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Sustainable Floral Waste Management: Environmental and Industrial Applications

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Abstract—India being a country of many festivals and lots occasions are celebrated round the year which eventually leads to the generation of solid waste. This causes a foul smell when they degrade as well as they pollute the water body causing serious problems. A significant portion of this waste is flower waste, which is discarded after single-use in rituals and events, amounting to around 4.74×10^6 tons per day. Some cities in India are known for temples and pilgrimages and in such cases, the flower waste content is increasing over tenfold. Flower waste can be transformed into a range of valuable products such as biofuel and biogas generation, extraction of dyes and perfumes, and also to produce valuable eco-friendly products like incense sticks, soaps, handmade paper, besides using them for some art and craft techniques. Thus, effective management of floral waste can significantly reduce environmental pollution and can have tremendous potential in the preparation of various ecofriendly products.

Keywords-- Biogas, floral waste, natural dyes, rituals, solid waste, vermicomposting

I. INTRODUCTION

India is a diverse country with many religions; wherein various religious festivals are celebrated throughout the year. Floral offerings are commonly used in religious ceremonies and are a symbol of devotion and reverence. Therefore, temples, gurudwaras, churches, mosques, dargahs, hotels and banquets generate large amount and variety of flower waste. According to many religious beliefs, flowers that are offered during prayers are sacrosanct and cannot be dumped into the garbage once they have wilted. This is one of the reasons why people prefer to discard them in rivers, lakes and other water bodies. Dumping of flowers in water bodies or open landfills consequence in environmental hazards (Singh et al., 2013). Dumping of flower waste in rivers/ponds/lakes results in a threat to the aquatic ecosystem as it decreases the amount of dissolve oxygen. Such kind of activity significantly affect the aquatic organisms (Mahindrakar, 2018). Every year approximately 80,00,000 tons of flowers are dumped in the rivers in India choking them to death.

With the increase of the human population, the number of visitors is also increasing which consequentially contributes to the generation of an enormous amount of flower (Samadhiya et al., 2017). Floral waste degradation is a very slow process in comparison to kitchen waste degradation (Jadhav et al., 2013). As a result, proper and environmentally friendly procedures for flower waste disposal are essential. Flowers like Marigold (*Tagetes* spp.) and rose (*Rosa damascena*) are used to make incense sticks and rose water. Moreover, various other valuable eco-friendly products such as herbal colors, natural dyes, decorative items, paper, food production, compost, medicines, sugar syrup, pigments, biosurfactants, biofuels, bioethanol can also be produced from these flowers (Bhattacharya et al., 2012; Ranjitha et al., 2014; Waghmode et al., 2016). The present study aims to explore the different pathways for the sustainable utilization of flower waste being generated in the various temples and other religious places of India along with the production of valuable products.

II. RESULTS AND DISCUSSION

A. Floral waste management

For successful solid waste management, a generalized framework can be employed (Pujara et al., 2019). This technology could provide integrated solid waste management techniques for extracting various products from municipal garbage, such as compost and energy. Floral waste material has a high chance of recovering various valuable items. When compared to other debris, floral waste material does not require separation and may be simply collected from religious sites (temple, mosque, gurudwara, and church), wedding functions, festival zones, and other cultural programs. Floral waste is collected in India at a rate of roughly 300 tons per day (Sharma and Yadav, 2017).

In India, a considerable quantity of flowers, such as marigolds, roses and carnations are incorrectly disposed at various religious sites, banquet venues, and other festivals.

These flowers are thrown in water bodies such as rivers, lakes, or ponds (because of sacred reason) or open landfills each year, posing an environmental danger. Decaying flowers contain organic material, which stimulates algal growth and lowers oxygen levels in water bodies, posing a serious threat to aquatic species. On the other hand, roadside abandoned floral waste (by flower vendors or otherwise) attracts vectors (Insam et al., 1996) and can be a source of disease transmission as well as worsening of air quality because their decomposition generates greenhouse gases such as carbon dioxide and methane (Sharma et al., 2018).

This floral residue can be turned into value-added items or compost by employing some current scientific procedures, such as the formation of biochar, vermicompost, natural dye, and biogas for industrial application (Singh et al., 2017). As a result, certain more suitable methods for obtaining value items from floral waste are in demand. The large trash generated by ritual offerings in India, such as various types of flowers, leaves, milk and its products, and so on, requires an acceptable management system for efficient disposal (Singh et al., 2017).

1) Extraction of essential oil

Perumal *et al.* (2012) collected flowers from five temples of Chennai, Tamil Nadu and around 2,350 kg of flowers were offered every day. The flowers offered were rose, marigold, chrysanthemum and jasmine. Out of all flowers collected rose petals were shade dried to extract essential oils from them by using a steam distillation process. The chemical components of rose oil were analyzed by GC-MS technique. 54 compounds were found out of which phenyl ethyl alcohol was recorded as a major component (23.19%), then by octadecane (10.49%), hexadecane (7.76%), phenyl ethyl decyl ester (5.77%) and tetra methyl trisilocen decanol (3.45%).

Naquvi *et al.* (2013) analyzed the volatile oil of *Rosa damascena* obtained by hydrodistillation of the petals using gas chromatography and gas chromatography/mass spectrometry method. It was observed that variation occurs in hexacosane, octacosane, octadecanoic, nonadecane, patchouli alcohol and t-cadinol and concluded that the variation of oils depends on their genetic variations, geography, time of collection, stages of plant growth and seasonal and environmental factors.

2) Extraction of Natural Dyes

Flower waste can be utilized in making dyes for the dyeing of clothes i.e. cotton, wool and silk on an industrial scale Vankar *et al.* (2009).

Marigold (*Tagetes erecta*) petals which mainly consist of carotenoids-lutein and flavonoid-patuletin are used, these colorants were identified, isolated and used for dyeing textiles. Innovative dyeing showed good results on textiles. Pretreatment with 1-2% of metal mordant and 5% of plant extract was found to be satisfactory and showed a very good result to dye cotton, wool and silk.

Rosa species were used for extracting and analyzing the essential oil (Khan and Rehman, 2009). Various parameters were assessed such as oil yield, color and other physical and chemical properties of *Rosa damascena* and *R. centifolia*. From their study, it was concluded that the aroma constituents of essential oil have quantitative and qualitative differences in chemical composition. Saffron flower petals were used to extract dye for application on the Pashmina shawl (Raja *et al.*, 2012). The extracts are then applied on Pashmina wool at two different pH (4-5 and 7-8) with and without the use of mordant. The results showed that saffron flower waste extracts were able to dye the Pashmina shawl with very good washing and light fastness properties. Natural dyes from the flowers of hibiscus and marigold and dyed them on the cotton and cotton/silk blended fabric with the help of different natural mordents like alum and ferrous sulfate (Teli *et al.*, 2013). And concluded that the dyes thus extracted show very good potential to dye cotton and cotton/ silk blended fabric.

Approximately 1450 tons of flowers (Rose, jasmine, marigolds, chrysanthemum, hyacinth, hibiscus and tuberose) are being offered to the deities in various temples all over the country (Ravishankar *et al.*, 2014). For the extraction of dyes, flowers were dried and ground and were dissolved in solvents such as ethanol, methanol and hexane. While for the extraction of essential oils, the soxhlet apparatus was used. A mixture of fresh flower and suitable solvent were heated and put in soxhlet apparatus and the distillate obtained gives the desired product. They concluded that the dye thus extracted gives satisfactory results and can be used on clothes. Various biodegradable temple waste and household wastes contains natural dye (Singh *et al.*, 2017). The extracted natural colors were produced by ultrasonication and then dried in the spray drier. They were used for the dyeing of various fabrics such as cotton, silk and wool and the remaining residue, left after dye extraction, was rich in nutrients and reported that it can be further used as the resource material, itself.

In Indian temples and other religious buildings, marigold (*Tagetes erecta*) flowers contribute significantly to floral waste. Marigold is used as a natural textile color because it contains carotenoid- lutein and flavonoid-patuletin.

Pre-treating silk, wool, and cotton with 5% plant extract and 1-2 percent metal mordant yielded a strong coloring agent for silk, wool, and cotton. The extraction of carotenoids and flavonoids from dry marigold flowers using ethanol and a new solvent allows for selective extraction. Kusum flower (*Carthamus tinctorius* L.) is used to remove natural colors so that it can be utilized as a taste enhancer in food items (Zohary et al., 2014). Hexane, methanol, and ethanol solvents are used to dissolve dried and ground flower waste in the extraction of dyes, while oils are extracted via distillation. Extracted dyes can be used as a coloring agent on clothing (Yadav et al., 2015). The by-product of the dye extraction process can be converted into an efficient absorbent or biochar, which can be utilized to treat water and enhance soil quality (Singh et al., 2018).

3) Production of vermicompost

Residents in India's most sacred places, such as Varanasi, Haridwar, and others, used to throw tones of offered flowers in the Ganga River, which aided the proliferation of disease-causing organisms and contributed to the filthy banks. Converting floral wastes into nutrients and humus-rich organic compost by aerobic composting was proven to be a major strategy as a solution to manage this problem and control negative environmental consequences (Singh and Sharma, 2002). Vermicomposting is a biotechnological process for floral waste management since it involves diverse soil microorganisms and earthworms converting organic waste into usable fertilizers (vermicompost) that enhances germination, plant growth and thus overall crop yield (Singh et al., 2013). Vermicompost has been recommended as an agriculturally useful material with little contamination and higher water holding capacity.

A microbial consortium for the effective degradation of flower waste generated from temples. The soil samples were collected from the areas near and around the temples and isolated bacterial cultures from them (Jadhav et al., 2013). Flower waste collected was dried and mixed with agar medium and streaking was performed with selected soil samples for isolation. It was observed that microbial consortium enhanced the digestion of the waste and the bio-manure consortium was found to have good quality without posing any harm to the environment. Thus, vermicomposting of temple flower waste is an excellent and ecofriendly method to get valuable products which will lead to a healthier and waste free environment.

Organic waste from agro-industries, sewage sludge and animal compost (dung, fodder residue) are all important sources of raw material for vermicompost.

By using mechanisms such as Phosphorus dissolution in the soil and nitrogen fixation from the atmosphere, these bio fertilizers help to boost crop output in a desired way without causing harm to the soil. The organic waste is a rich source of cellulose, hemicellulose, and lignin, which can be decomposed quickly using extremophiles such as *Pseudomonas* sp. and *Bacillus subtilis*, reducing the time spent in different stages of decomposition (Pan et al., 2012). The extremophiles present in floral waste can shorten the time it takes for organic wastes to reach the thermophilic phase of decomposition (Rathinam and Sani, 2018).

An approach has been developed to optimize the quantity of flower waste and determine the maturity during the vermicomposting of flower waste by using response surface methodology (Sharma et al., 2018). *Eisenia foetida* was used for vermicomposting of flower waste with cow dung. The experimental finding shows that compost obtained from the vermicomposting of flower waste and cow dung contains sodium, potassium and phosphorus and these are beneficial for plant growth. The compost is suitable for organic manure which reduces the quantity of waste by converting it into valuable products.

4) Production of Biogas

Success has been achieved in producing biogas from floral waste (*Chrysothemis pulchella*, *Markhamia lutea*, *Hibiscus sabdariffa*, *Peltophorum africanum*, *Albizia julibrissin*, and *Jasminum*) and vegetable residues (carrot, brinjal, lady finger, cabbage etc.) along with cow dung as inoculum (Ranjitha et al., 2014). Biogas produced from floral waste had a lower decomposition time of 16.7 g/kg, while biogas produced from vegetable waste had a lower decomposition duration of 9.1 g/kg. Furthermore, most flowers in India are appropriate for biogas extraction, and this will create a sustainable concept of wealth from waste (Yadav et al., 2015).

Biogas was created utilizing safflower (Kusum flower)-based lignocellulosic waste in an experiment (Hasan et al., 2019). It is cost-effective as well as proven to be suitable for biogas extraction via anaerobic breakdown of organic waste. Superior quality compost produced as a by-product of anaerobic digestion, on the other hand, may reduce the risk of air and water quality degradation (Divya et al., 2015). Biofuels such as methane and hydrogen can also be produced from many forms of lignocellulose-rich waste materials. However, compared to hydrogen energy production, methane production from such waste is more cost-effective. These types of wastes are abundant in agriculture related businesses, and creating bioenergy from them would be a valuable resource (Diaz et al., 2017).

The studies shown that waste flowers of Dahlia to produce sustainable biofuel using four kinetic models, can be exploited to release a significant quantity of bioenergy. As a result, it is clear that, as compared to other plants, silk tree mimosa and African wattle have a huge capacity to supply organic fuels. This study, on the other hand, reveals that flower waste can also be used to generate electricity for better use. Flower waste from temple has been utilized to determine the biogas yield production (Prasad et al., 2011). Tests were conducted in control by following parameters such as pH, temperature, Retention time, Moisture content, C/N. Biogas production was achieved in 10 days in a single-phase lab-scale reactor under ambient conditions. The pressure of biogas was 0.44kg/cm² in the reactor.

Rose flower residue has been used for biogas production and analysis of nutrient reduction potential under anaerobic digestion in a batch reactor (Kumar and Swapnavahini, 2012). 2.5 L batch reactor was used which was filled with rose residue and kept for digestion for 30 days retention period at room temperature. Various parameters like Total Solids (TS), Volatile Solids (VS), Chlorides, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Kjeldahl Nitrogen (TKN) were analyzed at 5 days interval. The process removed up to 73%, 45%, 82%, 42%, 58% of TS, VS, chloride, BOD, TKN respectively along with the production of biogas.

Success has been achieved in production of methane gas as a result of anaerobic digestion of flower waste (Singh and Bajpai, 2012). For this, gas chromatographer was used to determine the quality of gas produced and it was conducted in cold atmospheric conditions in Lucknow. They concluded that the process eliminates the pollution effects caused by flower disposal and also removed pollutants like BOD and TS and produced biogas in the process.

Biogas has been generated using vegetable and flowers waste using 1L capacity anaerobic digester and cow dung as inoculum in the laboratory (Ranjitha et al., 2014). The comparison showed that flowers produced a higher yield of biogas i.e., 16.69 g/kg than vegetable waste i.e.9.089 g/kg and the digestion period of flowers was less. It has been concluded that flowers are very good feedstock for biogas production and the generation of biogas from these flowers can turn waste into wealth in enhancing sustainability.

5) *Production of Handmade Paper*

Temple flower waste can be used as a sustainable source of raw material for the manufacturing of handmade paper (Yeboah, 2011). This method not only reduces the amount of rubbish generally wasted from city temples, but it also recycles and reuses it as a raw material for environmentally beneficial paper production.

Handmade paper manufactured from flower waste has a number of advantages, including being 100 percent wood and chemical-free, as well as producing no harmful by-products throughout the manufacturing process. As a result, the concept of reducing, recycling, and reuse can be utilized to produce handmade paper from floral waste. The difficulty of disposing of flower trash can also be solved.

B. *Production of miscellaneous products from floral waste*

Certain flowers can be used to create natural nanoparticles for use in modern medical sciences (for example, breast cancer treatment, gastrointestinal disorders, pancreas diseases etc.) since these nanoparticles have antibacterial and antifungal properties (Bachheti et al., 2020). Similarly, biochar was obtained from the blossom of *Cotinus coggygia* L. through carbonization method using chemical stimulation (Li et al., 2020). Biochar was obtained and employed as supercapacitors to improve the characteristics of an electrode.

III. CONCLUSION

Improper disposal of solid waste material has become a global issue. Solid waste mainly includes municipal solid waste. However, about 50% of the total solid wastes are organic. Floral residues are also a valuable organic waste material that can be converted into useful products including natural coloring agents, vermicompost and biofuels. Temple waste flowers make significant environmental and human health impacts. Floral waste can not only be disposed safely in an environment friendly manner but can also be utilized for making diversified products. Floral waste utilization would eventually be beneficial to the society as people would get to live in a clean and a healthier environment.

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