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Recycled Materials and Sustainable, Innovative, Affordable Housing (SIAH): Investigating the Current Status, Progress, and Way Forward

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Abstract

The research determines the role of recycled materials in enhancing SIAH. Implementing recycled concrete, plastics, renewable resources, wood, and glass helps in dealing with the issues related to environmental sustainability. Additionally, it addresses the financial and environmentally friendly benefits of using recycled materials in construction, as they lower costs and have a smaller environmental impact than conventional methods. The study also tends to the identification of recycled materials based on housing affordability, innovative approaches to designing, and the present status of recycled materials in the construction sector. The suggestions were also provided related to conducting educational programs for architects and engineers in the construction sector to develop knowledge.

Keywords: Sustainable Housing; Innovative Housing; Affordable Housing; Recycled Materials; Construction Sector; Environmental Sustainability

Introduction

Sustainable, Innovative, and Affordable Housing (SIAH) is considered an integrated approach to housing development that helps prioritize environmental sustainability, affordability, and technological innovation. The adoption of recycled products in recent years has surged in the construction sector to support SIAH initiatives [1]. Rapid urbanization is found to be a significant obstacle to the development of cheap and sustainable housing. Urbanization tends to provide room for innovation in the sector. Potential solutions for creating inventive, economical and sustainable housing are offered by new materials, cutting-edge construction technologies, and the sustainable design approach (SIAH) [2]. The sustainable activities include recycled concrete aggregates for foundations, reclaimed wood for flooring, recycled glass tiles, recycled plastic lumber for framing, recycled steel for structural components, and recycled paper-based insulation for energy efficiency [3]. It is observed that recycled materials offer benefits over their traditional counterparts such as reduced environmental impact, lower costs, and resource conservation, yet challenges such as quality control and durability must be addressed [1].

Affordable housing can be ensured by utilizing recycled products in construction, as they offer cost-effective alternatives to conventional materials while promoting sustainability and resource efficiency. Affordable housing is a necessity for addressing housing shortages and homelessness, particularly in urban areas where populations continue to grow. Incorporating recycled materials at every step of the process of planning, from designing and procurement to construction and maintenance, helps meet the demand for affordable housing while mitigating environmental impacts and reducing construction costs [4]. The increasing recognition of SIAH principles and the growing adoption of recycled materials in construction. It is identified that there is a lack of comprehensive investigation of prior studies that analyze the current progress, status, and way forward for sustainable, innovative, and affordable housing development.

It has been found that insulation made of hemp and sheep's wool is employed in the building process as a renewable resource. The reason behind this is that hemp can be produced again and the sheep sheared again in the next year [4]. It has been noted that recycled content and renewable resources are relatively new to the industry. Although wood waste is used to create wood fiber goods, this is not as much recycling as using a byproduct of another wood processing operation [5]. Whereas regained wood can be used to make various products, virgin timber is used to make wood chip boards and wood fiber. The majority of the products have a combination of materials. It has been noted that renewable and natural resources are superior to synthetic ones [6]. It is found that in 2010, there were around 5 million unoccupied dwellings in the country or 14 percent of the 35 million total homes. This is regarded as being 4.5 times the 1.1 million annual housing needs in 2011 [7]. The development of housing typology in developing countries indicated that there are two dominant building forms, as the individual incremental building method results in each plot having a house with its outside wall and project-based housing, which led to the production of a large number of subsidized housing units. One of the objectives has been to make housing more sustainable, as demonstrated by government publications [7]. Objectives for sustainable housing go one step further than creating durable housing since goals for protecting the earth and the climate are taken into consideration at the time of construction. In the last few years, the government's new objectives have been to make housing more sustainable as demonstrated by government publications [8]. The objectives for sustainable housing also moved one step further which further creates durable housing as the goal is to protect the earth and climate.

Additionally, [9] the book made clear that involving users in the planning and building stages of the home rehabilitation process yields the best results. In a similar vein, it showed that the best results from housing rehabilitation occur when it is integrated with community

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services, infrastructure, and the means of generating legitimate income. Twelve case studies from Australia, Vietnam, Bangladesh, Haiti, Sri Lanka, and Haiti highlight the process of rebuilding homes following earthquakes, tsunamis, floods, and cyclones.

It is determined that natural resources are consumed at higher rates compared with their production. Based on the type and composition, processing aggregates from C&D begins by demolishing a building to separate the different waste materials. The other materials have been selectively dismantled; concrete is torn down through machinery [10]. The crushing process of EoL concrete is discussed in the literature. The concrete waste crushed in this specific study has an average moisture content of 5-8%. The crushing cycle is designed for the generation of aggregates of the size of particles of 0-12 mm fed into ADR. This technology is considered a mechanical system for extracting the fine fraction from moist crushed concrete aggregates. It is observed that coarse aggregates are the primary products of ADR [10].

To balance the growing need for new infrastructure with sustainability criteria, the construction industry must increase resource efficiency [11]. Reducing non-renewable material use, producing high-quality products with little waste, and maintaining a product's long-term worth are the major components of resource efficiency. The growing use of industrialized house construction with cutting-edge building materials and techniques presents a potential source of resource efficiency [12]. With a focus on the use of recycled materials, the research looks into the current state, future directions, and novel approaches to inexpensive, sustainable housing development.

Review aim and objectives

The primary aim of this review is to investigate how recycled material can lead to sustainable, innovative, and affordable housing (SIAH). Considering this aim, the review has the following specific objectives:

- To reveal the role of recycled material in providing affordable housing.
- To investigate the environmental benefits of using recycled material in housing projects.
- To examine how recycled material can be maximized through innovative designs and construction techniques.
- To investigate the current status and progress of using recycled material for housing development.
- To determine how housing can help reduce crime.

Body of Review

Recycled material and its environmental impact

The study conducted by [13] offers insights into the methodology utilized to address the environmental consequences of construction materials. Determining influence and mitigation strategies for various materials and phases is one of the framework's recognized tenets. Pollutant emissions and resource and energy consumption are all part of the life cycle process of building materials. Fossil fuels are used in transportation and building, which has an impact on the environment by emitting carbon dioxide and nitrogen oxides. According to the research, building waste treatments like leftover wood and plaster were thought to be major causes of organic acid in landfills.

However, [14] said that several kinds of plastic trash are associated with the building industry and that these waste materials may be recycled. It has been noted that there is potential for usage in various applications following recycling depending on the qualities and type of plastic waste. Known for its hardness and rigidity, high-density polyethylene (HDPE) is used to make plastic lumber, tables, chairs, and other furniture. But light-density polyethylene (LDPE), a flexible substance, might be employed in the manufacture of bricks and blocks. Analyses show that carrying out life cycle assessments contributes to the provision of options for improving in-depth research on evaluations of the economic and environmental impacts.

According to [15], the large amounts of plastic garbage produced pose a severe threat to the ecosystem and its people due to their detrimental effects. The majority of this waste is produced on land and ends up in waterways, where it can have harmful effects such as animal poisoning and floods in the marine environment. It has been established that the major reasons plastics are utilized in greater amounts are due to their advantageous qualities, which include their lightweight nature, higher impact resistance, and capacity to form into various shapes. They are also resistant to bacteria. The production of plastic has long been seen as inevitable and is important to both society and garbage generation. To manage plastic waste properly, these materials help enhance environmental sustainability, and their use in the construction sector is also viable.

According to [16], waste concrete recycling materials (WCRMs) are used in the preparation of self-compacting concrete (SCC). Recycled powder (RP), recycled fine aggregate (RFA), and recycled coarse aggregate (RCA) are identified as the natural materials substituted with the WCRM. Analysis shows that WRCM's cooperation was a direct result of SCC's decreasing mechanical behavior and workability. It has been noted that resource scarcity and environmental contamination are problems that the building sector also faces. The issues were related to energy use and the consumption of natural resources, greenhouse gas emissions, and the production of construction and demolition waste (CDW).

Impact of using recycled material on housing affordability

According to [17], the study examined the usage of recycled materials in construction projects. It illustrated the usage of recycled materials and the alleged obstacles to its application. Six major stakeholder groups, including the government, recyclers, clients, and builders, were identified by the research as being impacted by the sector's decision to employ recycled items. The viewpoints, choices, and actions influencing the utilization of recycled C&D waste products are also covered in this. In addition to offering commentary on their attitudes, choices, and actions influencing the use of recycled C&D waste products, the research identified factors that support and undermine the model of C&D waste products made from trash. It has been noted that some characteristics influence the market for items made from recycled construction and demolition debris and serve as benchmarks for policymakers when evaluating the behavioral insights associated with policy change.

On the other hand, [18] talked about installing locally sourced, natural, and recyclable insulator material on rooftops as well as measuring and simulating internal temperatures in buildings. The work is important because it shows how to improve thermal comfort in building construction by using waste materials with lower thermal conductivity. When it comes to thermal insulation materials, recycled glass distribution has been found to offer the most improvement over straw bale and sheep wool. Improvements were noted in both the summer and winter months; in the summer, the average daily

temperature decreased, and in the winter, it rose by 7.4%. Thus, it can be said that the building's roof's thermal insulation had an impact on the temperature of the atmosphere within.

According to [19], the generation of plastic trash is deemed inevitable due to the large range of plastic materials used in the modern corporate environment. Aspects that negatively impact polluting land and water resources and contribute to environmental sustainability must be balanced with the development and management of polymer waste. It was discovered that by extending their lifespan and increasing their value through use as alternatives to traditional building materials, recycled plastics may be used in building and construction applications as a workable green building solution. The benefits of using applications that lessen waste that ends up in landfills and lower environmental pollution caused by disposing of plastic garbage.

Reusing leftover concrete is one of the actions needed to lower the quantity of construction and demolition debris disposed of in landfills, according to [20]. An increasing amount of waste concrete is formed annually, accounting for a larger percentage of all construction. The costs and advantages of manufacturing natural and recycled concrete aggregates for use in concrete were shown in the study. It was shown that there was no net benefit to generating recycled or natural concrete aggregates. Compared to fine recycled concrete aggregate, recycled concrete aggregates had a lower production cost. In addition to being an economical strategy, the building sector should support the commercial manufacture of recycled concrete aggregates from leftover concrete [Table 1].

Design Innovations for Using Recycled Material in Housing

[21] Stated that thin-tile vaulting is considered one of the design strategies involving distinctive features of thin-tile vaulting, which are used for fast-setting mortar and the planar positioning of the tiles in the soffit layer. It is determined that thin-tile vaulting is considered a formwork-free construction that needs geometric control. Thin-tile vaulting solely as vaulting without formwork is not precise since there are other free vaults including pitched barrel vaults which are also known as Nubian vaults. In the construction sector, designing and digital analysis tools can filter the space in which to build knowledge. The study emphasizes three approaches linked with craft-inclusive construction including training, policy, and design [22]. Emphasize green architecture and energy efficiency by involving construction techniques and innovative designs. It is observed that techniques related to construction and innovative design in green architecture underscore the potential of sustainable practices in shaping the future of business. There has been a rapid evolution in the green architecture landscape, from designing principles and sustainable materials to the adoption of advanced technologies. It is a determined journey toward green architecture, a collective endeavor that requires the collaboration and commitment of architects, industry professionals, and policymakers.

According to a study done in [23] architects continue to create permanent houses in the same way. In addition to pointing out prefabricated and recyclable building designs, the research suggested three new typologies. The primary goal of the study is to ascertain how the structure might incorporate characteristics of disassembly and recycling while also taking practicality into account. Prefabricated construction and modularity have played a significant role in the history of architecture in helping to comprehend and improve these techniques, making the process of disassembling the first structure at the end of its life cycle easier.

Information about prefabrication in supply chain management for the building industry is provided by [24]. Prefabrication has been shown to promote sustainable development and the urban economy. In the building industry, addressing environmental contamination and the acute lack of social resources is a new trend. Prefabricated building in supply chain management has emerged as a crucial factor limiting prefabricated construction's growth and popularization in the modern corporate environment. Databases used in the study were Elsevier, WOS, Emerald, and Scopus. Finally, prefabricated supply chain management was built in the study. Based on three levels of technology basis, market conditions, and the decisions made by key players to lower the cost of prefabricated building, the framework lays out recommendations to support the growth of prefabricated supply chain management.

Current Status and Progress of Using Recycled Materials

According to [25], concrete is widely produced worldwide and is regarded as the primary material in the construction industry. Because of resource depletion, increased energy consumption, and increased greenhouse gas emissions, the use of virgin materials in the manufacturing of concrete has placed a significant environmental burden on the environment. Waste materials have been the subject of global experimentation in recent decades to substitute virgin ingredients in concrete. The study's findings emphasized journals that have published a lot in the past ten years. The most studied waste products were found to be fly ash and recycled aggregate, while the most widely used applications were aggregate substitutes. The study's goal was to ascertain current practices, the focus of waste materials research, and research gaps about sustainability-related issues.

On the other hand, [26] discussed that green building is the practice of enhancing the efficiency of the building by considering not only the use of water, energy, and materials but also the site on which it will be placed. It is identified that globally the construction industry is one of the most environmentally damaging sectors. The resources consumed and the operational energy requirements of buildings are potentially for decades. The Intergovernmental Panel on Climate Change stated that construction is a segment in which significant improvements can, and indeed must be made. The research emphasizes themes related to social sciences on sustainable construction, involvement of sustainable construction, and sustainable technologies adoption in the construction [Figure 1].

Table 1:

Material Type	New Material Cost ($)	Recycled Material Cost ($)	Saving (%)	New Material Pc (psi)	Recycled Material Pc (psi)	Env Impact Reduction of Recycled Material (Kg CO_2)
Concrete	150 per m³	120 per m³	30	4000	3,500	30%
Wood	200 per m³	150 per m³	50	1,200	1,000	25%
Plastic	60 per m³	45 per m³	15	5,000	4,500	40%
Glass	80 per m³	65 per m³	15	10,000	8,000	30%
Insulation	30 per m³	25 per m³	5	150	120	25%

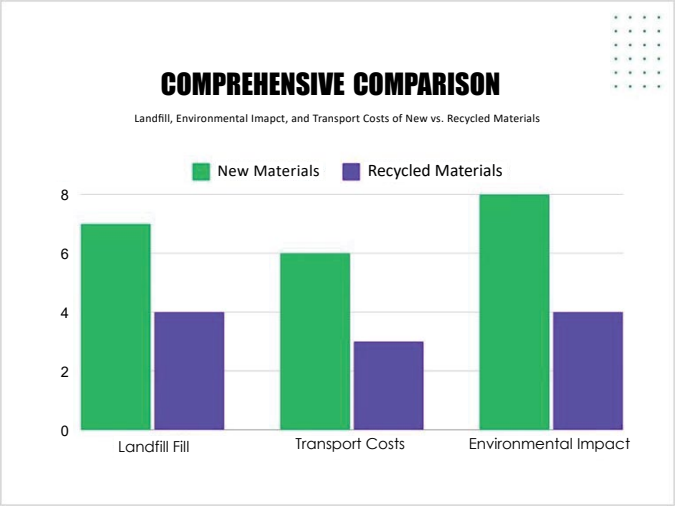

Figure 1: Comprehensive Comparison.

Challenges and Opportunities in maximizing Recycled Material Usage in Housing

As per the view of [27], recycling, construction, resilience, and demolition (CRD) plastic waste reduces environmental and human health impacts, as exemplified by considering various CRD waste studies. Decontamination technologies for CRD waste vary from simple washing to dissolution in a solvent. The ease of implementing decontamination methods was dependent on whether the contaminant was incorporated into the product. Automatic sorting and separation technologies exist for CRD plastic. The performance assessments of CRD plastic wastes revealed that the quality of recycled CRD plastics may compete with virgin plastic material. The challenges faced by the construction industry associated with recycled material usage focus on a lack of coordination among various CRD administration departments, a lack of incentive for distributors, and an insufficient amount of plastic produced from CRD waste [28]. Stated the determination of plastic waste generation sources and the severity of pollution in land and marine environments. The analysis discussed the techniques to treat waste plastic as well as the challenges to attaining sustainable plastic waste management. The influence of plastic waste is now a global concern associated with global warming and changes in climate by emitting toxic gases and contaminants into the environment. In managing plastic, conventional techniques are adopted that involve open dumping or landfilling, and these processes ultimately cause environmental pollution instead of achieving sustainable waste management goals. The research indicated opportunities linked with managing plastic waste from different aspects such as the development of infrastructure, emphasizing 3R and 4R waste management programs, strengthening existing laws and regulations to control plastic pollution, and introducing new alternatives to plastics.

Literature Gap

Previous studies carried out did not emphasize the environmental implications of utilizing recycled materials in construction. Research focuses on highlighting information linked with the use of recycled materials in construction as less research was carried out analyzing the environmental influence in the sector. Additionally, there was also a lack of information associated with the initial costs, long-term maintenance expenses, and affordability of homes built with recycled materials compared with conventional construction techniques. There has also been little research carried out to date to cover the use of recycled products in the construction industry after processing C&D waste, most studies have focused on strategies to reduce or recycle this waste stream. Studies also lack information associated with architectural and engineering strategies for maximizing the use of recycled materials in the construction sector.

Discussion

The present research related to recycled materials in the construction segment highlights environmental impacts, issues, and innovative design approaches. The research discussed that the environmental effects of the building are crucial, because of the consumption of energy and resources and the emissions pollutants including carbon dioxide, in the phase of construction. It is determined that building waste mainly from materials such as waste wood and plaster contributes to landfill pollution through the production of organic acids. On the other side, [14] discussed the recycling of plastic waste potential in construction, involving materials like high-density polyethylene (HDPE) and light-density polyethylene (LDPE) that can be used in construction involving different applications also supported in the reduction of environmental burden. It is analyzed that effective life cycle assessment of these materials is important for providing knowledge associated with the environmental and economic effects.

Using recycled materials in construction not only affects the environment but also has implications associated with housing affordability [17]. Determine key stakeholders in the process of decision-making regarding recycled materials including clients, builders, recyclers, and government entities. The research also determines enablers and barriers to the adoption of these materials further offering knowledge for policy reform. Innovative design in the construction sector also played a significant role in maximizing the use of recycled materials [21]. Emphasizes that thin-tile vaulting is a technique that involves recycled materials, determining the potential for innovative design and the reduction of environmental influence. Apart from this, [22] discussed green architecture and energy efficiency as key areas in which innovative construction techniques help in the promotion of sustainability. Integrating recycled materials in the construction sector helps in providing economic and environmental benefits. Adoption required overcoming issues related to dynamics in the market, the regulatory framework, and engagement of stakeholders [27]. Stated challenges for the adoption of recycled materials such as lack of coordination among CRD administration departments and insufficient incentives for distributors as a major issue in the construction segment.

Conclusion and Recommendations

It is analyzed from the research that integrating SIAH helps in carrying out business operations over a long period of time. Urbanization in the present market scenario possesses issues that also help in the promotion of innovation in sustainable housing using recycled materials such as concrete aggregates, glass, wood, and plastics, which offer cost-effective and environmentally friendly aspects. Recycled materials have benefits and similarly have challenges associated with durability and quality control. Integrating recycled materials in construction helps in dealing with environmental impacts, and reduction in the costs. The research depicted the need for enhanced resource efficiency and coordination with stakeholders to enhance the usage of recycled material. Studies focus on the economic and environmental benefits of recycled materials. It is observed that the gap also highlighted assessing long-term costs and the effectiveness

of present strategies. It is determined by innovative ideas including prefabrication and thin-tile vaulting support in carrying out activities in the long run. The research also discussed the benefits of recycled materials for the reduction of cost and environmental influence in assessing long-term costs and effectiveness. SIAH also supports dealing with challenges such as reduction in cost and mitigating environmental impacts. Prefabrication and use of thin-tile vaulting help in the construction process.

It is recommended that the construction sector should execute educational programs for engineers and workers to enhance their skills and knowledge concerning the use of recycled materials. Developing collaboration between private companies and the government to share resources and knowledge. Companies should be developing financing models that help in the development of housing projects by adopting sustainability and along with this involving green bond. Gaining affordable financing options for families with low incomes to access sustainable housing. They should promote the use of modular and prefabricated methods for construction that efficiently involve recycled materials and waste reduction. Governments should also emphasize developing policies related to the mandatory adoption of recycled materials in the projects. They should provide incentives related to subsidies that motivate architects in the adoption of sustainable practices. Implementation of a regulatory framework should ensure the safety of recycled materials to build confidence among builders as well as consumers in the marketplace [Figure 2-5].

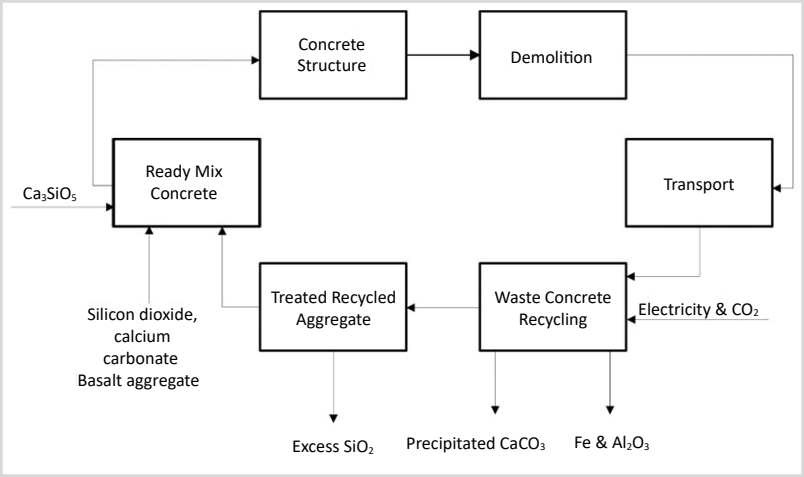

Figure 2: Recycled Concrete Process.

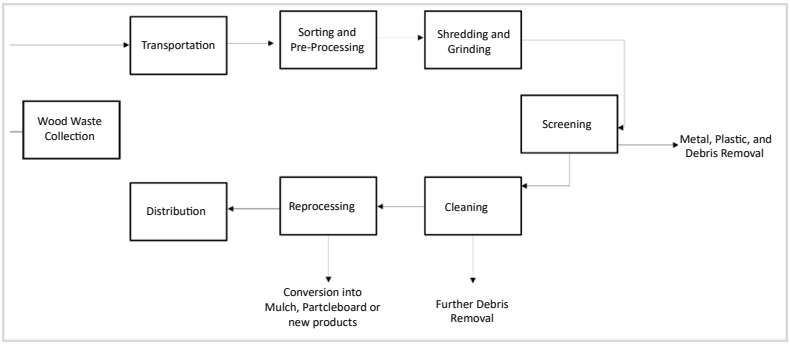

Figure 3: Recycled Wood Process.

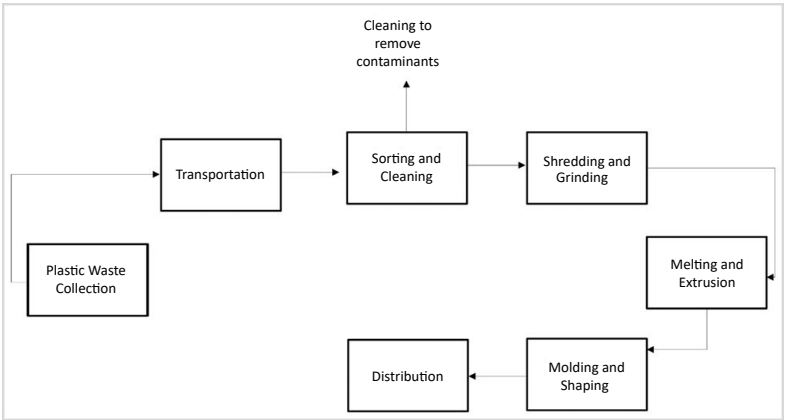

Figure 4: Recycled Plastic Process.

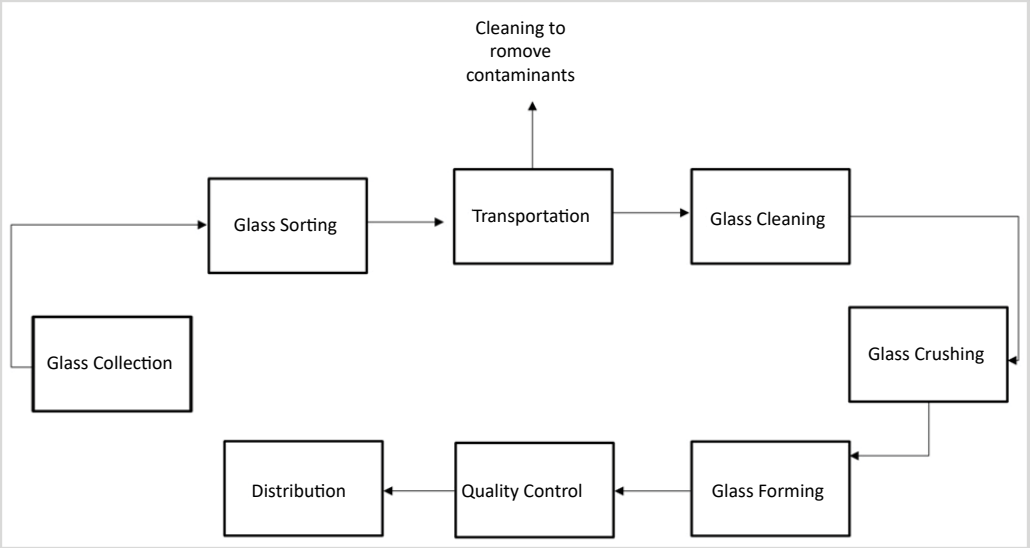

Figure 5: Recycled Glass Process.

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