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Study of Different Method of Plastic Waste Management in the Light of Ecosystem Balance

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Abstract: *The present study is related to different method of plastic waste management in the light of ecosystem balance. Plastic waste has become a major environmental concern, causing pollution in both land and marine ecosystems. As a result, plastic debris is accumulating in landfills and natural environments instead of decomposing. This accumulation is causing various environmental hazards and negatively impacting habitats and species distribution. To address this issue, researchers have been focusing on finding effective methods of plastic waste management that promote ecosystem balance. These methods include microbial agents and their metabolic enzymes for polymer degradation and destructive thermal treatments like combustion or pyrolysis. In addition, different countries have implemented varying waste management strategies to tackle plastic pollution. Indiscriminate use of plastics such as polyethylene causes environmental pollution and impacts human health due to irreversible changes in the ecological cycle. The future of plastic waste management research lies in the continuous innovation of recycling technologies, the development of environmentally friendly alternatives, and the integration of social and behavioural considerations in waste management strategies. By addressing these areas, research can contribute to the advancement of sustainable and effective solutions for plastic waste handling, furthering the goal of achieving ecosystem balance and minimizing environmental harm. A comprehensive assessment of plastic management strategies should consider their environmental, economic, and social implications to gauge their overall effectiveness in addressing the challenges of plastic waste. This multifaceted approach will provide a holistic understanding of the impact of plastic waste management efforts and guide future decision-making to further enhance the sustainability and effectiveness of plastic waste handling..*

Keywords: Plastic Waste Management, Ecosystem Balance, Microbial Agents

I. INTRODUCTION

Plastic is everywhere; it is unquestionably the foundation of globalisation. The word "plastic" has evolved into a catch-all for the wide range of materials composed of polymers and additives that may be cast and moulded into a variety of forms. Plastic comes from the Greek word "plastikos," which means "able to be shaped or moulded." Plastics are defined as polymers that can be cast into moulds because they begin to move when heated. All plastic materials—aside from biodegradable bioplastic—come from petrochemicals. Chloride, oxygen, hydrogen, carbon, silicon, and nitrogen make up plastic. Polyethylene, whose basic formula is CnH2n, makes up 64% of all plastic. In 1869, John Hyatt created celluloid, the first plastic polymer, while attempting to find a substitute for ivory. The solvent reaction of camphor on cellulose nitrate at low pressure and temperature produced celluloid. Since this evolutionary discovery, several plastic polymers have been created to further material science and overcome the limitations imposed by other materials such as wood, glass, wool, and cotton. Grand Review Research (2020) estimates that the global plastic market was valued at USD 568.9 billion in 2019 and is expected to rise at a compound annual growth rate (CAGR) of 3.2% between 2020 and 2027. Because they are widely used in consumer products, building and construction, health care, and agriculture, plastics are vital to every economic sector in the globe. They form the foundation of many businesses since they are utilised in the production of a wide range of goods, such as fake leather, tiles, plastic bottles, sanitary ware, defence supplies, and other domestic goods. Food packaging, drug packaging, detergent packaging, and cosmetic packaging are more applications for plastics.

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II. LITERATURE REVIEW

2.1 Plastic

"Plastics are easily moulded into a variety of items with a wide range of uses since they are affordable, lightweight, and durable materials (Hopewell et al., 2009). One of the materials most utilised worldwide, plastics are extensively incorporated into modern life and have a significant impact on nearly every product category. The main qualities that make them so beneficial are their dual qualities of durability and flexibility. When plastics are utilised on a daily basis, these qualities come in quite handy (Hammer et al., 2012).

2.2 Plastic Types

Micro-plastics are tiny (less than 1 mm) plastic particles that result from the breakdown of bigger plastic waste. These micro-plastics have been found in beach and sublittoral sediments globally, as well as throughout the water column, where they have been collecting in the marine environment for decades. It has never been determined, meanwhile, if the presence of micro-plastics in sediments is exclusive to areas where they accumulate quickly, like the continental shelf, or if deep-sea sediments also include them. The deep sea is the most distant marine ecosystem that has ever seen the presence of micro-plastics. Micrometer-sized plastic particles were discovered in deep-sea sediments collected at four separate locations, each of which represented a distinct deep-sea environment with a depth range of 1100 to 5000 m. The findings indicated that micro-plastic contamination had permeated all of the world's seas and oceans, even the deep sea, which is a remote and mostly unexplored area. In the maritime environment, the prevalence of micro-plastics has significantly grown. There is always fresh data about the fate of micro-plastic trash from laboratory and field study. We have seen this trash in all aquatic environments.

Critical analysis was done on at least 101 peer-reviewed publications that looked at micro-plastic pollution. Micro-plastics are often investigated in connection with: (1) plankton samples; (2) muddy and sandy sediments; (3) ingestion by vertebrates and invertebrates; and (4) interactions between chemical pollutants. Based on the information that is currently accessible, every category of marine creature is highly likely to come into contact with micro-plastics. Numerous publications on other pertinent topics (such as polymer degradation at sea, novel laboratory and sampling techniques, developing sources, and externalities) were also examined and addressed. It offers the first comprehensive investigation of micro-plastics' impacts on the marine ecosystem and biota. In response to the current and anticipated trends of plastic usage and disposal, there will be a rise in the quantity of scientific papers.

In a sizable, isolated alpine lake, Christopher et al. (2014) assessed the quantity, location, and composition of pelagic micro-plastic contamination. In Lake Hovsgol, Mongolia, they measured the amount of anthropogenic shoreline detritus and pelagic micro-plastics. Lake Hovsgol has a higher average micro-plastic density of 20,264 particles km^{-2}, which is higher than that of the more developed Laurentian Great Lakes lakes Huron and Superior. The most common forms of micro-plastics were fragments and films; few or no pellets and no plastic microbeads were found. Plastic bottles, fishing gear, and bags were the most common household plastics found in the beach litter. The density of micro-plastic was dispersed by the dominant winds and reduced with distance from the park's most inhabited and accessible area, the southwest coast. These findings showed that low-density people can significantly contaminate freshwater systems with consumer plastics in the absence of appropriate waste management.

With its excellent chemical, physical, and mechanical properties, ability to compare and contrast different PP types and thermoplastics to determine their advantages and disadvantages, detailed explanation of the Dow/UNIPOL PP technology process, and a plethora of reviews on PP applications, polypropylene (PP) is a promising plastic. Among other derivatives, it is discovered that PP accounts for two thirds of the consumption rate of propylene. With a density of 0.90 g/cm^3, polypropylene is the least dense form of plastic. The market shares of homo-polymer PP (HPP) is 65-75%. PP may be filled, branching, and reinforced to create polymers with better mechanical qualities. After recycling, semi-crystalline isotactic polypropylene (iPP) displayed the proper optical properties. The best polymers for electrical applications are BOPP and PP-OH films. Around the world, there are four PP facilities under development and 26 PP plants in operation. Applications for PP include, but are not limited to, sheets, films, textiles, bottles, and automotive items (Hisham, 2016).

2.3 Disadvantages of Plastic Uses

Consequently, throughout the past 60 years, there has been a noticeable growth in the manufacture of plastics. But the way they are now used and disposed of causes a number of environmental issues. About 4% of the non-renewable resource produced worldwide—oil and gas—is used as feedstock for plastics, and an additional 3-4% is utilised to provide energy for the process of making them. A significant amount of plastic manufactured annually is used to create packaging that is thrown away after a year of usage or other short-lived goods. The way plastics are now used cannot continue. Furthermore, due to the long-lasting nature of the polymers involved, large amounts of discarded end-of-life plastics are ending up as waste in landfills and natural environments around the globe (Hopewell et al., 2009).

Since plastics were first produced in large quantities in the 1940s, there has been an increasing concern over micro-plastic pollution of the marine environment. Micro-plastics are ubiquitous and plentiful in the marine environment, with the largest concentrations occurring in mid-ocean gyres and around coasts. Numerous marine species have been shown to consume micro-plastics; this process may make it easier for chemical additives or hydrophobic waterborne contaminants to enter the biota (Cole et al., 2011).

Adane and Muleta (2011) evaluated the use of plastic bags and its effects on the environment. A semi-structured questionnaire was employed to gather information from 230 respondents who were chosen at random. Regardless of age, employment, or level of education or income, the majority of respondents (176, 76.52%) used plastic bags more frequently than any other plastic product, according to the findings. Easy availability (152, 66.08%) and low cost (159, 69.13%) were the primary drivers of these items' widespread use. Of the methods for getting rid of plastic bag garbage, practically every city dweller engaged in open dumping (137, 59.56%) into neighbouring regions. Animal mortality (167, 72.60%), sewer line blockages (162, 70.43%), environmental degradation (144, 62.60%), and issues with human health (119, 51.73%) were a few of the main issues.

Plastics may linger in the environment for a very long time when they are dumped. Plastics can have a major impact on ecosystems because to their toxicity and practically indestructible shape (UNEP 2005; Hammer et al., 2012).

Plastics are under environmental scrutiny and have outgrown the majority of man-made products. But there is a dearth of reliable worldwide data, especially about their end-of-life situation. Humanity offers the first worldwide study of all mass-produced plastics ever made by locating and combining disparate data on the creation, application, and end-of-life management of polymer resins, synthetic fibres, and additives (Geyer et al., 2017).

Up to now, over 8300 million metric tons (Mt) of virgin plastics have been produced. About 6300 Mt of plastic garbage had been produced as of 2015; of that, 9% had been recycled, 12% had been burned, and 79% had accumulated in landfills or the surrounding environment. By 2050, some 12,000 Mt of plastic garbage will be in landfills or the environment if present manufacturing and waste management patterns continue (Geyer et al., 2017).

According to statistics on plastic bag usage provided by Shimran et al. (2017), 50% of participants consistently used plastic bags while they went grocery shopping. Due of its convenience for shopping, 40% of females reported using it occasionally as well as constantly. It was shown that 40% of people constantly use plastic bags, and 20% only occasionally do so because they are ignorant about environmental protection and pollution. The ranking result indicated that the primary reasons people use plastic bags are that they are convenient to use (ranked first), they usually forget to bring their own bags (ranked third), they are generally recyclable (ranked fourth), and they are inexpensive or free (ranked fifth).

Plastic waste is a common, persistent contaminant that sticks to hydrophobic persistent organic materials easily and is very resistant to environmental deterioration. contaminants and is connected to a variety of aquatic creatures' sickness and death. Micro-plastics (MPs) are a common occurrence in the natural environment and are a sign of improper waste management and the ongoing, fast expansion of synthetic plastic manufacture. MP pollution in aquatic habitats is caused by a variety of terrestrial and marine-based processes, including as wastewater treatment plant (WWTP) effluent, agricultural runoff, and residential and commercial drainage. According to Karbalaei et al. (2018), MPs have been found in human food and air samples, and exposure to MPs by ingestion or inhalation may have a negative impact on one's health.

Kumar et al. (2018) found a correlation between the rate of production of plastic garbage and the three socioeconomic categories that were identified: higher socioeconomic group (HSEG), medium socioeconomic group (MSEG), and lower socioeconomic group (LSEG). To determine socioeconomic groupings, four separate socioeconomic

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parameters—total family income, education, employment, and dwelling type—were employed. The chosen homes were given a questionnaire survey, which provided information on the defined parameters. For one week, the homes of all socioeconomic classes had samples of their plastic garbage. In the research region, the percentage of total municipal solid trash created that was made of plastic garbage was 5.7%. LSEG had the lowest rate (8 g/c/d) and HSEG had the highest (51 g/c/d) in terms of the overall amount of plastic garbage generated.

India's pollution control boards reported on the creation of plastic garbage in 2018–19, according to the Central Pollution Control Board (CPCB). The CPCB estimates that in 2017–18, plastic trash generation amounted to about 660,787.85 tons, or enough to load 66,079 trucks with 10 tons each. Over 60% of India's states and union territories do not have conditions similar to this. Currently, incinerators, also known as waste-to-energy (WTE) facilities, are used as a waste treatment method since they reduce the amount of solid waste dumped in landfills and generate fuel from used plastic. Nonetheless, data indicates that WTE systems release a sizable quantity of greenhouse gas emissions.

According to Schwarz et al. (2019), different environmental compartments have different forms of plastic waste polymers and product categories. In their investigation, differences in amount and composition were noted for the product categories and plastic polymer composition among the various environmental compartments. In epipelagic waters, polyethylene and polypropylene were most often detected.

High amounts of other polymers, including polyester and polyamide, were discovered in sediments. Studies have found that most product categories in rivers are packaging goods, even though only 36% of plastics manufactured are packaging products. Conversely, fisheries and aquaculture items dominated the oceans. changes in product size, surface area, and density can account for the changes that occur between compartments. Currents may only carry heavier, thicker plastic trash composed of low-density polymers horizontally from rivers to the ocean. As a result, it is thought that there is not much plastic garbage exchanged between rivers and the ocean, and the majority of the buoyant plastic debris found in rivers and the ocean comes from two distinct sources. A significant portion of the plastic debris is probably going to wind up on beaches or stay in river systems. This distinctive and worldwide perspective on plastic transport in aquatic settings is the outcome of connecting all individual research on various aquatic sub-environments and areas.

Alabi et al., 2019 detailed the many plastics that are produced, their potentially harmful chemical composition, the commonly used disposal techniques, and the overall consequences of these ingredients on land, water, air, animals, and human health in relation to various disposal techniques. Many consumer goods, such as food packaging, water bottles, medical devices, and heavy metals, are made of plastic varieties that include harmful substances like phenanthrene, heavy metals, bisphenol A, brominated flame retardants, nonylphenol, polychlorinated biphenyl ethers, dichlorodiphenyl dichloroethylene, and phthalates. An estimated 8 million tons of plastic are dumped into the ocean each year, degrading the marine environment and eventually having an impact on aquatic life. Toxic chemical components may seep into food, beverages, and water when plastics and plastic goods are used over an extended period of time and exposed to high temperatures. When plastics are burned outside or disposed of carelessly on land, hazardous chemicals may be released into the atmosphere, endangering the public's health.

Additionally, their study offers suggestions for the worldwide avoidance and management of plastic trash.In the Bangladeshi city of Mymensingh, the usage of polythene bags and its effects on the environment were assessed by Uddin et al. in 2019. Two semi-structured questionnaires were utilised to gather information from 100 merchants and 200 randomly chosen consumers. According to the findings, around 35% of customers used five to ten plastic bags every week. The majority of the merchants, or 65 percent, reportedly utilised 50 to 100 plastic bags every week, according to the statistics. Retailers (31%), on the other hand, mostly used plastic items due to a lack of substitute materials, while customers (42%) primarily used polythene bags because they were less expensive. Of the disposal techniques employed, door-to-door deposition accounted for 53.5% and was a common practice followed by nearly all study area inhabitants. Customers stated that the biggest environmental issues were air pollution (91%) and sewage line blockages (88.5%), with the decline of the environment's natural beauty (64%), issues with human health (62%), and a decrease in soil fertility (48.5%) rounding out the list. Retailers, on the other hand, believed that the primary effects of polythene trash on the environment were air pollution (94%) and sewer line obstruction (97%). Other issues included the decline in the environment's aesthetic appeal (64%), issues with human health (76%), and a drop in soil fertility

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(53%). The study's conclusions also suggested that, despite respondents' awareness of the negative consequences of plastic items, the tendency of using polythene bags is growing daily.

Mustafa et al., 2019 also gathered information from 200 randomly selected respondents using semi-structured questionnaires. To emphasise the key discoveries, data analysis was performed on the gathered information, with the results shown in tables and figures. The majority of respondents (162, 81.0%) to their survey reported using plastic bags more frequently than any other plastic product, irrespective of their age, employment, economic status, level of education, or gender.

The primary drivers of the extensive use of plastic bag goods were their easy availability (100, 50.5%) and the dearth of substitute materials (78, 39.0%). Of the methods utilised to dispose of waste plastic bags, open dumping into the surrounding surroundings (110, 55.0%) was the most common method, utilised by nearly all city inhabitants. The primary issues resulting from the pollution created by plastic bags were health issues for humans (115, 57.5%), environmental degradation (114), clogged sewage pipes (90, 45.0%), and animal fatalities (33, 16.5%).

In a study published in 2019, Kaur and Jegannathan employed a cross-sectional research design and a quantitative research approach to evaluate 180 students enrolled in a private school in the Sirmour, Himachal Pradesh, district. The students were chosen using a simple random technique, and the researchers assessed their knowledge of the health risks associated with plastic use. A self-administered questionnaire was used to gather data, and SPSS software was used for analysis. The study's findings showed that, when it came to the health risks associated with plastic use, 52% of respondents had inadequate information, 48% had average knowledge, and none had strong understanding. Teenage girls' age and their awareness of the health risks associated with plastic use were significantly correlated. The study's findings demonstrated that students' knowledge was lacking, which highlights the importance of using interventional measures to raise awareness of the health risks associated with children's plastic use.

Phanisankar et al. state that India has experienced a notable increase in plastic usage and manufacturing by 2020. Consequently, the management of waste plastic collection and discrimination procedures becomes challenging. According to Abdul and Faisal's study from 2021, India produced 9.4 million tons of plastic garbage in 2019, which is less than the world average of around 380 million tons annually. India therefore made up 3.1% of the world's total plastic garbage production.

Figure 1: Segregation of Household Waste by Municipal Workers.

Around the world, the construction industry uses 17% of all plastics produced, compared to 42% used by the packaging industry. In India, the building industry uses 23 percent and the packaging sector 35 percent.An assessment of the key relationships between plastic and persistent organic pollutants (POPs) in India's waste management system was given by Chakraborty et al. in 2022. Certain traits, such longevity, resistance to biological deterioration, and long-range mobility, are shared by POPs and plastics. Throughout the processes of manufacture, use, and disposal, plastics come into contact with and accumulate particulate matter pollution (POPs) and ultimately cohabit with it in the environment. Plastic debris may become microplastics and be carried by air, travel great distances via rivers and seas, or get stuck in landfills and garbage disposal yards. Over time, these plastic wastes leak and emit accumulated POPs due to environmental processes. Smelting, cleaning, and shredding of plastic trash is part of India's informal sector's plastic

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recycling, which is another significant source of POPs that need more research. By enhancing our knowledge of these processes, their research may help policy choices in India to prevent the emission of POPs from diverse waste kinds and processes.

2.4 Plastic Waste Management

Siddiqui and Pandey (2013) reviewed India's methods for handling plastic garbage. Plastics are frequently employed in food and water packaging, as well as in the production of plastic bottles and sachets that are widely used across the nation, especially in metropolitan areas. Nevertheless, approximately 5–25% of waste plastic is recycled. Many Indian cities are overflowing with plastic garbage as a result of the packaging revolution's lack of support from an appropriate strategy for managing plastic waste.

Çepelioğullar et al., 2013 selected two different plastic wastes as feedstocks in order to evaluate them instead of using traditional disposal methods such as landfilling or incineration: polyethylene terephthalate (PET) from daily use and polyvinyl chloride (PVC) from industrial use. As a thermochemical conversion method, pyrolysis, which produces different types of products depending on operating conditions, was chosen as an alternative technique. Pyrolysis experiments were performed with a thermogravimetric analyser from room temperature to 800°C under 100 cm3 min-1 N2 flow at a heating rate of 10°C min-1 in the first part of their study. Using the data collected, thermal and kinetic behaviours were identified, and a suitable temperature was established for the fixed bed trials. With the exception of a final temperature of 500°C, the same raw materials were pyrolyzed in a fixed-bed reactor under the same circumstances to create solid, liquid, and gas products in the second stage. Characterization methods for pyrolysis products included FT-IR, SEM, and GC-MS. The outcomes of the experiment suggested that co-pyrolysis would be a useful technique for figuring out operating parameters and an eco-friendly way to turn plastic trash into useful chemicals.

In order to evaluate the possible environmental effects of current plastic waste management scenarios on a number of impact categories for the research region of Dhanbad, India, Aryan et al., 2019 employed the Life Cycle Assessment approach. The two main plastic wastes examined in this study were polyethylene terephthalate (PET) and polyethylene (PE). The scenarios taken into consideration in their analysis were recycling (denoted by S3), incineration without energy recovery (denoted by S2), landfilling without biogas recovery (denoted by S1), and incineration with energy recovery (denoted by S4). All four scenarios' (S1–S4) environmental effects were evaluated and contrasted.

Using the CML 2 baseline 2000 method, the findings indicated that because recycled PET and PE flakes were used in place of virgin PET and PE flakes, as well as because there were fewer emissions produced during the recycling of these two plastic wastes, scenario S3 had the least environmental impact on the majority of the impact categories. Overall, Scenario S2 had the biggest impact on the ecosystem. In terms of abiotic depletion, abiotic depletion (fossil fuel), and acidification (only PE recycling), S4 performed better environmentally than S3. This study will help decision-makers create more effective plans for managing plastic trash. In 2019, Gwada et al. evaluated the kind and amount of plastic garbage that Watamu ward households disposed of. Data was gathered from homes in four sub-locations within Watamu ward using stratified random sampling.

Descriptive and inferential statistics—the Freeman-Halton version of the Fisher's Exact test—were used to examine the data. Low density polyethylene, polyethylene terephthalate, high density polyethylene, and polypropylene made up the majority of the plastics that households often threw away as garbage (FH=37.959, $p = 0.000$). According to the data, just 0.7% of participants recycled their plastic garbage. Open dumpsites (61.4%) were the most popular way to dispose of domestic plastic garbage, followed by burning (12.9%) and discarding (6.4%). The majority of respondents (93.6%) said they reuse some plastic containers for storing food, water, and oil. Regarding how the respondents recycled their plastic garbage, there was a significant variation among the four sub-locations (FH=36.437, $p=0.005$). In conclusion, recycling is still done on a limited scale even though it has the potential to create jobs, improve the environment, support ecosystem services, and enhance human well-being. However, the present plastic waste disposal techniques in Watamu are not ecologically friendly.

A 2019 research by Leal et al. examined the issues raised by plastic items and the function of extended producer responsibility in Europe.The European Union as a whole and several European countries in particular were reviewing the various policy alternatives to deal with the issue of growing plastic trash. The Extended Producer Responsibility

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concept is one strategy that may be used to lessen the pressures caused by plastic trash. It is regarded as one of the main tools for waste management strategy that helps the European trash hierarchy be implemented.

Its use might encourage the gathering and recycling of plastic-containing waste streams. They gave a summary of the issues raised by plastic garbage and delineated their environmental implications. They talked about the function of the extended producer responsibility concept and offered some suggestions that could be helpful in strengthening it.

The adoption of measures by African nations to lessen the pollution caused by single-use plastics (SUPs) is also on the rise; however, little research has been done on these policies. In particular, West African SUP reduction programmes are reviewed in this research. West African legislation SUP prohibitions, mostly pertaining to plastic shopping bags, are the primary policy tools employed by their nations. Out of the sixteen nations, eleven have implemented prohibitions, one has a market-based tool, and the remaining four have no plan. Penalties associated with bans are severe (fines and jail terms). However, there is little national campaigning, little consultation while bans are being drafted, and little warning (less than a year) between the announcement of the ban and its eventual implementation. Provisions for reusable substitutes are absent. We advise that in order to decrease SUPs, both present and future policies should involve stakeholders and give enough time for publicising the policy before it is put into effect. It is recommended that governments provide low-cost, reusable alternatives (Adam et al., 2020).

The pyrolysis process offers an efficient, hygienic, and functional way to remove plastic debris from the environment and investigate novel ways to convert waste into useful products like petrol, diesel, petrol, and high-speed petrol (Phanisankar et al., 2020).

According to research by Patnaik et al. (2020), the accumulation of plastic wastes makes natural recycling more difficult and time-consuming; as a result, pyrolysis is the most efficient way to recycle these polymers and turn them into energy. The kinetics of such waste plastics are investigated using thermogravimetric analysis at different heating rates of 10°C, 20°C, 40°C, 60°C, 80°C, and 100°C in nitrogen atmosphere, followed by characterization of the pyrolysis products, in order to better understand the pyrolytic behavior of such waste plastics. Using iso-conversional techniques like Friedman, Coats-Redfern, FWO, and Kissinger, the kinetic parameters for the two main phases of decomposition are determined over the temperature ranges of 250–620°C and 620–855. The kinetic equation is well fitted by the regression coefficient data (>0.9) from kinetic plots acquired using different techniques. According to proximate analysis, 74.33% of the component is volatile. For the biodegradable plastic plate with varied conversion (0.1-0.6) and (0.1-0.3), the average activation energy varies between 120.7013 kJ/mol and 140.7707 kJ/mol at two different temperatures. A semi-batch reactor produces pyrolysis products, which are characterised to ascertain their composition and other characteristics.

Due to the abrupt increase in medical waste that has caused a global waste management problem, the Coronavirus Diseases 2019 (COVID-19) pandemic has had a significant influence on the management of plastic trash in many nations. A number of causes, such as the expanding public consumption of single-use plastics, the lack or scarcity of infrastructure for the proper handling of plastic waste, and urbanisation, are fundamental to this growing danger.

For the purpose of lowering the risk of exposure to Severe Acute Respiratory Syndrome (SARS) Coronavirus 2 (SARS-CoV-2), plastics-based personal protective equipment, such as millions of surgical masks, medical gowns, face shields, safety glasses, protective aprons, sanitizer containers, plastics shoes, and gloves, has been widely used (Benson et al., 2021).

In light of the SARS-CoV-2 epidemic, Benson et al., 2021 assessed and explained the increasing amount of plastic garbage in African nations. Face masks were found to include both natural and synthetic fibres, such as polyester, polypropylene, and natural latex resin, according to an FTIR spectral fingerprint. According to their estimation, approximately 12 billion medical and fabric face masks are abandoned each month, which means that Africans may dispose of over 105,000 tons of face masks into the environment each month. Overall, 15 of the 57 African nations contribute significantly to plastic garbage, with Nigeria (15%), Ethiopia (8.6%), Egypt (7.6%), the Democratic Republic of the Congo (6.7%), Tanzania (4.5%), and South Africa (4.4%) at the top of the list. The solid waste management paradigm was studied by Ranjan et al. in 2022 in an effort to decrease landfilling and recover abandoned landfills. Resource recovery and landfill mining are thus in great demand. The possibility for recovery of plastic garbage that was unearthed from an active, unclean landfill site that was more than 50 years old was evaluated and defined. Polyethylene (PE) accounted for 59% of the plastic waste samples gathered from the dumpsite, followed by

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Polyethylene Terephthalate (PET) at 8%, Polypropylene (PP) at 7%, and miscellaneous materials at 26%. PET and HDPE degraded the least, whereas PP and LDPE (low-density polyethylene) degraded the most, according to physicochemical, thermal, and strength studies. The calorific and proximate values of excavated LDPE and PP were unaffected by age or degradation level, indicating the suitability of energy recovery options for the most degraded plastics (LDPE and PP). The preferred treatment option for reclaiming these areas is the recycling of PET and HDPE from old landfills.

2.5 Mismanagement of Plastics Waste

Over the last fifty years, new plastic materials have increasingly displaced old metal, wood, and leather materials in a variety of applications. Ironically, plastics' most desired quality—their durability—also poses the most risk to the environment.

Recycling has essentially failed to offer a secure way to get rid of plastic waste—just 5% of the 1 trillion plastic bags made in the US each year are recycled. Given that polyethylene (PE) is the most often used plastic (around 140 million tonnes annually), any decrease in the amount of PE trash that accumulates on its own would have a significant effect on the reduction of plastic waste in the environment as a whole.

Since synthetic polymers are thought to be nearly innocuous, attempts were made to isolate special microbes that might use them. Recent information revealed.

The purpose of the Yintii et al., 2014 study was to determine the state of plastic trash, identify household plastic waste management techniques and issues, and to determine the best course of action for cutting down on plastic waste from the viewpoint of the home. Twelve randomly chosen electoral zones participated in this questionnaire-based study, and the analysis of the data revealed that 81.67% of families thought there was a serious problem with plastic garbage. One of the recognised household waste management methods was storing garbage over time in dustbins, boxes, buckets, and big polythene bags. Plastic garbage was often gathered at the home level alongside other rubbish and temporarily held in waste storage containers. Regarding the ultimate disposal of household garbage, around 54.77% of households dumped their waste at authorised disposal facilities, 34.77% burnt their waste, 8.92% dumped their waste in any open area, and 1.54% buried their waste.

The distance to disposal sites, the scarcity of dustbins and disposal sites, and the inconsistent garbage pickup by waste management companies were all noted as home waste management challenges.The state of solid waste management at the home level in a peri-urban region (Kottawa in Colombo) was investigated by Warunasinghe and Yapa (2016). Batteries, food, paper, plastic, metal, and glass are among the common waste categories. More than 70% of the homes generate more than 2 kg of garbage every day. The kitchen accounted for 94% of the garbage collected. Waste pits are utilised by over 50% of home gardeners. Garbage truck collection (44%), burning (44%), composting (16%), and incineration (10%) were other means of disposing of kitchen trash. Sixty-six percent of the households burn cardboard and paper waste. Glass, plastic, batteries, and metal were among the non-biodegradable materials that were disposed of using a different garbage truck. 52% of households separated their waste at the household level, compared to 42% who did not. Compost bins were favored by thirty percent of homes. 6%, however, were unaware of compost containers. Of them, 26% actively participated in home composting. There was complete awareness of the risks to the environment posed by inappropriate garbage management. Just 2% of respondents said they were not very concerned about how poor waste management may affect their health. Of the households surveyed, 54% expressed dissatisfaction with the current waste management techniques, and 70% anticipated further government intervention to address the issue. Additionally, according to the data, 26% of the families lacked knowledge on trash reduction, recycling, and reuse. Nonetheless, 96% of the respondents said they would cooperate and take part in a competent trash management system. Composting (34%), effective waste separation (14%), the establishment of government-owned waste collection canters (28%), standard garbage trucks with a special honking facility, and standard waste bins for household use under subsidised programmes are among the suggestions made by the respondents to implement an efficient waste management programme. 12 percent.

A survey on the effects of the Swachh Bharat Abhiyan on Jaipur's slum areas was carried out in 2019 by Mathur et al. They used a questionnaire to conduct a random survey to find out people's opinions about the Swachh Bharat Abhiyan

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and how it has affected their community. In all, residents of Jawahar Nagar, Tila No. 4 in Jaipur, a slum, answered 25 questions on the new Swachh Bharat Abhiyan system.

A few respondents learned about Swachh Bharat Abhiyan from radio commercials, while others learned about it from the clean drive song played by trash vans. They all agreed that the rubbish is collected by the garbage vehicle at least twice a day. Sixty-five percent of respondents said they had hired a private sweeper to collect their rubbish from door to door. In the event that the sweeper doesn't arrive, 40% of them store their waste somewhere inside their homes, and 35% make it a routine to gather their rubbish at a predetermined location outside their homes. None of them reported keeping dry and wet waste apart when questioned about it. 56% of people didn't even know what the blue and green garbage cans that Nagar Nigam places at the sides of the road meant. Vegetable garbage and polythene were the most often mentioned waste kinds when questioned. This suggests that nearly all of them were making a substantial contribution to the most dangerous type of non-biodegradable garbage, which is polythene bags. Sixty-five percent of respondents said they were dissatisfied with the waste collection system because Nagar Nigam employees do not pick up waste from door to door and the garbage van does not wait long enough for them to come out and dispose of their waste because they have to travel a long way to get to the van.

In 2020, the TERI-UNEP "Rethink Plastic" Campaign polled people online using Google Forms and in-person interactions. More than 865 responses were obtained through online and in-person surveys. Of these, 97% of respondents think that plastic is bad for the environment and human health, 80% think that plastic can be recycled, 85% think that cloth bags are better for shopping than paper or plastic bags, 76% think that charging for plastic bags would help people stop using them, 56% say they separate waste into biodegradable and nonbiodegradable categories, and 60% know about microplastics and their effects.

Additionally, Shah and Neema (2021) made an effort to research the contribution Indore city's female residents made to the Swachh Bharat Abhiyan. According to the analysis, women were prepared to put in the effort to separate their home garbage in order to protect the sanitation workers' health. In order to dispose of their recyclable household waste goods in an environmentally friendly manner, the respondents were prepared to sell them. They were aware of the harmful consequences of plastic bags and containers, so they tried to limit their use. When it came to trash in public areas, the female residents were mindful of their actions. Additionally, they were open to incorporating the four R's of trash management—refuse, reduce, reuse, and recycle—into their everyday routine.

Similarly, Prajapati et al., (2021) provided an assessment of the state of municipal solid waste management in Jaipur, India, including its problems. suggestions. In the city of Jaipur, half of the municipal solid waste (MSW) is processed, while the remaining half is dumped in an unhygienic landfill. Just 21% of MSW is treated by insufficient MSW management procedures in Indian cities. According to their research, unregulated landfilling, a lack of public involvement, poor MSW law implementation, and waste conversion are the main obstacles to MSW management in Jaipur. Public awareness campaigns, public-private partnerships, lined landfill investments, recycling, and waste-to-energy methods are among the suggestions for improvement. The use of life cycle assessment techniques and optimisation models can reduce MSW management expenses and its negative environmental effects.

Inadequate handling of plastic garbage can have detrimental effects on the environment, wildlife, and public health. Adopting appropriate waste management practices, the appropriate technology, and a fresh perspective on the existing situation, however, would present an opportunity. Of the plastic garbage, about 40% was disposed of in landfills, 25% was burned, 16% was recycled, and the remaining 19% was released into the environment. An excellent economic signal for investors and government initiatives to invest in technology that turn plastic waste into value-added products like fuel and building materials is the rise in plastic trash and the demand for plastic markets. By doing this, a sustainable circular economy will be achieved, closing the loop on the life cycle of plastic trash (Khoo et al., 2021).

2.6 Biodegradation

Concerns about plastics stem from their slow rate of degradation, the closing of landfills, and the growth in land and water contamination. In recent years, there has been an increased demand for biodegradable plastics and the biodegradation of plastic wastes due to the overuse of plastics and the mounting strain on the capacity for disposing of plastic trash. The topic of biodegradable polymers is seeing a resurgence of interest as people become more conscious of the waste problem and its effects on the environment. There is an increasing need to develop materials that do not materially hurt the environment due to the public's increased interest in environmental concerns. Because water-soluble or water-immiscible polymers ultimately find their way into streams that cannot be burnt or recycled, they must biodegrade. To comprehend the conditions and mechanisms of biodegradation, one must take into account the microbial breakdown of both natural and manmade polymers. It is necessary to comprehend the interactions that occur between materials and microbes, as well as the resulting metabolic changes.

Many research on plastic biodegradation have been carried out in order to solve the environmental challenges related to trash made of synthetic plastic (Shah et al., 2008).The rates and paths of environmental degradation for the main categories of thermoplastic polymers were compiled by Chamas et al. in 2020. Half-lives are extrapolated using the specific surface degradation rate (SSDR), a statistic that unifies diverse types of data. Due to deterioration experiments carried out in a variety of natural settings, SSDR values vary somewhat across a broad range. SSDRs for high density polyethylene (HDPE) in the maritime environment range from almost 0 to around 11 µm year/1.

This approach produces a lot of fascinating findings. The projected half-lives for HDPE in the maritime environment can range from 58 years for bottles to 1200 years for pipes, based on linear extrapolation from a mean SSDR. For instance, despite the fact that PLA degrades around 20 times quicker than HDPE on land, the SSDRs for PLA and HDPE are unexpectedly similar in the maritime environment. Their results emphasise the significance of standardising rate reporting, improving experimental research under well-defined reaction circumstances, and creating techniques to mimic polymer deterioration.

The current understanding of plastic additives (PAs) in sludge and the noteworthy advancements in their impacts on sludge anaerobic digestion (AD) and biodegradation performance were presented by Chen et al. in 2021. In particular, a comprehensive summary of the chemical compositions and concentrations of flame retardants, stabilisers, and plasticizers found in sludge around the globe is provided. Analysed and contrasted are the disparate effects of PAs on the processes of hydrolysis, acidification, and methanogenesis, with matching patterns inferred. There is currently little information on the destiny and consequences on AD of the majority of PAs found in sludge. Furthermore, it was still unclear how AD microorganisms may contribute to the release of PAs from microplastics. Concern should be given, in particular, to the possible consequences of PAs produced from biodegradable micro-plastics on sludge AD and their eventual destiny. The new information would bring our understanding of PA risk assessment and control in sludge AD up to speed.

2.7 Rules Governing India's Production of Plastics, Plastic Waste, and Recycling

2.7.1 Particular Rules Regarding Plastic Wastes

Plastic is utilised in a wide range of items, including toys, wrapping paper, shopping and trash bags, packing films, and fluid containers. The primary issues with Products made of plastic are disposed of. Plastics don't biodegrade and can linger in the environment for many years. Because colouring agents, stabilisers, flame retardants, and other chemicals are mixed in with recycled plastic, the environmental impact of recycled plastic is even greater than that of virgin plastic items. An estimated 8 million tonnes of plastic garbage are produced annually in the nation, according to estimates (2010). Approximately 12 million tonnes of plastic products are consumed annually in India, making it one of the country's top users of plastic products (2012). In India, there are now a number of laws governing the plastics sector as well as limits and controls over plastic waste, with new laws being adopted on a regular basis.India, which consumes the most plastic goods worldwide, has taken significant, decisive action to control the manufacturing of plastics and the disposal of plastic garbage. Enforcing laws consistently and strictly across the board is necessary to increase their efficacy.

2.7.2 The 1986 Environmental Protection Act

The Indian government's main regulatory direction is this. The law's primary goal is to put in place an effective system of environmental protection. It gives the federal government the ability to control trash in all its forms and address any unique issues that could arise in various parts of India. It remains India's principal legislation, encompassing several environmental regulations and actions.

2.7.3 Rules for the Manufacture and Use of Recycled Plastics, 1999

This is the first official regulation on plastic trash in India, and its goals are to manage the serious litter problem and restrict the packaging of food items in recycled plastics. The primary standards include the following: any carry bags smaller than 20 microns are prohibited; recycled and virgin coloured polybags are permitted to package non-food applications but are discouraged to package food goods; and required guidelines for the recycling of plastics.

2.7.4 The 1999 Plastic Manufacturing, Sale, and Use Regulations (modified in 2003)

The primary goal of this legislative amendment is to regulate plastic bags. With the passage of this legislation, the Indian government established strict bag laws to combat plastic bags, which are the primary source of trash and litter. The primary guidelines of these regulations prohibit the following: using recycled plastic bags or containers for food storage, transportation, dispensing, or packaging; making, stocking, distributing, or selling carry bags made of virgin or recycled plastics that are smaller than 20 by 30 centimetres in size and 20 microns in thickness; and requiring plastic bag manufacturing units to register with the relevant State Pollution Control Board (SPCB) or Pollution Control Committee (PCC) prior.

2.7.5 The 2009 Regulations on the Manufacture, Use, and Waste Management of Plastics

The purpose of this regulation was to replace the Recycled Plastics Usage and Manufacture Rules that were in place in 1999. The regulations aim to control how plastics are used for different reasons.

The following regulations state: Carry bags and containers made of virgin plastics must be in their natural shade; carrying, dispenseing, or packaging food items shall not be done with carry bags or containers made of recycled or biodegradable plastics; carry bags and containers made of recycled or biodegradable plastics used for anything other than storing and packaging food items shall be made using pigments and colourants in accordance with the Bureau of Indian Standards' specifications, entitled "List of pigments and colourants for use in plastics in contact English. Carry bags made of virgin, recycled, or biodegradable plastic that are smaller than 12 by 18 inches (30 x 45 cm) are prohibited from being manufactured, stocked, distributed, or sold. Except in the case of food packaging, no one shall manufacture, stock, distribute, or sell non-recyclable laminated plastic or metallic pouches, multi-layered packaging, or other non-recyclable plastics. Recycling of plastics shall be conducted in accordance with the Bureau of Indian Standards specifications: IS 1453: 1988, entitled "The Guidelines for Recycling of Plastics." No one shall manufacture carry bags, containers, pouches, or multi-layered packaging from biodegradable plastics unless these meet the Bureau of Indian Standards' specifications, entitled "Specifications for Compostable Plastics."

2.7.6 The 2011 Plastic Waste (Management and Handling) Regulations

The Indian government is currently implementing a new initiative to combat plastic waste, replacing previous ones. The following are the new laws and regulations:

1. Plastic bags now have a minimum thickness of 40 microns.
2. Recycled carry bags composed of biodegradable polymers must meet certain requirements set out by the Bureau of Indian Standards (BIS).
3. It is no longer permitted to store, package, or sell tobacco-based products (including regional variations) in plastic sachets.
4. The local government must interact positively with rubbish pickers, waste management organisations, and agencies.

The local government may set the minimum price for plastic bags, and no plastic carry bags should be given out to customers for free. This is another crucial policy proposal. Nevertheless, because each state government has its own policy regarding the application of these regulations, enforcement of them is uneven.

2.7.7 The 2016 Plastic Waste Management Act

For the first time, the plastic waste regulations were expanded to include rural regions in 2016, along with distinct responsibilities assigned to Gramme Panchayats.

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The Indian government approved the Plastic Garbage Management Act, India 2016, which is a crucial regulation that governs the handling of plastic garbage. The legislation was adopted with the intention of encouraging sustainable behaviours and lowering the quantity of plastic trash produced in India. Plastic waste is defined by the act as any plastic substance that is disposed of or planned for disposal. It also addresses every facet of managing plastic garbage, such as disposal, processing, transportation, and collecting. The act's ban on using particular kinds of plastic is one of its main features. The usage of plastic bags with a thickness of less than 50 microns is forbidden by law. Because they are difficult to break down and frequently wind up in landfills where they cause pollution, these bags are regarded as environmentally dangerous. The act also places obligations on those who make, consume, and generate plastic. Manufacturers and producers of plastic goods must make sure that their items are labelled with recycling information and are constructed of recyclable materials. They must also retrieve and properly recycle or dispose of the plastic trash produced by their goods.

It is mandatory for those who utilise plastic to make sure they don't leave behind litter or discard plastic garbage in public areas. The creation of a system for managing plastic garbage is also required under the legislation. It is mandatory for local government bodies to set up a mechanism for gathering, classifying, and discarding plastic trash within their jurisdiction. In order to pay for the installation of the plastic waste management system, they must also set up a plastic waste management fund. Extended producer responsibility (EPR) is another idea that is supported by the Plastic Waste Management Act, India 2016. Under the EPR policy, manufacturers are held accountable for the complete lifetime of their goods, including the disposal of any waste they produce. The statute requires plastic product makers and producers to be accountable for the garbage that their goods cause. This incentivizes manufacturers to create recyclable and ecologically friendly items.

The economy is affected by the legislation as well. The implementation of a plastic waste management system has prospects for the growth of the recycling sector. This can bring in money for the local government and provide up job possibilities. Utilising technology to handle plastic trash might also present chances for the creation of novel technologies and creative solutions. Nonetheless, there are a number of obstacles in the way of the Plastic Waste Management Act, India 2016. According to the legislation, local governments must set up a system for managing plastic trash, which calls for a substantial investment in infrastructure and resources. It's possible that local governments lack the necessary resources to carry out the act's requirements. In order to comply with the legislation, plastic makers, users, and producers must work together, which may be challenging in real-world situations.

III. METHODOGOLY

The goal of the current survey is to determine the types of garbage created at home, where household plastic waste is disposed of, issues with the solid waste management system that is already in place, etc. about the management of household plastic waste in Pune, Maharashtra. The following provides a detailed overview of the study location, materials, and methodologies employed in the current inquiry, "Household Plastic Waste Management in Pune City."

3.1 Study Area

Pune, Maharashtra, India was the research region chosen. With 3.1 million residents, the city ranked eighth in the nation for population density. The lack of large-scale enterprises, commercial buildings, health care facilities, and educational institutions has made the city more appealing to tourists. A sizable number of year-round visitors, both from inside and outside the state, reside in the city. Numerous foreign visitors are drawn to the city's historical sites and surroundings. Pune municipality is becoming more significant for a variety of reasons.

3.2 Sampling Technique

160 respondents provided information. The random sample approach was used to choose the research participants. A deductive method was used for the data collection. The target population included every home in Pune City, however conducting an inquiry with such a vast number of people would be impracticable. For this reason, a multi-stage random sampling procedure was used to choose a suitable sample for assessing the study's goals. Thus, in the first phase, four significant areas in Pune city were chosen at random for each direction. Out of all the big places, four minor areas were randomly chosen from each direction for the second stage. In the third phase, ten residents from each small region were

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ultimately chosen as the sample size from nearby homes that were between 100 and 200 metres apart. Regardless of age, sex, education level, or employment, at least one family member from each of the visited homes was chosen at random for the research as long as they were agreeable.

3.3 Method of Data Collection

The sample approach provided the data for the investigation of the kind, pattern, quantity, and variability of plastic consumption in each home. Plastic bags, plastic bottles, storage containers (buckets, bins, barrels, etc.), plastic disposables, and packaging materials (sachets, food packets, food containers, and others) were the most widely used plastic items. These were grouped based on the kind of plastic. A bar graph diagram was used to display the survey's data. An online survey with 30 questions was also conducted in order to study the use, disposal, and management of plastic by each household. The questions covered a variety of topics, including people's behaviour regarding the use and disposal of plastic, its effects on the environment, their dependence on it, and the use of plastic at different levels at home. Pie charts were used to illustrate the survey data. Numerous questions were asked throughout the online survey, which has the structure indicated below.

IV. RESULTS AND DISCUSION

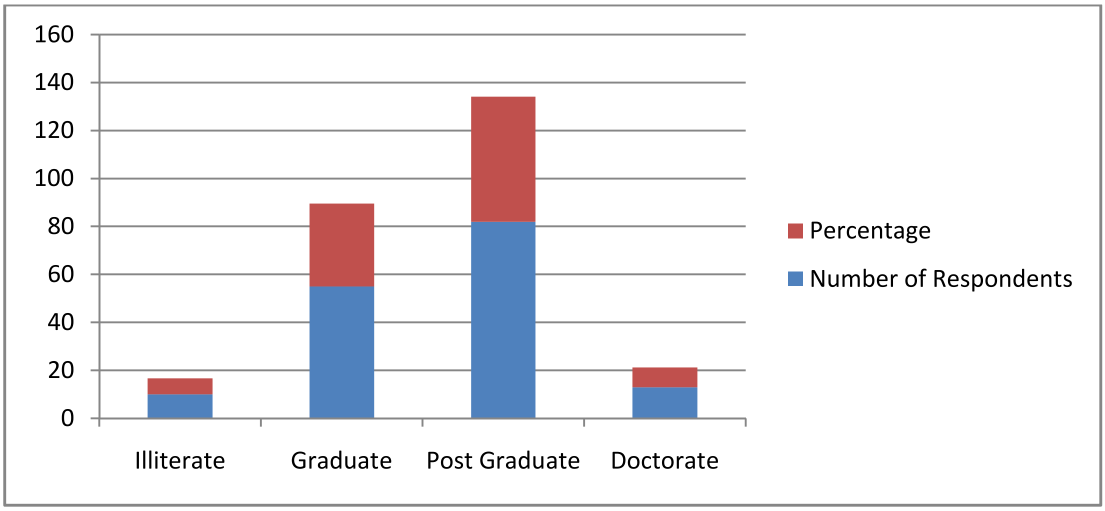

Figure 2: Respondents' Educational Background

Only 6.7% of respondents to the poll reported never having had any formal schooling. Only 8.2 percent of respondents hold a doctoral degree, compared to 34.60 percent who have studied up to the graduate level and 52.10 percent who have studied up to the post-graduate level.

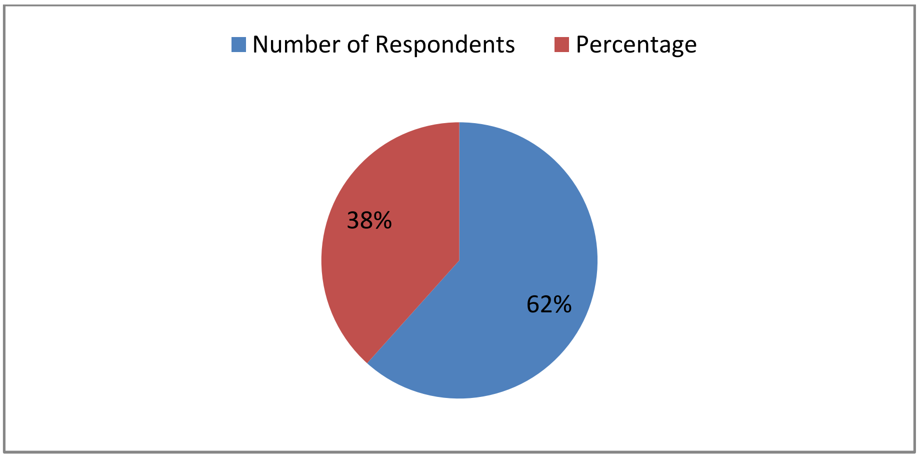

Figure 3: Awareness of the Plastic Pollution Issue

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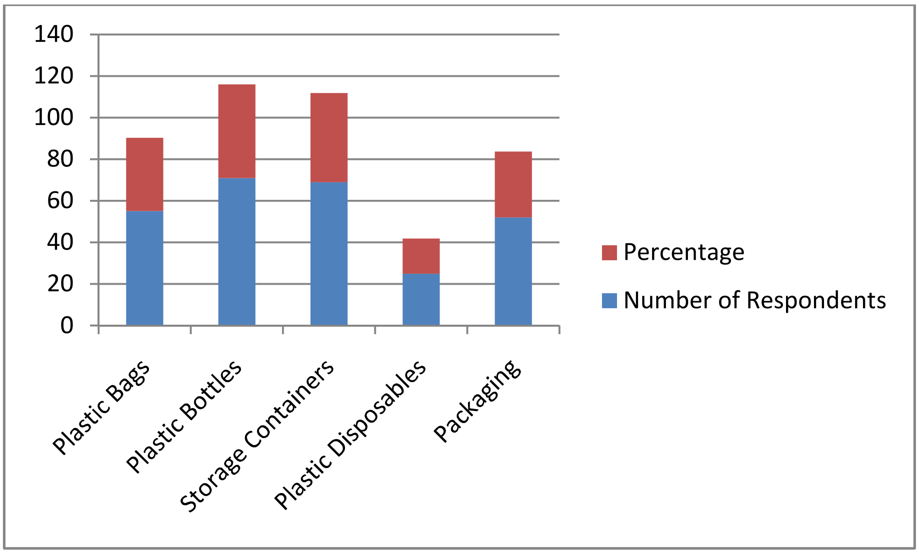
When asked if they were aware of the problem of plastic pollution, 97% of respondents said they were quite aware of it, while 4.2 percent said they didn't.



When compared to other plastic items, the majority of the 160 respondents (45%) said they frequently used plastic bottles. Even though people are aware of the harmful effects plastics have on the environment and human health, they nonetheless choose plastic items because they are less expensive, lightweight, durable, readily available, and don't require much maintenance. The most widely utilised plastic goods include packaging materials, bottles, carry bags, and storage containers. The use of plastic bags, plastic packing items, plastic storage containers (such as buckets, barrels, and baskets), and plastic disposables came next. According to these findings, the majority of respondents in each group said they regularly use plastic bottles. The findings also showed that a large percentage of Pune City's population uses plastic bottles, and the city's citizens occasionally see an increase in this consumption tendency.

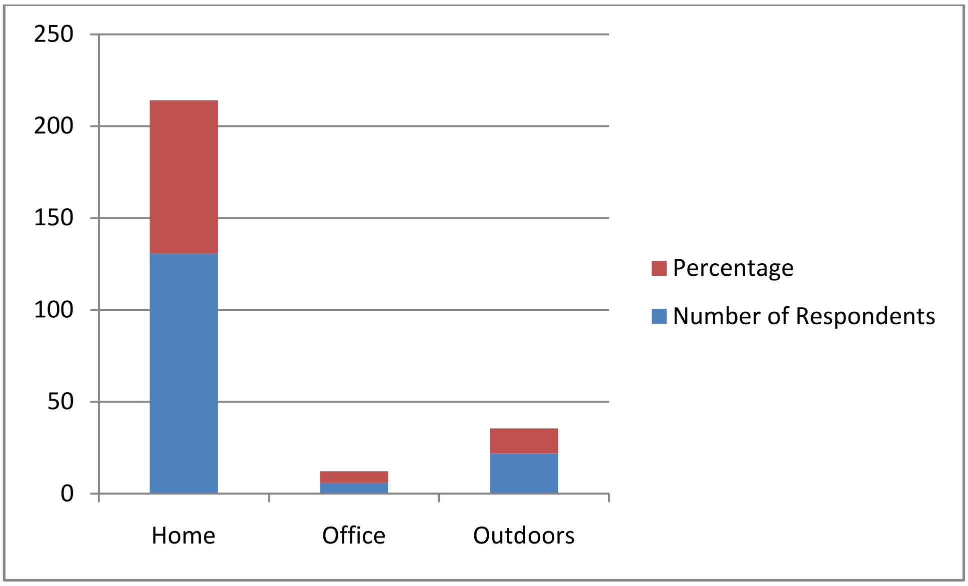


Figure 4: Plastic Products' Maximum Use

According to the poll, department shops (13.75%) and grocery stores (80%) account for the majority of plastic use in households. Nevertheless, the supermarket (6.25%) contributes less to household intake of plastic.

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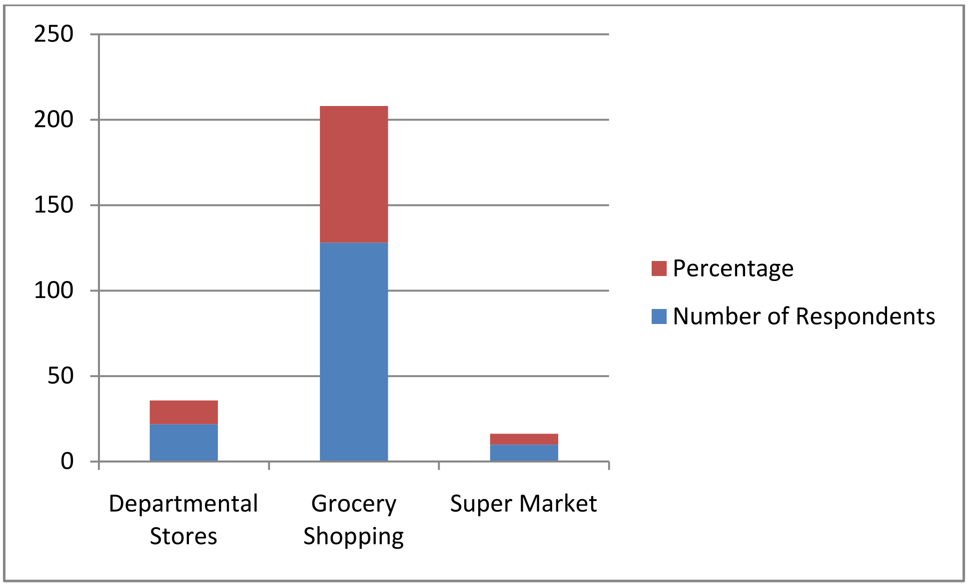
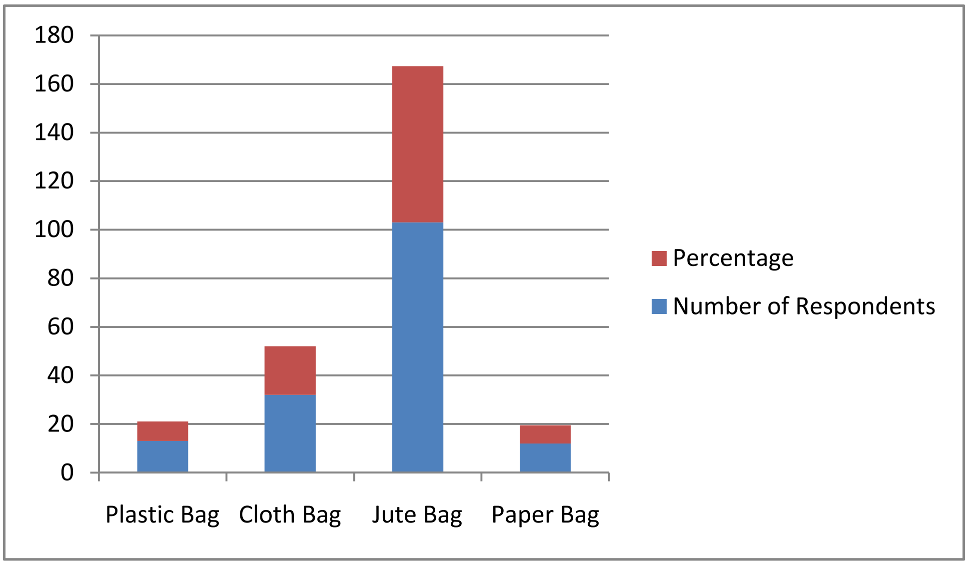


Figure 5: Household's Maximum Plastic Intake Source



Following the restriction on plastic use, it was found that individuals were using more jute (64.37%) and cloth (20%) food shopping bags than plastic (8.125%) and paper (7.5%) bags

V. CONCLUSION

Due to the numerous negative consequences plastic manufacture and widespread use have on the environment and public health, they represent a significant concern. Plastic items are chosen despite the serious negative effects that plastics have on the environment and human health. This is because plastic is inexpensive, lightweight, durable, readily available, and has fewer substitute materials than other materials. The most widely utilised plastic goods include packaging materials, carry bags, storage containers, and bottles. Initiatives such as the Swachh Bharat Mission are seen as a good way to handle and sanitize solid waste in a safe and appropriate manner. Due to the awareness regarding the environmental issues like plastic pollution and proper waste management, more than half the respondents practice waste segregation at home. More such initiatives and awareness campaigns should be promoted. In order to promote waste segregation at home, housing societies should be encouraged to tie- up with local waste recyclers who could collect recyclable waste from the societies at monthly/ fortnightly basis depending on the amount of waste being generated.

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Cloth bags and paper bags are the most common alternatives to plastics used by the citizens, followed by metal crockery. Numerous studies on the biodegradation of plastics—an alternative process that doesn't affect the environment—have been conducted in an effort to preserve the ecosystem from the accumulation of plastic garbage. Pseudomonas spp. were tested for their degradation efficiency during the investigation on two polythene samples that were isolated from the Malviya Nagar (78% and 53.33%) and Mansarover (78.33% and 68.75%) locations. During the investigation, plastic-degrading bacteria were also found, and it was shown that they were crucial to the bioremediation of plastic in soil. Pseudomonas spp. is an efficient and successful choice for the breakdown of plastic, it may be inferred.

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