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CHALLENGES AND OPPORTUNITIES OF WASTE MANAGEMENT FOR SUSTAINABLE DEVELOPMENT

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Abstract: The rising quality of life and high rates of resource consumption patterns have had an incidental and negative impact on the environment - the generation of wastes far beyond the handling capacities of governments and agencies. India generates about 68 million tonnes of food waste every year. This number goes up to about 350 million tonnes when we talk about agricultural waste. The world needs eco-friendly products which minimize the current damage to the environment. Hence, using residues to make useful products, not only helps in waste management but also is a way of greener production. Producing paper from agricultural wastes promotes afforestation. On the other hand, the production of bioplastics from food wastes not only saves the land from pollution but also helps in protecting the atmosphere from toxic chemicals which are released from burning plastic products. At last, the production of essential oils from dry leaves is an innovative initiative to make the best out of waste. This review summarizes research and studies on sustainable waste management with an emphasis on the challenges and opportunities present today. Various methods have been described to manage the waste from dry leaves, food, and agricultural residues to essential oils, bioplastics and paper respectively. This ensures saving the environment and moving towards a world of sustainable development and minimal wastage.

Keywords **- Waste management, Bioplastic, Paper, Essential oils, Sustainability**

I. INTRODUCTION

The world is witnessing tons of environmental issues that are slowly becoming a threat to human and animal life. Among such adverse problems, waste management is a growing concern. The world generates 2.01 billion tons of municipal solid waste annually, and at least 33 percent of that is extremely conservative and not managed in an environmentally safe manner. Looking forward, global waste is expected to grow to 3.40 billion tons by 2050. Improper management of solid waste is represented by a low collection rate of waste, waste accumulation on pavements, illegal dumping or burning of waste [1, 2]. Unrestricted waste disposal generates heavy metal pollution occurring in the water, soil, and plants [3]. Open burning of waste causes CO, CO_2, SO, NO and other pollutant emissions thus enhancing environmental contamination. Hence, solid waste mismanagement is the cause of acute environmental and social impacts, which do not allow improvements in sustainable development [4, 5, 6]. Globally, the major constituents of solid wastes are agricultural wastes and food wastes. Most agro-industrial wastes are untreated and misused, it is disposed of either by burning, dumping, or unplanned land filling. The untreated wastes create different problems by increasing the number of greenhouse gases [7]. Food losses and wastes are generated throughout the food chain and the FAO estimates that the annual global volume of food wastage generated has a carbon footprint of 3.6 Gt of CO_2 eq [8]. Solid waste management is an important service for urban society and has attracted remarkable attention from experts [9]. Managing solid waste requires unified assessments and holistic approaches for finding a viable solution. Achieving economic growth and sustainable development involves reducing the global ecological footprint, changing the way of produce-consume-waste of goods and resources. The global waste management aims at improving sustainability by 2030 and is to ensure adequate, safe, and affordable solid waste collection services; to stop uncontrolled dumping and open burning; to attain sustainable and environmentally friendly management of all kinds of wastes, particularly the hazardous ones [10].

Different kinds of wastes are treated in different ways, which are decided based on their form, composition, and quantity. Once treated, waste is disposed of by using processes that are the least harmful and environmentally friendly. Solid waste is dumped into landfills or is incinerated, it may also be subject to pyrolysis or composting [11]. Now, the waste which is not harmful to the environment is used as feedstock for animals, a primary supplement of agricultural manure, a resource for the production of sustainable products [12]. Through the years, the importance of reusing and recycling waste has been understood. Although using renewable energy and recycling took us to newer heights, the severe effects of improper waste management continue to degrade

the environment [13]. And hence, new ways and technologies are being introduced to several uses of resulting fiber several concerning as much waste as possible. It is our moral duty, as the humans of this generation, to start a sustainable movement for the betterment of this world. Therefore, the novelty in the review presented in this article is focused on the unified assessment of major sources of waste and conversion processes of the following waste into sustainable products with an emphasis on challenges and opportunities.

a. Agricultural waste to paper
b. Food waste to bioplastics
c. Dry leaves to oil

The paper is divided into three main sections: the first scrutinize the environmental impact due to unsustainable management of dry leaves, agricultural waste and food waste; the second is focused on techniques for converting solid waste to sustainable products. The last section is a discussion on current and future challenges of waste management with possible solutions. Finally, according to the literature review, some suggestions are explored.

II. ENVIRONMENTAL IMPACTS OF UNSUSTAINABLE WASTE MANAGEMENT

(i) Agricultural waste:

Agricultural waste is defined as "the outcome of agricultural production following the different harvesting activities". The word 'Waste' normally highlights "something around us which should be recycled, reused, reduced or even eliminated, if possible" [14]. The factors responsible for increased agricultural production include technological advancement toward green revolution and expansion of soil for agricultural production. Every step of agricultural production, processing, and consumption generates quantities of agricultural solid wastes, depending on the type of agricultural product, processing techniques, and purpose of use (Figure 1).

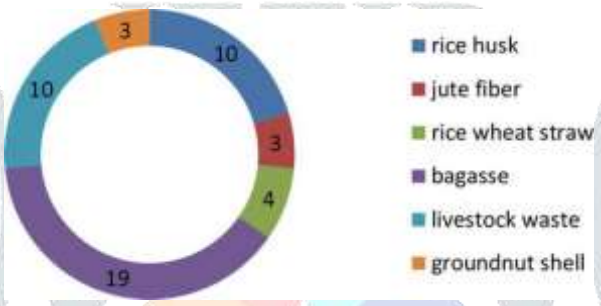

Figure 1: Agriculture waste percentage from different sources [15]

Agricultural waste contributes to a number of considerable environmental issues that cause environmental degradation including-climate change, deforestation, biodiversity loss, dead zones, genetic engineering, irrigation problems, pollutants, soil degradation, and waste. The burning of wastes such as straw and livestock dung has led to a series of environmental problems. The increasing quantity of waste and its inappropriate removal especially in developing countries has always been a pressing concern for the safety of the environment's health and alongside, amplifying the contribution of these countries in the global GHGs emission [16]. Because of agriculture's importance to global social and environmental systems, the international community has committed to increasing sustainability of food production as part of Sustainable Development Goal 2: "End hunger, achieve food security and improve nutrition and promote sustainable agriculture. As indicated by the research, all agricultural wastes have incredible potential benefits. Thus, the effective transformation of these wastes, recycling, and utilization is very significant in the control of environmental pollution and GHGs emission. There is an urgent requirement for activating the most suitable methods for converting agricultural wastes into economic and valuable products. These materials can add immense value to crops and productivity, energy saving, enhancing the environmental quality, and increasing the rates of self-sufficiency [17]. Although agricultural waste can be used as feedstock for animals and manure for soil fertility, with a subsequent rise in waste, new techniques have been discovered to ensure its proper disposal and usage. Now, it is being recycled into several products such as paper, therefore leading to tree-free paper production by indirectly reducing deforestation and promoting eco-friendly methods of production.

(ii) Food waste:

Food waste is a major contributor to greenhouse gas emissions (GHG) and therefore a significant cause of global warming. Therefore, the management of food waste can play a key role in the reduction of preventable emissions associated with food waste. Food waste accounts for 50% of the total solid waste produced in some countries [18]. Fruits, vegetables, root and tuber fruits (about 45% of food grown), fish and seafood (35%), and cereals (30%) are the most wasted. Loss of food is defined as a "reduction in the quantity or quality of food. In the opinion of several authors exists specific classification for food loss and food waste [19, 20]. Food losses are mainly due to poor technology and investments. Food waste ends up misusing nearly a quarter of the water supply in the form of uneaten food or over $172 billion in wasted water. Managing food waste is crucial as it in turn helps in reducing energy requirements and water resources [21]. The global food system is responsible for up to one-third of all human-caused greenhouse gas emissions, making it one of the largest contributors to climate change (Figure 2).

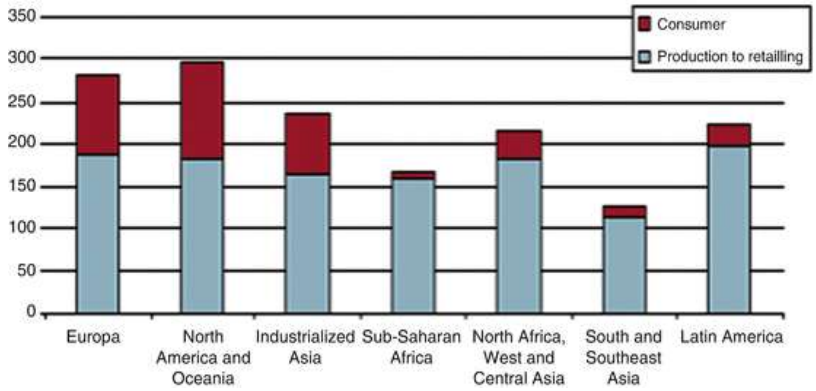

Figure 2: Per capita food losses and waste (kg/year) [22]

Over the last few decades, food waste has gained the attention of environmental associations, policymakers, analysts and researchers [23]. The FAO has implemented a project called Food Wastage Footprint (FWF), which illustrates that reducing food waste is a logical priority to create more sustainable ways of producing and consuming food and providing a global overview of the environmental footprint along the food chain. There are various food waste treatment options that can be explored, such as pyrolysis which produces solid biochar and biogas with anaerobic digestion, produces digestate water, biogas, syngas (through gasification) [24, 25]. In addition to other methods, land filling, incineration and composting are common methods used to treat food waste. Reducing food waste is not just about disposing but also recycling and using it as a major source for the production of various useful products (Eg: Bioplastics). The motivation behind this procedure is that it solves two major environmental problems in one shot- when food wastes are being processed and converted, they need not be wasted or dumped in landfills; hence reducing any sort of pollution caused by them. Secondly, replacing plastics (especially single-use plastic) with bioplastics minimizes pollution and causes close to no harm to the environment. Even in the case where it might be thrown away in water bodies or on land, it will simply degrade.

(iii) Dry Leaves:

One of the largest constituents of municipal wastes is dry leaves and fallen leaves. The burning of leaves leads to air pollution, health problems, and fire hazards. Stubble burning is considered to be one of the major contributors to air pollution especially in South Asia (Figure 3). It is a significant source of gaseous pollutants such as carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and methane (CH_4) as well as particulate matters (PM10 and PM2.5) causing serious damage to human health and the environment [26]. Leaf smoke consists of hazardous chemicals such as carbon monoxide, that mix with hemoglobin in the bloodstream, and can reduce the amount of oxygen in the blood and lungs. Another poisonous chemical commonly present in leaf smoke is benzo (a) pyrene, which causes cancer in animals and is believed to be a major cause of lung cancer. Burning dry leaves in the soil can change the structure of the mineral soil because of the elevated temperatures of the fire. When the fires take longer, they will ignite organic matter in the soil as well as alter the structure of soil clays. The main effect of burning leaves on the water resource is the potential for increased runoff of rainfall. When surface runoff increases after burning, it could carry suspended soil particles, dissolved inorganic nutrients, and other materials into adjacent streams and lakes, reducing water quality. Dry leaves are a great source for the production of essential oils. Ayurvedic oils have always played a prominent role in Indian history but nonetheless, this technique is now being put to use in order to find efficient applications of dry leaves as a resource.

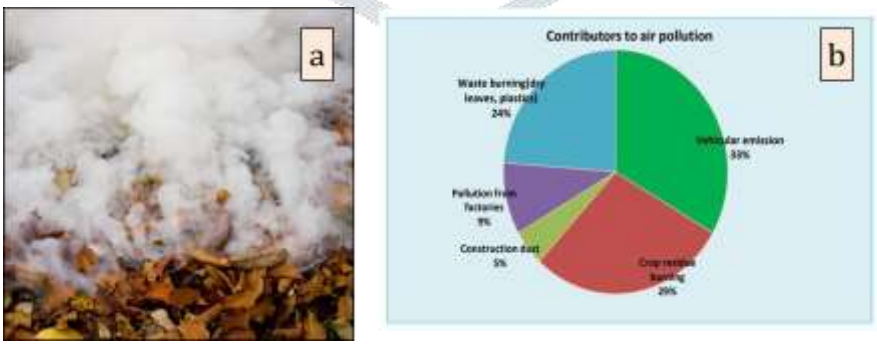

Figure 3: (a). Burning of dry leaves; (b). Major contributors to air pollution

III. TECHNIQUES FOR CONVERTING SOLID WASTE TO SUSTAINABLE PRODUCTS

Waste Management refers to the collection, transportation, processing, recycling, reusing, or disposal of materials that are not of direct use. Solid waste management is an elaborate system including collection, transportation, pre-treatment, processing, and final abatement of residues. These processes are a basic prototype that is followed to treat all waste. However, the final steps are taken based on how this waste is utilized. For example-in cases where it has to be reused, it is processed according to requirements and converted to new products, usually by the most environmentally friendly methods. The way waste is treated also depends on its type and source; some of the common sources of wastes are: domestic wastes, commercial wastes, ashes, animal wastes, biomedical wastes, construction wastes, industrial solid wastes, sewer, biodegradable wastes, non-biodegradable wastes,

and hazardous wastes. In this paper, we focus on solid waste, mainly food and agricultural waste. We discuss the useful products that can be made from three different categories of waste and the methods followed.

(i) Agricultural waste into papermaking:

The consumption of paper and its byproducts is a yardstick of the development of a society or a country and its use is absolutely crucial in our daily life. There are several challenges faced by the Indian paper industry, among these is the scarce availability of quality raw material. The raw materials used in papermaking are classified into three groups: wood (31%), non-wood (22%), and recycled waste paper (47%). Owing to the growth in the global demand for fibrous raw materials, shortage of trees in many countries, and growing sustainability consciousness, agricultural residues have become one of the most important substitute resources. The current applications of non-wood plant fibers such as rice straws, corn stalks, cotton stalks, and bagasse play a chief role in increasing paper-making raw materials [27]. Production of pulp and paper from non-wood materials includes many benefits compared with wood, such as ease to form pulp, good-quality bleached pulp, and excellent sources for special types of paper (Figure 4).

Figure 4: Potential non-wood fiber sources for papermaking
(a. bagasse, b. wheat straw, c. cotton stalks, d. corn stalks)

The properties of paper are dependent on the structural properties of the fiber network and the strength of individual fibers. The cellulose content in most non-woods is comparable to that of woods commonly used for papermaking, while the lignin content is much lower than in woods. Hence, the delignification of non-woods is relatively easy and consumes fewer chemicals [28]. In India, sugarcane bagasse (Saccharum officinarum) and wheat straw is found to be a promising alternative to wood in papermaking because of their low cost, longer fiber, low refining energy consumption, good sheet formation, and paper smoothness [29]. Wheat straw is a good fiber material, produced annually worldwide. It has a much shorter growing cycle than wood. Pulp from wheat straw can be used for manufacturing various paper product grades, such as liner board, corrugated medium, writing and printing papers, etc (Table 1).

Table 1: Strength properties of non-wood pulp fibers [30].

Parameter	Bagasse	Wheat straw
Burst index, kPa m^2/g	4.0	4.30
Tensile index, Nm/g	68.5	74
Tear index, mNm^2/g	4.10	3.80

The studies on pulping of non-woods materials like bagasse were reported by various researchers [31, 32]. This pulp is produced from materials of non-wood using Mechanical, Chemical (kraft) and Chemical thermal mechanical pulping (CTMP) methods. Kraft process is predominantly used around the globe for chemical pulp production. Kraft process can even tolerate species with bark. It utilizes NaOH and Na_2S as active chemicals. The aqueous solution of required chemicals i.e the white liquor is used. The delignification occurs with the cleavage of β-aryl ether linkages that degrade and dissolve the lignocellulose components, followed by the liberation of the fibers [33]. Neutralizing of organic acids is achieved by reaction of NaOH with lignin and resins of wood. The principle of Mechanical pulping is mainly to separate fibers from one another by mechanical energy that is applied to the matrix of wood that causes gradual breakage of bonds between the fibers resulting in the release of single fibers, fiber clusters and fiber fragments. Chemical pre-treatment is used to overcome some of the stated problems concerning mechanical pulping. The procedure starts with the penetration of 2-5% sodium sulfite and chelating agents of a pH of 9-10. This mixture is then heated for 5-10 mins at 120-130^oC and is thoroughly refined. The yield ranges between 86-90%. The chemical pretreatment of the wood chips allows lignin sulfonation which causes swelling and weakening of the lignin matrix, consequently separating fibers from the wood to result in a higher and longer fiber consistency, with lower fine content.

(ii) Food waste into Bioplastics:

According to the National Food Waste Baseline in the year 2016-2017, 7.3 million tons of food was generated, which is equal to a volume of 13,000 olympic sized pools. Now, this food waste decomposes in landfills leads to the release of greenhouse gases like carbon dioxide (CO_2) and methane. The large quantities of food waste are a burden if it is not disposed of appropriately and thus, to resolve food waste issues, implementation of biorefinery procedures is essential. The adoption of such a process (eg: volarization) can result in the production of value-added products while reducing the trash. Production of bioplastics from food waste (cassava Peel, banana peel, jackfruit seed, orange peel, etc) was found to be more prospective and offer a wide scope of applications (packaging, agriculture, gastronomy, consumer electronics, and automotive) (Table 2).

Table 2: List of food waste, their constituents & its importance in bioplastics making

Food waste	Constituents	Important properties for bioplastics making
Cassava peel	High starch content	Promotes tensile strength of bioplastics (1.37 MPa)
Banana peel	cellulose, starch, pectin, and other polymers	Increases intermolecular bonds in the film.
Jackfruit seeds	Starch, amylose, ash, amylopectin, proteins and fats.	Promotes hard exterior and biodegradability.
Orange peel	Cellulose, pectin, high tensile polymers	Low in density and high in tensile strength

Biodegradable polymers contribute highly towards material recovery, landfills reduction and renewable resources usage [34]. Bioplastics are made from renewable resources such as corn, sugars, potatoes, etc and they are produced by a range of microorganisms [35]. Bioplastics are largely used in the packaging industrial sectors although potential applications are seen in the automotive industry and electronics sector. Bioplastics also play an important role in increasing the revenue generated from renewable crop production which in turn develops bioeconomy. Therefore it can be clearly concluded that bioplastics are going to dominate the plastics industry in the future. For countries that are still developing, the bioplastics sector will create abundant opportunities. Production of bioplastics from waste materials such as soybean, banana peel, potato peel, microalgae, and agricultural waste was found to be more prospective and offer a wide scope of applications (including the medical field). The biodegradable plastics made of soybean can replace petrochemical products for some applications. The two major categories of soybean-derived plastics are namely polyurethane products and polyester thermoset products. When mixed with the respective chemicals, soy polyols rival their petroleum counterparts in terms of durability, strength and often cost [36]. According to research, there are over 31 million tons of orange residue all over the world. About 50% of orange peels are wasted and burnt after juicing which releases harmful gases like CO_2 and greenhouse gases. Peels are also dumped into landfills, where the oil due to rotting peels accumulates into the soil that spoils the health of plants. The techniques employed for the breakdown of orange peel requires high-power microwaves. Orange peel contains cellulose that consists of a high degree of polymerization. This high chain length promotes high tensile strength. Compared to starch, cellulose is more crystalline and can resist higher temperatures before it turns amorphous in water. These characteristics give orange peel-based bioplastic excellent tensile strength & high-temperature resistance [37]. Potatoes contain starch, which is one of the most effective and versatile kinds of polysaccharides. Starch consists of amylose and amylopectin. Starch-based bioplastic plays as a replacement for plastics, giving no negative effects on the environment. Plastic made from potato peel is degradable and can even be also turned into edible oils products [38]. The process of creating bioplastic is to first collect the food waste followed by extraction of the starch making a homogenous mixture through filtration and sedimentation. The starch extracted is then mixed with additives like glycerol (for flexibility), vinegar (to break down the starch molecules) and heated such that glucose molecules are bonded and form polymer chains. Then, the gel-like plastic formed is baked and dried in an oven at 250°F for 30mins. A tensile test is conducted on the plastics using a spring scale and a decay test is done over 10 days.

(iii) Dry leaves into essential oils:

Dry leaves disposal is a recurring issue as the world consists of almost 400 billion trees. These leaves can be used for various purposes like compost making, bonfires, soil fertility fertilizers and a lot more. Dry leaves have various properties that can be put into good use such as the extraction of essential oils. For example.,

a. Stevia leaves- Dry leaves of Stevia consist of diterpene glycosides that contribute to its sweet taste and thus, the use of stevia as a sugar substitute in the production of flour products. The estimation of amino acid composition Stevia leaves showed that their composition includes seven essential amino acids among which the limiting amino acid is valine. During experimental study, it was concluded that they contain sufficient water-soluble, fat-soluble components of vitamins in their composition. Hence stevia leaves are widely used for essential oils extraction.

b. Pimento leaves - Pimento leaf oil is manufactured by distilling fresh/dry leaves. Oil can be extracted using supercritical extraction, extraction procedure with CO2 [39]. Leaves used for distillation can be fresh/withered/dried and stored for 2-3 months before distilling. Yields from dried leaves and fresh leaves are 0.5–3.0 % and 0.3–1.25 %, respectively. Recently, it was reported that the yield of essential oils in leaves and fruits varied from 0.97-1.41% with the major component being eugenol [40]. The leaf oil is a brownish-yellow liquid with a dry, rough, warm, spicy aromatic odor.

Essential oils are mostly a mixture of volatile and natural components produced by aromatic plants as secondary metabolites. Many factors influence its yield, chemical composition like plant organs and their developmental phases [41]. A few factors that can influence volatile emissions are the damages to leaves by mechanical, chemical, as are the areas, or biotic injury [42]. Herbivory is the biotic injury that affects chemical composition causing any effect on essential oil yield [43]. Some of the most common methods used to extract oil from plants are steam distillation, hydro distillation and maceration processes. In the Steam distillation process, steam is passed from the inlet channel through the raw material containing the oils which are needed for extraction and then the plant's aromatic molecules are turned into vapor (Figure 5). The vaporized aromatic compounds travel into the condensation flask where these vapors condensed and liquid form is attained. These aromatic liquid byproducts drop from the condenser and are collected at a place underneath called a separator. As water and oils don't mix, the oil is siphoned off.

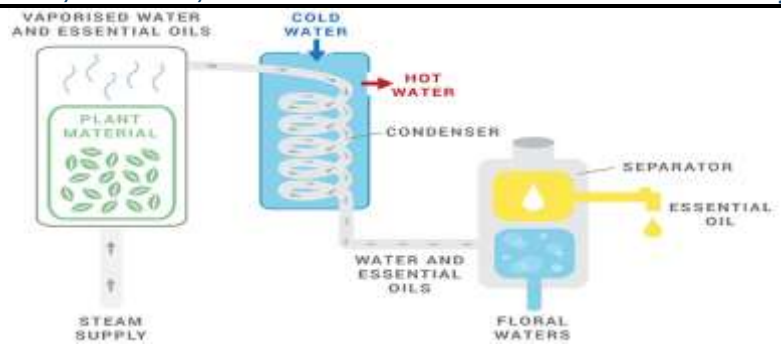

Figure 5: Steam distillation process for extraction of oils from dry leaves

In hydro distillation, steam is injected into the plant charge. Due to hot water and steam application, the essential oil in the plant tissues is freed from the oil glands. The vapor mixture of water, oil is condensed by indirect cooling with water. Now from the condenser, distillate flows into a separator, where the oil separates from the distillate water. Macerated oils are also referred to as infused oils, they are produced when carrier oils are used as solvents for extraction of therapeutic properties of plant materials. This process is beneficial as it traps the essence of plants which are usually heavy and larger compounds that are not usually collected in distillation processes. The oils extracted are close enough to the real benefits of plant materials without losing their originality. In the maceration process, the dry leaves are crushed, turned into a coarse powder, and placed in a closed vessel. Solvent (Menstruum) is added where the mixture is allowed to settle for 1 week with occasional shaking. The liquid is strained, solid residue (Marc) is pressed out to recover any remaining liquid. The strained and expressed liquids are now mixed. After which, liquids are clarified (separated) with filtration or subsidence.

IV. CHALLENGES AND OPPORTUNITIES OF WASTE MANAGEMENT

The world faces major environmental challenges associated with significant waste generation and inadequate waste collection, transport, treatment, and disposal. Current technologies and systems are unable to cope with the volumes of wastes that are generated due to the increasing urban population and their effects on the environment and human health. The main challenge of using agro residue for papermaking is that, if pulped by strong alkali, the silica dissolves in the pulping liquor and reprecipitates on process equipment in the liquor recovery operations. Evaporator tubes can be plugged and lime mud setting rates seriously disturbed by silica. Also, agricultural production requires high inputs for growth, thereby contributing to climate change problems. Another major problem of non-wood fiber pulping is the significant variation in their chemical and physical properties compared to wood fiber. On the other hand, a major advantage of agricultural residues is that they are widely distributed in the country. The benefits of non-wood plants as fiber sources are their fast annual growth rate and smaller amounts of lignin compared to wood. Also, non-wood fibers such as agricultural raw materials can be pulped with lower chemical charges. Short fiber length with high content of fines and low bulk density are the very important features of agricultural residues [44, 45].

The emission of greenhouse gases like methane and carbon dioxide, while bioplastics are degrading, is very large at landfill sites. This can be handled by designing plastics so that they degrade slowly or by collecting the methane released and using it elsewhere as fuel. The concept of materials coming from nature with environmental advantages is very attractive to the industry and the consumers. Bioplastics play a crucial role in the packaging industry, agriculture sectors, gastronomic sector, consumer electronics, and automotive industry. Biodegradable plastics are usually understood as the possible solution for waste disposal and utilization but biodegradability is just an additional feature of the material to be exploited. They should be used priorly for applications that demand a cheap way to dispose of the item after it has fulfilled its job (e.g. for food packaging, agriculture, or medical products). Dry leaves are the essential 'browns' or carbon ingredients that turn organic waste into compost. When dry leaves are left to decompose on the forest floor, they break down into rich, compost-like humus that retains moisture and shelter a variety of microorganisms that are beneficial to the soil. Non-biodegradable plastics cause pollution when burnt and take a long period to decompose and thus, the focus is put into the utilization of disposable materials made from plant leaves, which are renewable and biodegradable, enriched with antioxidants and medicinal values. The extraction of oil from dry leaves has gained a lot of momentum recently and has opened up new opportunities in the global production of renewable oils. But, extraction of essential oils is usually expensive because of the large amounts of raw material required for the production of a few milliliters of oil. These commercial processes for the extraction of oils involve high consumption of resources such as water, heat, electricity, etc. Careful management of resources should be taken into supervision to avoid wastage of resources. Regular inspections of processing plants and equipment are done to avoid higher risks and damage.

V. FUTURE SCOPE

The current generation is in greater need of sustainable products which do not damage the environment. Usage of biodegradable raw materials for the production of biodegradable products helps the environment. The promotion of tree-free paper reduces global warming, greenhouse gases, soil erosion. Trees promote health and social well-being by omitting air pollution, encouraging physical activity, and promoting social relationships with the community. Trees also promote a strong economy and provide several resources to the people. While cities are getting hotter, trees help in the reduction of urban temperatures. They provide habitat and food for animals. On a wide aspect, methods of waste to paper play an important role in saving the environment and pursuing sustainable development.

Bioplastics can be replaced with conventional plastics in various applications which can be used in sectors like food packaging, plastic plates/cups, cutlery, plastic storage bags/containers. Materials we are buying can help majorly in making the environment sustainable. Bio-based polymers are more similar to conventional polymers than ever created before. Currently, biobased polymers are commonly found in applications that include commodities to high technology applications because of advanced research development in biotechnology and social awareness. Applications involve biopolymers in stem cell technology, ceramics, biopolymers in drug delivery, global bio-based market growth of biopolymers, biopolymers in marine sources, etc.

Although extraction of oils from leaves is an ongoing research area, it has numerous benefits. Humans can easily get access to therapeutic substances without oral consumption of healing plant material. It can be seen in medical basis procedures, pharma industries, ayurvedic industries, bio-medical products production, physio-therapeutic advances, etc. Dry leaves, Agricultural & Food waste are zero-value and non-consumable resources. In this context employing well-structured and efficient technologies such as distillation of dry leaves to extract oil, pulping of agricultural residues for papermaking, and valorization of food waste for making bioplastic can be attractive and viable approach to counter the current global energy crisis and in establishing a sustainable bioeconomy.

VI. CONCLUSION

This paper focuses on sustainable development and making the best out of waste. Extensive waste products are seeing the light of day because of industrialization, increase in population, and increased production of goods. This has led to overfilling of landfills and pollution that is resulted from the improper disposal of waste materials. Hence, using residues to make products that are useful not only helps in the proper use of waste but is also a way of greener production. In the paper, we have reviewed numerous methods for the production of materials in ways that are least harmful to the environment and also use up the residual matter. This ensures saving the environment and moving towards a world of sustainable development and minimal wastage.

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