Innovations in Green Chemistry towards Sustainable Development

*Manisha Kumari Sharma

1. ABSTRACT

Sustainable chemistry is a broad term that includes the development, production, and execution of effective, safe, and more environmentally friendly chemical processes and products. The concept of sustainable chemistry may be an important vehicle for attaining the Sustainable Development Goals (SDGs, 2015), which include a high number of targets for chemicals and waste management. When it comes to today's waste management problems, sustainable chemistry may be a useful tool. Recycling of waste and recovery of resources from waste fractions are often severely restricted by the chemical composition of used products. These restrictions apply to parts that turned out to be hazardous, materials that are blended with many additives, like plastic, composite materials that are difficult to separate, such as plastic and wood, and low concentrations of rare metals in electronic devices.

Following the concept of Sustainable Chemistry-

- Higher resource efficiency and the largest utilization of natural assets obtained from waste.
- Use of substances that are not only better biodegradable in natural conditions but also less hazardous ("benign by design").
- Designing products to enable recycling by stepping away from inseparable combinations of materials and firmly fixed modules (referred to as "design for recycling").

might be achieved.

The article aims to illustrate the advantages of integrating waste management issues into the concept of sustainable chemistry. To avoid further unilateral technical solutions that do not take into account resource recovery or reuse.

2. KEYWORDS- Scientific waste management, Sustainable Chemistry, Sustainable development goal, Green Chemistry

3. INTRODUCTION-

Residential and most commercial waste are nothing but crude mixtures of used or useless products, spoiled foodstuffs, remaining materials from construction and demolition, used packaging, etc. Each component of the waste is made from various substances based on specific chemicals and raw materials. Concerning the two main objectives of waste management, i.e.

- Disposal of residual waste in a manner that protects both the environment and human health,
- Recovery of materials and substances from waste to substitute virgin materials (resource conservation),

Successful disposal or recovery depends on the characteristics of chemicals used as ingredients or building blocks in materials. Globalization of consumer products also means the global application of chemicals used in these products and the global spread of these chemicals with waste when the products come to their end of life. This leads to the global availability of hazardous chemicals as ingredients in certain goods and in waste. Waste management is challenged by the disposal of hazardous substances in specified or mixed waste not only in the countries where these substances were produced but also everywhere else in the world where they have been used, disposed of, or recycled.

In two instances, we must disagree: On the one hand, there's a chance that waste contains dangerous compounds. To achieve safe disposal in this situation, special techniques (neutralization, high-temperature incineration, etc.) must be utilized. According to what is known about many chemicals that were once used in products, if waste of this kind is discovered in countries with inadequate industrial infrastructure, it could be a sign of serious threats to both humans and the environment. Numerous instances come to mind, which were banned years ago but are still prevalent in many places despite never having been produced, including PCBs. They are still used in transformers, tiny capacitors found in home appliances, and joint sealants in buildings. A global strategy is necessary to address the issues brought by persistent organic pollutants (POPs) like PCB. Most developing and advanced economies lack the disposal techniques and resources necessary to handle this kind of waste. Because recycling steps are limited to incineration or other degradation processes in this case, the exposure of used items containing precious resources to hazardous compounds is also a significant issue for industrialised countries.

On the other hand, certain chemicals frequently make it more difficult to recover valuable materials from waste (used paper, plastic, metal, etc.).

- which is no longer appropriate for certain uses (e.g., cadmium stearate, formerly used as a stabiliser in PVC in Europe).
- which have a particular use but shouldn't be present in applications based on the same raw material in other scenarios (e.g., oil-based inks for printing newspapers migrating into food packaging made of used paper).
- which are technically challenging for the recovery process but not hazardous (e.g., certain combinations of metals in alloys that cannot be separated due to metallurgical reasons).

These phenomena share a common aspect and are connected to certain other phenomena that are quite significant in terms of waste management tactics. This implies that there are several obstacles in the way of a "circular economy," including the following:

- When multiple materials are combined to create one product, complicated and energy-consuming recovery processes result (increasing entropy by material mix), if possible. Most of the time, recycling products made of various materials such as electronic appliances, plastic goods, and functional textiles would result in a significant loss of valuable materials. Recyclability, which integrates the economic and ecological dimensions, is generally based on the number of separation steps and the cost of valuables purchased on the market.
- High product dissipation makes collection difficult because entropy rises as dissipation occurs. Policymakers frequently underestimate the two-fold entropy problem.
- Depending on the characteristics of the product, there may be a delay of a few months, a few years, or even a few decades between production of a good and its eventual disposal. As a result of the severe information loss that occurs over time, it is unknown what chemicals and construction materials used in a product that discarded years after it produced. The materials and chemicals in a manufactured product frequently change over time, discouraging recycling businesses and preventing investment in new technologies. Since there is only one direction, we cannot halt technological advancement.

In general, there is no opportunity to solve these problems. However, there are some barriers we can remove and some borders we can possibly redraw:

- Chemical production that produces less hazardous wastes.
- Chemicals that are less hazardous or non-hazardous and are not persistent in the environment are invented and used.
- Materials and products are designed with resource recovery after use ("design for recycling") in mind .

4. THE CONCEPT OF SUSTAINABLE CHEMISTRY-

By the end of the 20th century, pesticides and fertilisers had enabled India to become food self-sufficient. Additionally, by using improved agricultural technology, irrigation, top quality seeds, etc., India was able to achieve food self-sufficiency. However, overusing the soil and applying fertilisers frequently cause the quality of the soil, the water, and the air to decline. So, how do you resolve the issue? Putting an end to India's path towards development or halting the development process? Without a doubt, no. Therefore, it is crucial to find and implement better methods that do not restrict or halt development but instead aid in reducing environmental degradation. In this case, green chemistry is applied.

The "principles of green chemistry" are a set of guidelines that were established in the 1990s to ensure that chemical production is less dangerous and environmentally safe. These guidelines include waste prevention (during production), tailored synthesis that maximizes atom economy, and the development of safer chemicals and products. An overarching concept is sustainable chemistry, as it has been defined in the last 10–15 years since a joint workshop of German and OECD (Organization for Economic Co-operation and Development) agencies. "Sustainable chemistry generally includes all product attributes related to sustainability, for example, social and economic attributes related to resource use by shareholders, stakeholders, and consumers." The green chemistry approach incorporates this idea as a tool at the molecular level, or throughout the stage of synthesis, but it must go beyond this level by accounting "for not only the functionalities of a molecule that are necessary for its application but also their impact and significance at the various stages of its life cycle," including the final stage when the materials and the product made here become waste. Sustainable chemistry is described by the OECD as "a scientific concept that seeks to demonstrate the effectiveness with which natural resources are used to satisfy human needs for chemical goods and services." Sustainable chemistry includes the research, manufacture, and application of effective, secure, and more environmentally friendly chemical processes and products. (OECD, 2015). Although internationally recognised definitions for sustainable chemistry are still being developed, the following summary based on recent studies and discussions may be taken as "state of the art";

- Sustainable chemistry contributes to the long-term advancement of society, the environment, and the economy. It creates value-creating products and services for the requirements of society using innovative approaches and technology.
- Sustainable chemistry is gradually using chemicals, materials, and procedures with the least possible adverse effects. Natural resources are also conserved, and substitutes, alternative processes, and recycling concepts are applied. This prevents harm and depletion of resources, ecosystems, and people.
- Sustainable chemistry is based on a comprehensive strategy that establishes measurable goals for a recurring change process. This development has important foundations in scientific research and education for sustainable development in schools and vocational training.

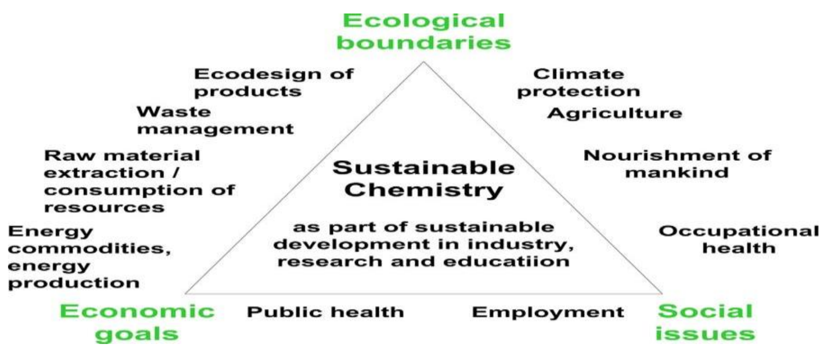


Fig. 1. Sustainable Chemistry interfacing other global issues.

Fig. 1 shows the intersections between sustainable chemistry and other major worldwide development issues. According to the definition of sustainability, it is a method and an objective rather than a fixed goal; this is also true for sustainable chemistry. This concept could serve as a potent asset to accomplishing these goals, which include a large number of targets for the use of chemicals and waste management in light of the difficulties outlined in the Sustainable Development Goals (United Nations, 2015).

Instead of addressing issues brought on by improper application of chemicals and unsafe residues left over from use, the development of sustainable chemistry depends more on the success of innovative new business and marketing models than it does on increased regulation because green chemistry principles and the sustainable chemistry concept offer opportunities not only for the chemical industry but also for other manufacturers along the value chain.

5. WASTE MANAGEMENT AND SUSTAINABLE CHEMISTRY: THE WAY TO LONG TERM STABILITY

5.1 Principles into Practice: Green Chemistry in Daily Life-

A. Green Dry Cleaning of Clothes:

The solvent most frequently used in dry cleaning clothes is percholoroethylen (PERC). The disposal of PERC (Cl2C = CCl2) is considered carcinogenic and contaminates groundwater. There is now a new method of dry-cleaning garments known as Micelle Technology, which uses liquid carbon dioxide as a safer solvent in combination with a surfactant. Some dry cleaners are now employing this technique on a commercial basis. Using this technology dry cleaning machines have been modified so that a green solvent takes the place of the carcinogen PERC.

B. Green Bleaching Agents:

Traditionally, lignin from the wood used to make good quality white paper is removed by soaking small pieces of wood in a sodium hydroxide solution and sodium sulphide, followed by a reaction with chlorine. Chlorine also reacts with the lignin's aromatic rings to produce chlorinated dioxins and chlorinated furans. As carcinogens, these substances have negative effects on health. In the present, a green bleaching agent has been created that uses H2O2 as a bleaching agent in the presence of activators like TAML, which catalyse the quick conversion of H2O2 into hydroxyl radicals that cause bleaching. This bleaching agent degrades lignin more quickly and at a lower temperature.

C. Eco Friendly Paint:

Volatile organic compounds (VOCs) are released in large quantities as oil-based "alkyd" paints dry and cure. These VOCs have many environmental effects. To replace petroleum, paints, resins, and solvents derived from petrochemicals, a mixture of soya oil and sugar is currently used, which reduces the hazardous volatiles by 50%.

D. Putting Out Fires the Green Way:

The ozone layer is destroyed, and toxic substances are released into the environment by the widely used chemical firefighting foams that are used to put out fires. Since other firefighting materials produce toxic by-products, the new foam pyro-cool has been developed to effectively put out fires without doing so.

E. Turning Turbid Water Clean in Green Way:

Traditionally, alum is used to clean municipal and industrial wastewater. In treated water, toxic ions increase when alum is present, which causes Alzheimer's disease. The powdered tamarind seed kernels, typically discarded as agricultural waste, are equally effective and more affordable than alum in cleaning up municipal and industrial wastewater. Tamarind kernel powder is also inexpensive, environmentally friendly, and non-toxic.

F. Biodegradable Plastics:

Worldwide, a lot of non-biodegradable waste plastic is present. In this direction, numerous industries have been active. Nature Works, for instance, uses polylactic acid to create food containers. Scientists at Nature Works have discovered a process that uses microorganisms to turn corn starch into a resin that is just as durable as the petroleum-based plastic used to make containers, water bottles, etc. The company is trying to use agricultural waste as a raw material. Another illustration involves making fully biodegradable bags using biodegradable polyester film, calcium carbonate, and cassava starch. The Biodegradable Products Institute has certified the bags as completely biodegradable into water, carbon dioxide, and biomass in industrial composting systems. These bags are used in place of traditional plastic bags because they are tear-resistant, puncture-resistant, waterproof, printable, and elastic. Throughout municipal composting systems, they will break down quickly along with yard and kitchen waste.

G. Building with Green Technology:

A building can be constructed with a significantly lower carbon footprint using green eco-friendly practices such as reflexive solar design, natural ventilation, and green roofing technology than typical construction using domesticated materials. These methods are not only cost-effective but also good for the environment. Green ventilation methods allow for natural airflow, which reduces the need for conventional air conditioning.

5.2 From linear to circular economic model: the building blocks of a sustainable society

The linear economic model of extract, process, consume, and dispose of has been the foundation of our society. It is equally unsustainable whether organic carbon is used to synthesise plastic or indium to make mobile phones. In addition, we frequently treat this "waste" in a way that harms the environment. It happens when we turn a valuable and limited resource into waste (often after a very brief lifespan, like a plastic bag). How might the circular economy make things better?

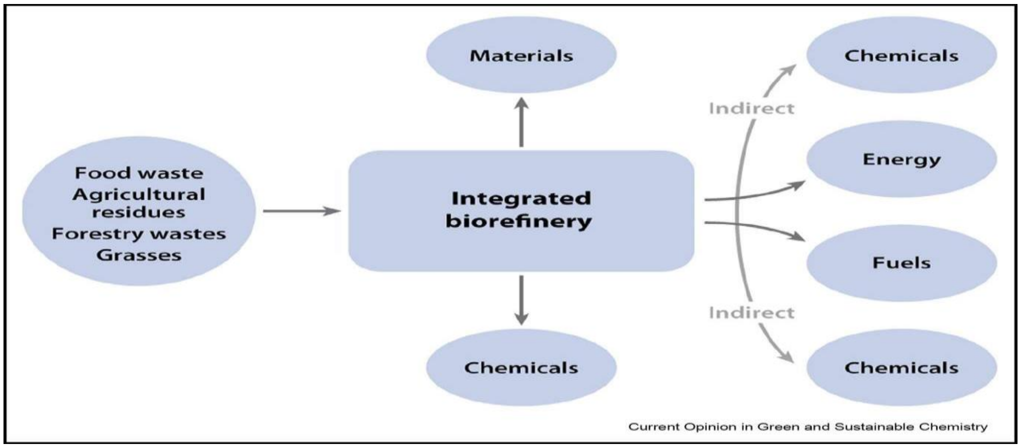
We must ensure the resources integrated into every good or service we create and use are returned for future use, whether it is a similar product or something entirely different. Most circular economy models achieve this using either the natural biosphere for organic products/substances or the man-made Technosphere. We would achieve sustainability if all resources were used again within a century of their initial use and if we could build anything the world's population might desire using only already existing and easily accessible resources.

Waste is a valuable resource, that we have accumulated over a long period. Plastic and food supply chain waste are practical examples of organic "waste-to-resource" opportunities. They will work well in a circular economy when used as chemical feedstocks. Plastics present a significant opportunity for waste reduction: we only recycle a small percentage of the plastic we use, even though manufacturing plastic uses about 10% of the oil we use overall and results in the negligent release of a significant portion of it. Wastes from the food supply chain's chemical composition are much more complex and diverse than waste from the plastic industries that also contain a wide range of valuable chemical products.

5.3 The biorefinery: the substitute for fossil resources

Since the early 20th century, society has benefited from a manufacturing sector that is closely related to petroleum refining. However, the manufacturing sectors, which give us an abundance of products, are currently facing challenges to their long-term development due to limited feedstock reserves highly dependent on non-renewable crude oil, declining "new oil" discoveries, and a corresponding dramatic drop in investment, growing public concern over the environmental and human safety of current products and processes, and the expansion of legislation and policy affecting the sector. Scientists are currently searching for safer, more environmentally friendly, and renewable alternatives to the petrochemical-based products we currently use. As an alternative to refineries based on petroleum, bio-refineries show promise.

Bio-refineries are integrated complexes where a variety of renewable feedstocks (biowaste and biomass) can be processed into a variety of useful products, such as chemicals, materials, and fuels that are equivalent to and or sometimes identical to those derived from petroleum. To take advantage of this opportunity to move towards a green and sustainable manufacturing industry, these must utilize environmentally friendly technologies (such as microwaves, continuous flow processes, heterogeneous catalysis, etc.).



Waste-Based Biorefineries to Produce a Wide Variety of Products

6. CONCLUSION

Waste management's contributions to Sustainable Chemistry, on the one hand, and new links between chemicals, product design, and resource recovery, on the other, should be discussed in the waste management community. The two fields of science might inspire one another through research. Regarding the debate over the circular economy, this has particular significance. Beyond the physical impossibility of closing material loops up to 100% (which would require infinite energy according to the second law of thermodynamics), there are many achievable goals for less waste production and significantly more material recovery in comparison to current practice if the Sustainable Chemistry concept becomes widely accepted for the synthesis of chemicals and life cycle approaches of products.

Sustainability is impossible if we ignore our waste legacy. In reality, the best we can hope for is a slow (but hopefully steady) transition to a circular economy model as we simultaneously learn how to add value to our waste accumulation. We require a complete and committed three-way partnership between industry, the government, and the general public to address both of these. We all need to understand and support a shift in perspective about what we currently understand as something that has no significant value and is best disposed of. The industry needs to introduce the concept of new feedstocks and the new technologies needed to valorize them. Governments need to make sure that legislation isn't obstructing its use (e.g., on waste labelling and movement). We mandate a waste education platform that helps everyone see the value in waste, whether it is through resource recovery, refurbishment into another item, or direct reuse by someone else (which ultimately degrades to the component molecules, which could then be used for multiple applications).

***Assistant Professor**
Department of Chemistry
SCRS Rajkiya Mahavidhyalay,
Sawai Madhopur (Raj.)

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