia foetida*, *Dendrobaena venata*, and *Lumbricus rubellus* from temperate areas and *Eudrillus eugeniae* and *Perionyx excavates* from the tropics. For optimum growth of the *E. fetida* in different animal and vegetable waste medium, temperature and moisture should range between 25-30ºC and 75-90%, respectively. It has been observed that *Eisenia fetida* with bio-solids as a feed substrate can process 75% of their body weight per day (Ndegwa *et al.*, 2000). From the ancient times (< 4000 years, 2600 B.C.) earthworms have been used as food and medicines for several human diseases in various parts of the world including Japan, Vietnam, India, Korea, China, Cambodia, Myanmar (Burma) and Iran. They may be used in organic waste management, vermiculture, vermicomposting and vermin wash. It is now time for India to commercially think about vermin technology to promote organic farming.

Composting is considered as biological decomposition process under various conditions (self-heating, aerobic and moist conditions) to form a stable and nutrient-rich product which is used as organic fertilizer (Bustamante *et al.*, 2009). Various works are reported for "flustered pile composting" of waste such as vegetable waste, water hyacinth, municipal waste (MSW), chicken litter, sewage sludge, pig faeces, food waste and saw dust (Huang *et al.*, 2004; Iyengar and Bhave, 2006; Gao *et al.*, 2010; Zhou *et al.*, 2014; Varma and Kalamdhad, 2014; Singh and Kalamdhad, 2015). However, there is limited literature related to composting of floral waste with cow dung. It is a sustainable option for the organic waste management. It is easily managed and forms high quality product if managed properly. Its growth and fecundity depend upon the availability, nature of food and various parameters such as temperature, moisture content, density etc. (Evans and Guild, 1948). It is a well-known and broadly used method for preparation of highly nutritive and rich quality product as compost (Wu *et al.*, 2014; Lim and Wu, 2016). The end product is stable, free of pathogen and helpful in enhancing the fertility of soil. This organic fertilizer is environmental friendly and do not harm other living organism. It is also helpful to prevent environmental pollution. It also improves the level of soil organic matter, soil microbial biomass and its activities (Lim *et al.*, 2015). Evans and Guild (1948) and Kale and Bano (1985) reported that earthworms mainly prefer N_2 rich diet that can help to grow faster and increase the production of cocoon as compared to other feeding on mineralized soil. Surface-dwelling earthworm are suitable for bio conversion of organic wastes into high quality compost. These types of earthworms live in soil as well as in the mixture of organic waste with cattle dung having good aeration and humidity (<40%). They are excessively greedy in nature. They remain active in whole year and works continuously like a machine. Their interdependence (mutualistic) approach with aerobic bacteria helps to prevent the propagation of pathogen waste.

Vermicomposting as Bioremedial Measure to Manage Temple Waste:

A number of scientists have completed their research work on the vermicomposting and waste management. It has been observed that vermin technology can influence all-round sustainable development of human society. It involves bio-degradation or stability of organic waste (either natural or anthropogenic) by using earthworms and microbes (Figs. 2, 3) (Hand *et al.*, 1988; Suthar, 2007; Mainoo *et al.*, 2009; Garg and Gupta, 2011). Vermicomposting of activated sludge and the effect of population density on growth and production of *E. fetida* has been studied (Hait and Tare, 2011). Now, the vermicomposting facilities have been gone to the industrial and domestic marketing in many countries such as USA, Canada, Italy and Japan. Vermicomposting process was primarily started in Ontario (Canada) during 1970 and it is now handling nearly 75 tons of waste every week. In addition to this, there are nearly 3000 vermicomposting plants sited in Japan with 5-50 tons capacity of handling waste per month.

Various researchers have reported the

Fig. 3: Temple Waste Management.

possibility of using *Eisenia foetida*, *Eudrilus eugeniae* and *Perionyx excavatus* for composting of various animal and plant residues under semi-natural conditions (Kale *et al.*, 1982). The content of methane gas varied between 60%-72%. As a result of the negative effects of chemical fertilizers people's interest has been stimulated for the use of organic manures. Kale *et al.* (1982) and Parlekar *et al.* (1992) studied the laboratory and semi-natural condition of waste degradation using different species of earthworms, for example in trays, wooden boxes, plastic crates, cement tank etc. Vermicomposting is considered as a sustainable source of plant growth hormones, macro- and micro-nutrients, suppressive microbes and enzymes etc. which helps to stimulate microbial population and retain nutrients for long periods (Ndegwa and Thompson, 2001). Vermin compost contains plant-growth regulating materials, such as auxins, gibberellins and cytokinins) and humic acids (Atiyeh *et al.*, 2002) which are responsible for increased plant growth and production of crops (Atiyeh *et al.*, 2002). However, these plant growth-regulating factors are formed by action of tiny microbes such as fungi, bacteria, Actinomycetes etc. (Pathma and Sakthivel, 2012). The physical properties such as aeration, drainage, high porosity, water holding capacity and microbial activity deliver favorable environment for earthworm population development (Atiyeh *et al.*, 2002; Suthar, 2009). Furthermore, earthworms also decrease the amounts of human pathogens, an effect attained in traditional composting through rise in temperature (Contreras-Ramos *et al.*, 2004). A number of organic wastes of dissimilar origin have been used as vermicomposting source including animal manure, sewage sludge, and agro-industrial wastes (Bernal *et al.*, 1998; Paredes *et al.*, 2002; Gomez-Brandon *et al.*, 2011; Suthar *et al.*, 2012). However, the present study was designed to check the temple floral waste degradation with the help of vermicomposting process.

Value-added products derived from floral wastes:

Temple floral waste can be converted into useful products such as biofuels, bioethanol, organic acids, pigments, dyes, food products, bio-surfactants production, incense sticks, compost etc. with the help of solid state fermentation (Fig. 4).

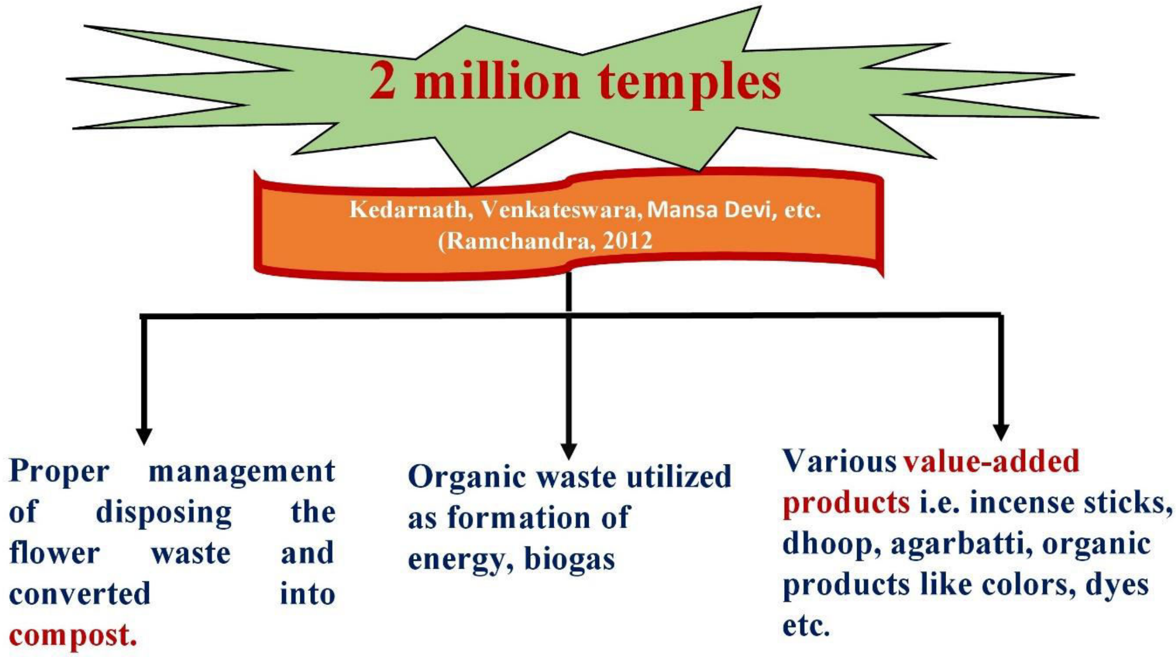

Fig. 4: Production of Compost and Value Added Products.

Production of biofuels, bioethanol and biogas:

A number of microbes are used by fermentation biotechnologist as a tool to convert sugar into ethyl alcohol. There are huge commercial benefits of ethanol which is derived from Mahua flowers by the process of submerged fermentation (Johar and Kumar, 2020). Temple floral waste may ascertain an important source for the production of biogas. Efforts have been made to develop a method which induce the production of the energy from the temple flower waste. Ranjitha *et al.* (2014) conducted a study for production of fuel from mixture of floral and vegetable waste through anaerobic trial, in addition to this, an experimental trial (in anaerobic conditions) has been undertaken by them to produce fuel from the mixture of flower and vegetable waste.

Organic Acids, Dyes and Pigments:

In India, sugarcanes constitute the principal raw material for the production of oxalic acid. Considering the presence of more sugar in Mahua (*Madhuca longifolia*) flowers, it set up an alternating potential to the production of oxalic acid (Das *et al.*, 2010). Oxalic acid is extensively used as a preservative and chelating agent as well. Flower waste generated in temples of Aurangabad especially marigold and rose have been used for the preparation of dyes (Karolia and Dilliwar, 2004). Biodegradable dyes are best alternative to synthetic dyes as they are environmental friendly. Dye extracted from petals of the saffron flower are used on the Pashmina shawl (Raja *et al.*, 2012). It has been reported that Hibiscus (*Hibiscus rosa-sinensis*) are used as a natural dye for coloration in textile industries (Vankar and Shukla, 2013). Various researchers have reported the extraction of patuletin dye from floral wastes including marigold (*Tagetes erecta* L.) and French marigold (*Tagetes patula* L.) and their use in textile industries as well as in antioxidant treatment. Carotenoids, anthocyanins and betalains are the pigments responsible for the coloration in flowers (Grotewold, 2006). Radical scavenging and antioxidant action of betalains indicates its future use in medical field (Escribano *et al.*, 1998; Gandia-Herrero *et al.*, 2012). Safflower pigments such as red (carthamidin) and yellow (carthamin) are used as dye material (textile coloration). Safflower petals have about 0.83% red and 30% yellow pigments (Machewad, 2012). These pigments are extensively used as additive in beverages, natural food colorant, stain, cosmetics, dyeing and in printing. In addition to this, carthamidin pigment is used in preparation of ice creams and many other food products. African marigold flower (*Tagetes erecta* L.), grown as a cut flower and a garden flower, is a major source of carotenoids and lutein. Marigold flowers are yellow to orange red in color and a rich source of lutein (a carotenoid pigment). Currently, lutein is becoming a popular active ingredient used in the food manufacturing and textile pigmentation (Bureau and Bushway, 1986). This pigment has attained more importance due to its excellent color value.

Food Products:

The extract of Mahua (*Madhuca longifolia*) flowers is commonly used in various food industries. It is used for making jams, jellies, biscuits, many nutritional components including vitamins, sugars, amino acids, organic acids, enzymes (protease) and other compounds such as tannins, betaine, crude pigments etc. Extract of marigold flowers are used as a colorant in various food industries and a natural source of xanthophylls as well.

Bio-surfactant Production:

The bio-surfactants are surface active biomolecules having various useful activities including strong antibacterial, antifungal and antivirus activity. They act as anti-adhesive agent against many pathogens and also useful for treating many diseases as therapeutic and probiotic agent (Gharaei-Fathabad, 2011). Waghmode *et al.* (2018) studied the production of surface active agents by Microbispora sp. by using flower extract of Mahua (*Madhuca latifolia* L.) where the surface active compound produced possessed bio-surfactant activities. The glycoprotein bio-surfactant possesses good wetting capability and also disclosed strong antifungal, antibacterial, and antivirus activity.

Medicinal Value of Flowers:

Mahua (*Madhucalatifolia* L.) flowers are used to cure bronchitis and also help in milk production in feeding mothers (Sunita and Sarojini, 2013). The calendula oil derived from the infusion of olive oil and dried calendula flowers, is a value added product and a good source of massage oil. Passionflower (*Passiflora*) reduces anxiety, insomnia and stress; Lily (*Lilium*) flower is used against jaundice, respiratory and gastro-intestinal ailments and *Rhododendron arboretum* flower juice is used to regulate high blood pressure. Chamomile essential oil is useful for the treatment of various skin disorders such as eczema and also helpful in muscular cramps. In most parts of the India, rose flowers are present throughout the year which generate a high scope for commercial cultivation of rose for the production of floral extracts. About 80% of rose flowers are utilized for the preparation of rose water, 10% for scent, 1–2% for pankhuri and remaining are used for the manufacturing of gulkand. Rose oil is used as a chief fragrance ingredient in preparation of lotions, ointments, creams, soaps, perfumes etc. Gulkand prepared from crumpled rose petals is consumed as tonic and medicine against various disorders. Mountain arnica (*Arnica montana* L.) is used in homeopathic and traditional medicine (Puhlmann *et al.*, 1991), and is supposed to have antiseptic, antiphlogistic, anti-inflammatory and analgesic properties (Lanigan, 2001). The plant extract is used in liniments (medicated preparation to relieve pain and strain) (Lanigan, 2001). Saffron petals hold anthocyanin pigments which is a member of parent class of molecules known as flavonoids. Phenolic compounds include flavonoids and anthocyanins, and these are mainly linked with health benefits for humans and animals. Antioxidant properties of flower pigments including carotenoid, anthocyanins and betalain contribute their usefulness against human cancer (Escribano *et al.*, 1998; Johnson, 2002; Castaneda-Ovando *et al.*, 2009).

Incense Sticks, Dhoop sticks and Rose Water Using Floral Wastes:

Incense sticks and Dhoop sticks are the most common product which is produced out of the temple waste. Flowers like marigold, lily and roses are mostly used to make incense sticks. Roses are also converted to manufacture rose water. Everyday huge quantity of flowers offered to the deity at Chandrika devi temple situated at Kathwara village in Lucknow. The womenfolk of this area, utilized the flower waste and produce several value added products such as incense sticks, dhoop sticks etc. and sell them to the small traders in the village markets, which becomes a source of income for them (Waghmode *et al.*, 2018). The incense sticks manufactured by this way are environmental as well as human friendly.

Conclusion

One of the major causes of environmental pollution is mismanagement of organic waste including temple waste. In India, the organic waste (temple wastes) are randomly dumped which causes different pollution (air, soil, water) and unhealthy environment. Large quantities of waste is generated from the temples. The environment around the temple area becomes polluted and it creates pollution, foul and unbearable gases which influence human health. Biological processes such as composting followed by vermicomposting to convert floral waste in useful organic fertilizer would be of great benefit.

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