

## 1.1: Introduction to Green Chemistry

### Introduction

The rise of the industrial complex and society's strong need to increase its quality of life, security, wealth, and future productivity have helped to relegate the discipline of chemistry and its work to a very lofty position of prominence. Our progress toward achieving a Utopia of human intellectual growth, freedom of choices, equality within classes, and wealth acquisition have been supplemented and encouraged by the fruits of chemical research & development efforts since the dawn of last century. For example, we have witnessed significant strides in the following facets of our lives:

- Water: the introduction of reagents such as chlorine and fluoride to not only reduce and eliminate microbial contamination, but to also improve dental health, respectively;
- Food: we have seen the ability to use fluoro, chlorocarbons (CFCs, "Freon") to help refrigerate foods for much longer "shelf life", packaging that has specific mechanical and antimicrobial properties, and preservatives/food processing aids for eliminating spoilage;
- Clothing: synthetic fibers such as rayon, nylon, polyester, and Kevlar have been indispensable to not only normal wear, but to military, geologic, agricultural, and packaging applications;
- Safety: materials chemistry has spurred the manufacture of lightweight, but tough materials such as helmets, resins, plastics, etc., that have helped save lives in a number of military and industrial sectors.

The chemical industry has played a vital role in the emergence of high quality life within our human societies in these latter areas as well as many others. In fact, the industry is among the top ten industrial sectors in terms of gross output and sales. One of the most adverse realities and perceptions of the industry is its impact on the environment. Although it is a very safe industry as a whole, well publicized disasters have contributed to a poor public perception. For example, issues such as eutrophication, persistent organic pollutants, BOD, and the famous burning Cuyahoga River are typical of the calamities that damage the reputation and importance of our industry.

Please see <http://clevelandhistorical.org/items/show/63#.V7NI5BWU2og>

In fact, the morning of June 22, 1969 was witness to a fire from the burning of oil and debris that collected on the surface of the Cuyahoga River (Cleveland). The event roused up a media storm, captured national attention, and was featured in a commentary on the nation's environmental problems (Time magazine, Aug. 1). It was a clarion call to how calamitous the nation's environmental problems had become. The then EPA Administrator Lisa Jackson commented years later (2011) that the fire evidence of "the almost unimaginable health and environmental threats" from water pollution of the time. Clearly, as one environmentalist stated, "when rivers are on fire, you know things are bad." The image was seared into the nation's emerging environmental consciousness and fueled a demand for greater regulation. In 1972, Congress passed the federal Clean Water Act (CWA). Today, the nation's waters are far cleaner, and many credit CWA with preventing other rivers from befalling a similar fate.

The reality is that the fire was a symbol of how bad river conditions in the US had once been. That fire was not the first time an industrial river had caught on fire, but it was the last. For example, the late 19th and early 20th century saw many river fires. At least 13 on the Cuyahoga occurred, whereas there were others on rivers in Detroit, Baltimore, Philadelphia, and elsewhere. Although industries, chemists, and governments do not ever intentionally wish to or contribute to cause harm, the law espoused by "Murphy" holds. The contemporary form of the law can be traced back to 1952 as an epigraph for a mountaineering book by Sack who described the adage as an "ancient mountaineering adage":

*Anything that can possibly go wrong, does* (Sack, 1952).

Thus, the challenge for contemporary chemists and allied workers in view of the law is to ensure that any and all reactions, processes, and designs keep this general philosophy in mind. Our goal in the twenty first century is to mitigate potential disasters that can occur from our chemistries and engineering.

### Sustainable Development

The concept of "sustainable development" was articulated from a UN Commission on Environment and Development in 1987 (Brundtland Commission). It is simply stated:

'..meeting the needs of the present without compromising the ability of future generations to meet their own needs.' Since the Brundtland Commission, a number of governments, NGOs, and societies have considered deeply what sustainable really means.

Several of the key drivers heating up this discussion include:

1. What is an acceptable rate of depletion of fossil fuels? Is there?
2. Is there an acceptable level of pollution to release into the atmosphere and water?

Obviously, waste is a given in any industrial process, but the primary question is not its generation, but how it is handled. If we produce a waste stream, can it be recovered, recycled, or reused? If carbon dioxide is the waste stream, can we conclude that nature will sequester it or will it contribute to global warming (climate change)? These are questions that warrant intense analysis and follow-up. The overall fate of the planet (humanity, ecosystems, and our way of life) hang in the balance. Methods to address ensuring the continuation of our planet and its resources include:

- Not allowing for the accretion of toxics (e.g., heavy metals) from the earth's crust and other beds;
- Not continuously creating non-degradable/perishable compounds (e.g., CFC's, benzodioxocins) that can cause significant damage to the ozone and aquatic life, respectively;
- Ensuring that the natural processes in place on earth are not disrupted (e.g., ravaging rainforests, polluting watersheds);
- Not depleting or hoarding natural resources (e.g., water).

We as an educated community (students, teachers, government workers, industry workers, etc.) recognize and appreciate that the Earth is equipped to deal with hiccups and disturbances in its processes, but continuously pushing such boundaries of recovery will only lead to disasters. Indeed, a paradigm for ensuring that our chemical processes do not exceed the capacity of the Earth to engage in buffering and recovery is the following:

*To promote innovative chemical technologies that reduce or eliminate the use or generation of hazardous substances in the design, manufacture, and use of chemical products.*

The above statement defines the concept of "Green Chemistry." The subject has now become a very well accepted and welcomed part of many chemistry curricula and industry philosophies. In fact, the concept of a triple bottom line, i.e., financial, social, and environmental owes its existence to green chemistry. Green chemistry has become an incredibly indispensable field within the panoply of chemistry subject matter. Its content and mission, however, are very unique in comparison to its sister courses because it embodies a social and environmental focus.

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