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Review article

A comprehensive assessment of manufacturing towards zero waste

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Abstract: The word "waste" typically refers to something in our environment that can be recycled, reused, reduced, or even completely eliminated. Electronic and electrical goods, manufacturing scraps from daily necessities, etc.-a large amount of waste is produced every day, but the processing of this waste is delayed. The concept of zero waste encourages manufacturers and consumers to continually adopt sustainable practices to reduce costs and improve the world. Researchers have already discussed various approaches to dealing with physical litter, but the chemicals typically produced from this litter are more dangerous and have received less attention. The capability of utilizing CO_2 and nutrients from wastewater to make a variety of commercial bioproducts is provided by microalgae. It is difficult to create self-sustaining systems for the full valorization of algal biomass into valuable biobased products. Sustainable algal processing currently confronts a number of difficulties, such as expensive cultivation, challenging harvesting, and insufficient biomass vaporization. This evaluation assessed the potential of developing technologies with an emphasis on integrated strategies for the development of sustainable algal biorefineries, ensuring the sustainability of the relationship between the environment, water, and energy. Despite enormous efforts and resource expenditures, oleaginous microalgal biodiesel still cannot compete with petroleum-based diesel on a sustainable basis. The main reasons for this are the technical and financial difficulties associated with large-scale cultivation and downstream processing of algae, water and land use, stabilized production technology, market forces, and government regulation of alternative energy and carbon credits.

Keywords: Zero Waste; Electrical Waste; Algal Processing; Microalgae; Biodiesel.

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Introduction

When something in our environment should be recycled, repurposed, reduced, or even eliminated, that is what is typically meant by the phrase "waste." The concept of zero waste (ZW) is continually pressing businesses and consumers to adopt sustainable practices to reduce costs and improve society (Figure 1). The ZW may be aided by the creation of precise production systems, the use of optimization tools, sustainable manufacturing ideas, and the recycling and repurposing of manufactured waste. The ideal goal of ZW has emerged as a means of solving waste problems. Many cities, such as Adelaide, San Francisco, and Vancouver, have zero waste targets as part of their waste management plans (Connett & Environment, 2013).

The Development of Zero Waste

The waste disposal practices currently in use were developed long before our modern civilization. Over time, new methods for advanced treatment, landfilling, composting, and recycling have all been developed. The

ZW represents the most thorough innovation in waste management system development in the twenty-first century (Zaman, & Lehmann, 2011). In 1973, the phrase "zero waste" was coined to describe the recycling of resources from chemicals. However, the idea has drawn a lot of public interest since the late 1990s. The zero-waste concept has been adopted by a number of organizations around the world with the goal of eliminating trash disposal in landfills. Due to community involvement, the groundbreaking idea was first presented in Canberra, Australia. Canberra, Australia, became the first city in the world to formally adopt a zero-waste objective when municipalities there submitted the first "no waste" legislation, No Waste by 2010, in 1995 (Zaman & Connett, 2013).

Figure 1. Illustration of zero waste and its process.

The zero waste movement in New Zealand began with the establishment of the Zero Waste New Zealand Foundation, which promotes waste minimization. According to the Trust, it aims to establish a "closed-loop materials economy" in which products are designed to be reused, repaired, and recycled to reduce and ultimately eliminate waste (Tennant-Wood, 2003). In 2000, Del Norte County, California, implemented the nation's first completely no-waste strategy. The California Board of Integrated Waste Management adopted zero waste targets as strategic waste management plans in 2001 (Connett, 2013).

Zero waste was defined by the Zero Waste New Zealand Trust in 2002: "...a new goal that seeks to change how materials and resources are distributed in society from a "whole system" perspective. This "end of the pipe" solution uses a design strategy to maximize recycling and waste reduction while also ensuring that items are reused, repaired, or recycled for the environment or market. The industrial system will be totally reconstructed, according to the ZW, so that we will no longer regard nature as an endless source of raw materials (Tennant-Wood, 2003).

The first definitive definition of zero waste was made in 2004 by the International Zero Waste Association. In 2009, a peer-reviewed panel expanded it further. The International Zero Waste Association's definition of zero waste is as follows: Helping people change their lifestyles and activities to resemble the sustainable natural cycles for which all waste products are intended is an ethically fair, economical, sensible, and forward-thinking goal become resources for other people to consume. ZW stands for "zero waste", which is defined as the systematic prevention and elimination of waste, material volume, and toxicity as well as the conservation and recovery of all resources rather than incineration (ZWIA, 2009). Others have embraced and applied the working definition in their efforts to realize comprehensive ZW goals. According to the Department of the Environment in San Francisco, "sending nothing to a landfill or an incinerator" constitutes zero trash (Environment, 2011). Zero waste is a term used in England to describe "a concise means of expressing the goal to go as far as eliminating the environmental impact of trash." To prevent waste from occurring, conserve resources, and recover all of the value in materials is a lofty goal (Phillips, et al., 2011).

Consumption and Production of Sustainable Trash

One prerequisite for accomplishing ZW goals is the utilization of sustainable resources. Sustainable consumption refers to using resources intelligently to increase the standard of living while minimizing waste and environmental harm, not to consume less (Zurbrugg, 2002). Surprisingly, little research has adequately addressed the issues and difficulties posed by waste issues and overconsumption. The ambitious goal of "zero consumption" takes into account resources that can be used for purposes other than their original ones. Therefore, as resources are added to closed-loop systems, the concept of "consumption" itself is changed to that of "use" (Orecchini, 2007).

The current overconsumption inclinations, challenges, and requirements of sustainable behavior to achieve ZW goals were only briefly discussed in a few studies (Bartl, 2011). Numerous studies show that excessive consumption leads to the development of trash (Clapp, 2002; Wahab & Lawal, 2011). Sustainable consumption patterns promote responsible consumption by preventing the production of additional trash. Through sustainable consumption, it is possible to halt and avoid the accumulation of unwanted and needless waste. In addition to promoting sustainable consumption, manufacturing practices must be methodically updated to replace outdated, ineffective ones in order to reduce waste production.

Management and Treatment of Zero Waste

The majority of ZW research has examined waste avoidance, recycling, and advanced waste treatment technologies while also analyzing full ZW management systems (Figure 2). Trash is seen as a product that has reached its "end of life" and is produced at the final stage of product use in traditional waste management systems. Therefore, "end-of-pipe" solutions are the primary building block of management strategies. Recognizing that waste is a resource conversion that takes place at the middle stage of resource consumption zero waste challenges the traditional notion of waste. Therefore, through integrated ZW management systems, resources that are squandered as a result of our consumption actions must be diverted toward production (Zaman, 2014). As a result, ZW management employs integrated design and waste management principles. Today, the majority of cities have zero-waste landfill targets set (Connett & Sheehan, 2001). For instance, San Francisco's zero-waste objective seeks to get rid of waste in landfills by the year 2020. There is no question that our society's current methods of production, consumption, and waste disposal keep us from achieving a 100% divergence rate. It is necessary to replace the current systems for extraction, production, marketing, consumption, management, and purification.

Waste from Electronics and Electricity (E-Waste)

The E-waste is an issue now and in the future since its improper recycling and accumulation can have a negative impact on the environment and on people's health. E-Waste in India: A Technical Report (Agnihotri, 2011). Due to the availability and affordability of a wide variety of goods, the rise of cutting-edge technology and the globalization of the economy have significantly altered people's lifestyles. Electronics are an essential part of modern life since they provide us with convenience, security, entertainment, and the capacity to communicate information quickly and easily. The E-waste has also led to alarming waste production and unrestricted resource usage. It is made up of a variety of electrical and electronic devices, many of which include dangerous elements. Examples include refrigerators, washing machines, laptops, printers, televisions, mobile phones, iPods, and others (Figure 3). "E-waste" refers to all electronic and electrical device garbage that is either at the end of its useful life or is no longer appropriate for its original intended purpose and is either being recovered, recycled, or disposed of. It includes typewriters, cell phones and chargers, remote controls, CD players, headphones, batteries, LCD and plasma TVs, air conditioners, and other home appliances in addition to computer displays, printers, keyboards, and other peripherals (Jawahir & Dillon, 2007). The stages of the e-waste recycling process are as follows (Figure 3): all electronic wastes are collected in the first stage; the collected wastes are taken in the second stage; the electronic wastes are sorted in the third stage; all possible hazards are eliminated in the fourth stage; waste is processed in the fifth stage; and finally, all e-waste is calculated and reported in the sixth stage.

Depending on its composition, e-waste is either labeled "hazardous" or "non-hazardous." The principal materials include printed circuit boards, non-ferrous and ferrous metals, concrete, ceramics, rubber, and ceramics. Also included are plastics, glass, wood, and plywood. Plastics, non-ferrous metals, and other materials make up the second-largest portion of the waste, which is primarily composed of iron and steel. Non-ferrous metals include both common metals like aluminum and copper as well as precious metals like silver, gold, platinum, palladium, and copper (Cui & Forssberg, 2003; Vasile, 2008). Printing circuit boards have traditionally been recycled using mechanical and hydrometallurgical methods.

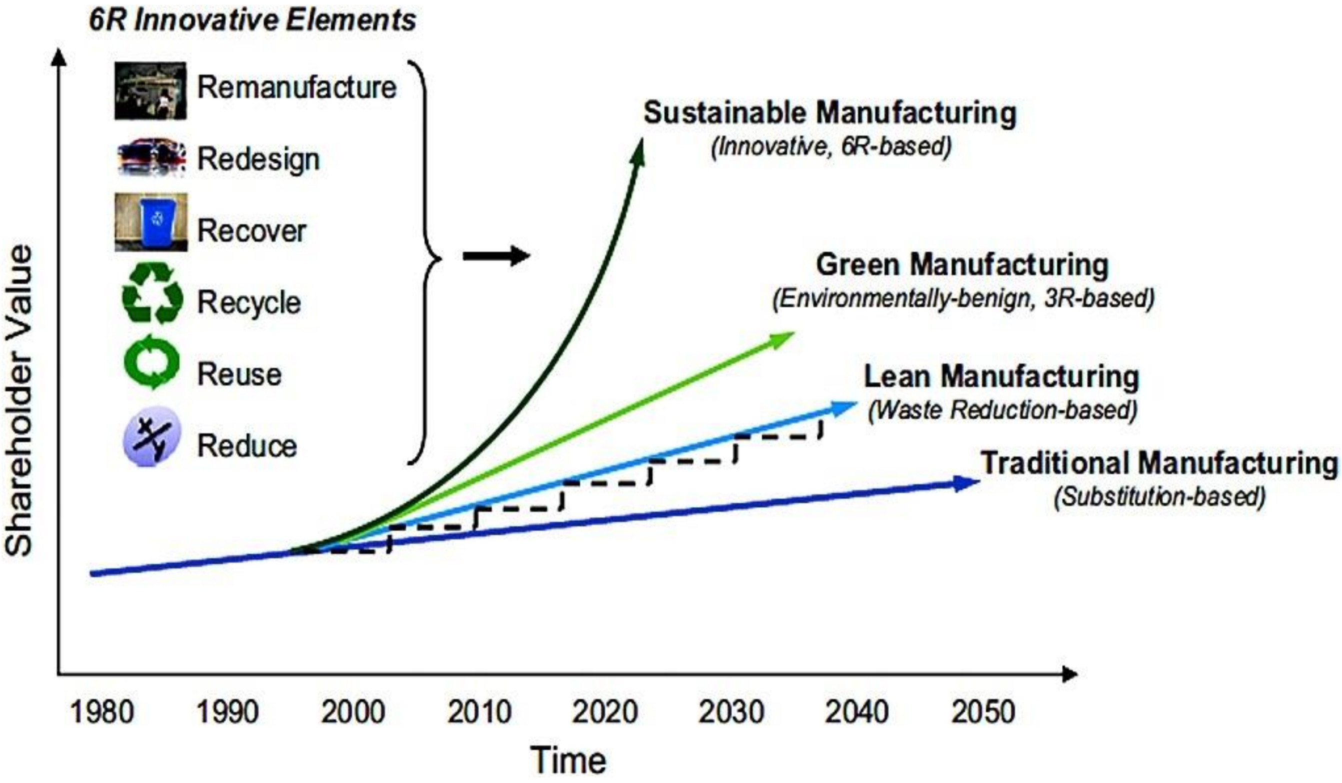

Figure 2. Sustainable-directed production (Jawahir & Dillon, 2007).

Figure 3. E-Waste recycling: Out with the Old and in with the New

Dust is the main source of e-waste pollutants that are emitted into the atmosphere. Humans are exposed to this in considerable amounts through eating, breathing, and skin absorption (Mielke & Reagan, 1998). Between 50 and 80 percent of the US's collected e-waste for recycling is transported to less developed countries, according to the 2007 report "Exporting Harm: Trashing of Asia" by the Basel Action Network and Silicon Valley Toxics Coalition. Human exposure to dioxins is 15–56 times higher than the WHO recommends due to air pollution (Chatterjee, 2007). E-waste differs from other types of domestic or industrial waste in terms of both chemical and physical structure. It contains both useful and dangerous ingredients that require careful handling and recycling procedures to prevent environmental pollution and adverse health effects. Effective electronics recycling requires human involvement, as this would not be possible without our courage and knowledge. Effective electronics recycling requires human involvement, as this would not be possible without our courage and knowledge. The best way to deal with e-waste is to reduce its volume. Designers must make the product reusable, repairable, and/or upgradeable to achieve this.

Upstream Processing Algae in wastewaters

Because algal biomass has a promising future as a source of biodiesel, food and feed additives, and other high-value industrial goods while also fixing atmospheric carbon and recycling wastewater, multiproduct algal biorefineries are an emerging concept within the context of the circular bioeconomy. It has become crucial to develop a self-sustaining system that completely valorizes algal biomass into valuable bioproducts. The goal of the multi-product biorefinery approach is to gradually convert algal biomass into a set of unique, commercially important products for various biotechnological applications (Fan et al., 2020) This technique is more complex than it first appears to be due to the numerous difficulties microalgae encounter during upstream, midstream (harvesting), and downstream processing in a biorefinery. A number of obstacles need to be removed before algae biorefineries can be marketed.

Due to population growth, urbanization, and industrialization, wastewater production has significantly increased in recent years. Untreated wastewater is widely thrown into reciving waters such as rivers, lakes, and seas in emerging and undeveloped countries, posing major threats to aquatic life (Nizami et al., 2017), due to a lack of resources, poor administration, and poorly implemented legislation. The culture of microalgae in wastewater is a low-cost, eco-friendly, and sustainable technique of wastewater treatment that also yields high-value algal biomass (Shahid et al., 2021). Depending on the type and source, microalgae can utilize 80–100% of the nitrogen and phosphorus in effluent. Numerous studies carried out over the past few decades have demonstrated the viability of treating wastewater from a variety of sources using microalgae, including municipal wastewater, dairy wastewater, brewery wastewater, winery wastewater, and aquaculture wastewater (Khatoon et al., 2018). Several research has examined the viability of using animal wastes and wastewaters in *Arthrospira* cultivation. Biomass production pigments, protein, carbohydrate, malondialdehyde, proline, hydrogen peroxide content, and total phenolic compounds by *Arthrospira platensis* were evaluated in relation to the use of wastewaters as a low-cost and environmentally favourable cultivation medium (Çelekli et al., 2016). Cow effluents, a low-cost model medium, had a high potential for the production of protein-rich biomass by *A. platensis*. The amazing results of these tests have demonstrated the viability of using wastewater as a low-cost growth medium for large-scale microalgae production.

Due to the microscopic size of algae cells and their negative surface charges, which encourage their stable suspensions in the growth fluid and make separation very challenging, algal biomass collection on a large scale is very challenging (Goswami et al., 2019). Due to the significant expenses involved in extracting algal cells from growth media, which results in expensive finished products, algae fuel has not yet achieved commercial viability. This negative charge has been neutralized using a variety of physical, chemical, and biological techniques, each of which has advantages and disadvantages (Choudhary et al., 2020). Recently, the only intended product made from microalgal biomass was biodiesel. However, this business could not be successful because the leftover (de-oiled) biomass was not being used. The cost of growing, gathering, and processing biomass may be significantly reduced by the gradual conversion of the valuable metabolites present in microalgal biomass, such as carbohydrates, proteins, lipids, and pigments (Goswami et al., 2019; Choudhary et al., 2020).

It is now necessary to cascade resource recovery from algae biomass using a zero-waste method for the development of algae-based biorefineries. Because of this, scientists are focusing on fully valorizing microalgal biomass within a framework of biorefineries built on the zero-discharge concept (Goswami et al., 2019; Choudhary et al., 2020). This study demonstrates the various options, problems, advantages, and limitations of processing algal biomass upstream, middle, and downstream in a multiproduct-based biorefinery paradigm (Figure 4). New prospects that could be applied in a zero-waste strategy are given particular consideration.

Despite having several biotechnological applications in the microalgal harvesting, the promise of microalgae was not completely fulfilled because of the numerous difficulties in large-scale collection. It is thought that the main barrier to the successful commercialization of products made from algae is the harvesting of algal biomass, which accounts for 20–30% of the production costs. Since algae cells have a negative surface charge and are small, they can form a stable suspension in the growing fluid, making separation challenging (Christenson & Sims, 2011). This makes harvesting challenging. Since each species responds differently to various harvesting techniques, there is no single method that is effective enough to harvest the majority of microalgal species. This method has a high recovery efficiency, is quick and dependable, and is not strain-specific, although it is energy-intensive (Ghernaout, 2019). The filtration-based gathering is useful because it is straightforward, uses little energy, and poses no risk of biomass contamination. In order to prevent biofilms from forming on the filter membranes, it does, however, have expensive operating and maintenance expenses for membrane replacement and cleaning (Zhao et al., 2020). Because it requires little energy input, is simple to operate, and has little risk of biomass contamination, filter-based harvesting can be used. To avoid algae and bacterial biofilm formation on the filter membranes, however, it has considerable operating and maintenance costs for membrane cleaning and replacement (Shahid et al., 2021). Even though the algal biomass couldn't be used directly for processing downstream after flocculation, it nevertheless helped to reduce the cost and energy needed to dewater the enormous volume of algal suspensions. Some microalgae can naturally flocculate when exposed to specific abiotic stressors like salts, nutrients, pH, temperature, and light (Muhammad et al., 2021). Self-flocculation or auto-flocculation is the term for this type of flocculation, which happens when microalgal cells create extra polymeric substances exopolysaccharide that act as clump-forming adhesives (Choudhary et al., 2020). Microalgal flocculation is caused by one of the four processes listed below: adsorption bridges, patching, charge reduction, and net sweeping. Many organic and inorganic compounds have been used to induce flocculation in non-flocculating microalgae (Huang et al., 2019). An ideal flocculant should have the following qualities in order to achieve economical and robust flocculation: it should (i) be effective with a small dosage, (ii) be affordable and environmentally friendly, (iii) pose little risk of contamination, (iv) offer higher biomass recovery, (v) require less settling time, (vi) be applicable to a wide range of microalgae species, and (vii) allow for the recycling of used media (Goswami et al., 2019). Since bioflocculation is practical, environmentally benign, and uses less energy than any other flocculant known to date, researchers have begun to concentrate on this process. By creating exopolysaccharide to allow the attachment of microalgal cells with one another to produce large flocs, a variety of microorganisms, including bacteria, fungi, yeast, and microalgae, can generate flocculation. However, this process is not highly productive (Nguyen et al., 2019).

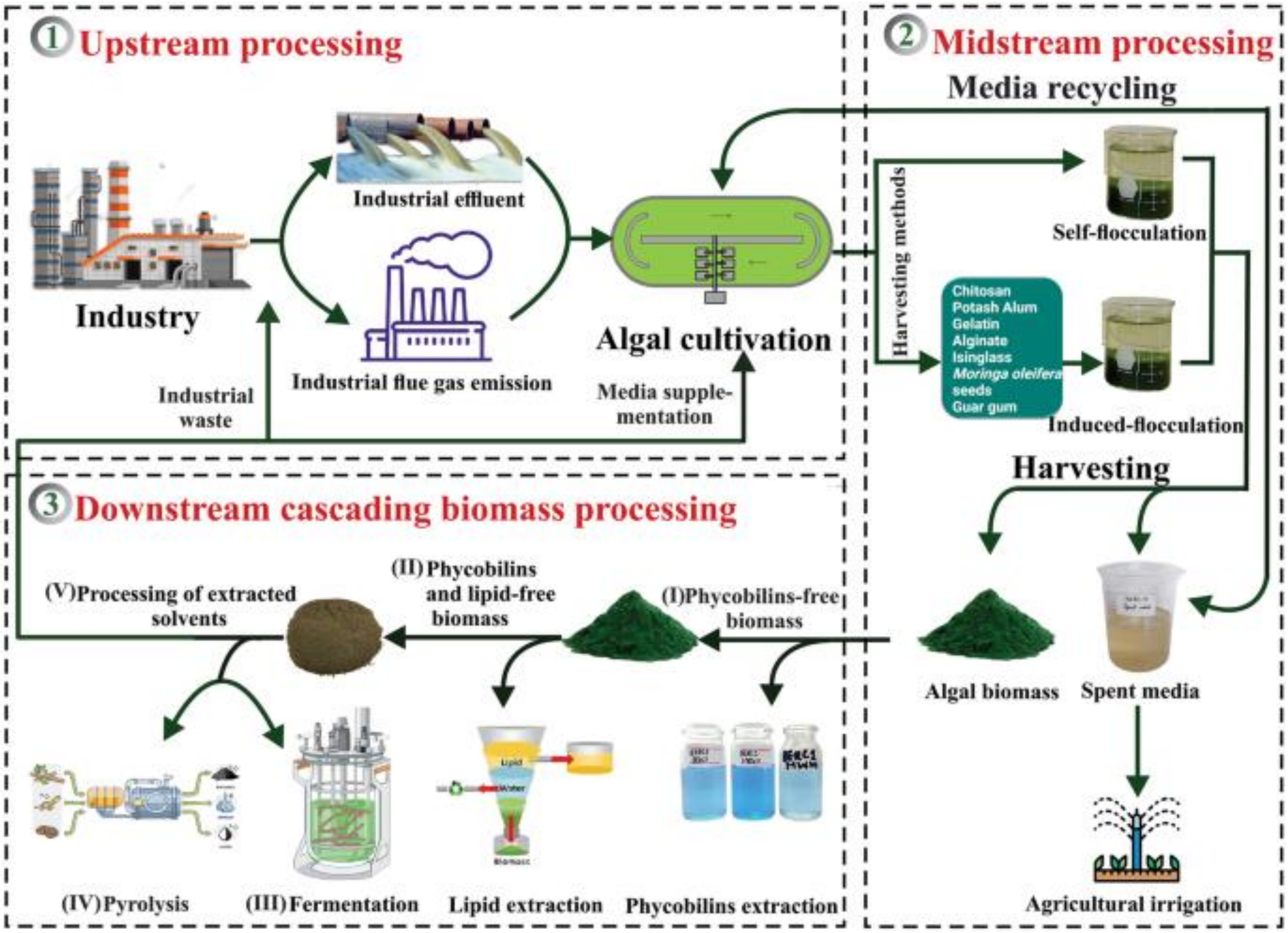

Figure 4. Microalgae Processing in wastewaters

Conclusion

A comprehensive strategy for addressing waste issues in the twenty-first century is ZW. This study comes to the conclusion that zero waste is still being developed after reviewing the literature. To attain ZW targets, experts have put forth a variety of concepts, plans, laws, and tactics that have been put into practice in cities. However, we must rework the comprehensive ZW plan in order to make it more workable and practicable. The ZW plan is now focused on achieving zero landfills through waste diversion. The report does agree that our society's production, consumption, and waste management processes do not currently allow for a 100% diversion rate. We need all current extraction, production, marketing, consumption, management, and treatment systems to be transformed. Therefore, research on how to convert current systems into ZW systems is essential for advancing ZW aims. This review study made an effort to include all pertinent research on ZW that has been done in recent years. In relation to the implications of the zero-waste philosophy, the study determined the scope and relevance of earlier investigations. Given that it identified the major gaps and patterns in existing ZW studies, the study's findings are crucial for policymakers who create ZW regulations. The study has provided broad and guiding concepts as well as recommendations for zero-waste development based on the available data. Even if the volume and scope of ZW are varied, this review study showed that many professions are using it in a number of contexts. Studies on the ZW design, production, sustainable consumption, and ZW assessment and evaluation domains were few and far between. Developing a national ZW strategy and incorporating and encouraging ZW initiatives (in communities and businesses) in waste management policies may help countries reach their ZW targets. The significant study on ZW has been critically reviewed in this article. This study draws the conclusion that the ZW concept has been widely utilized in various production phases and waste management systems based on the review's findings. The study's conclusions help define the ZW strategy's focus areas and create national ZW standards. As a result, decision- and policy-makers who create zero-waste recommendations based on evidence may find this article helpful.

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Ethical Approval

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Conflict of Interest

The authors declare that they have no conflict of interest.

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