Int.J.HIT.TRANSC:ECCN.Vol.2: Issue 2A (2016) Page 14-19 ISSN: 0973-6875

Available Online at www.hithaldia.in/locate/ECCN

ORIGINAL CONTRIBUTION

CHEMICAL INDUSTRIES AND ENVIRONMENT: POSSIBILITY OF AN ECONOMICALLY LUCRATIVE SYMBIOSIS

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(Received Date: 22nd May, 2016; ; Revised Date: 20th June, 2016; Acceptance Date: 15th July, 2016)

ABSTRACT

Chemical industries play a central role in modern world economy converting mostly inorganic raw materials of very little or no value to produce more than 70,000 different products that are valuable to develop and run today's modern human civilization. However, these industries are considered to be one of the major sources of environmental pollution. The point sources of pollution such as disposals from industry wastes, as well as non-point sources such as urban and rural run-offs have been contributing significantly to destruction of natural ecosystems and several human diseases. It has even been established that some of the products of chemical industries are responsible for emission of greenhouse gases having significant contribution to global climate changes. Over the history of human civilization, particularly since industrial revolution in the middle of the twentieth century, banning of several chemical industry products strengthens the case for chemical industries' contribution to environmental pollution. Considering the importance and indispensability of chemical industries in modern times, it is important that innovative, novel, and environmentally-sustainable technologies are explored, researched, and applied to develop an economically viable industrial production system, in which growth of human wealth, and enrichment of natural ecosystem co-exist.

KEY WORDS: Chemical industry, environment, pollution, air pollution, water pollution, global warming, climate change, sustainability

1. INTRODUCTION

Chemical industries globally constitute a 3 trillion dollar enterprise producing almost 80,000 different products, without which today's modern world couldn't have been imagined. Among the twenty largest chemical industries in the world, five are American, three German, six Japanese, and most of the rest six are from other European countries. Clearly, historically and presently European countries lead in total chemical industry output, followed by the United States, and Japan. However, fast growth rate of chemical industries in developing countries like China, India, Korea, the Middle East, Nigeria, Trinidad, Thailand, Brazil, Venezuela, and other South East Asian countries like Indonesia have been significant in changing the global structure of chemical industries. Indian chemical industries, although only contribute 2% of the global output, are growing at a rate of 10 – 12% annually. They contribute 13% of India's total industrial output, 13% of our country's total export, and 7% of India's GDP.

More than 80 years of development and growth of chemical industries worldwide have enabled us to deal with 100,000 chemicals either as raw materials or reagents or intermediate or final products. But, this has exposed us and our surroundings to numerous hazardous chemicals such as DDT, PCBs, dioxin, sulphuric acid, phosphate fertilizer and heavy metals, such as lead, arsenic and mercury. The World Wildlife Fund (WWF) has reported that more than 500 chemicals are now present at detectable levels

in our physiological system, and were never detected before 1920s. The United Nations have simplified the list of hazardous wastes by dividing them into six major classes – (i) persistent, bio accumulative and toxic substances (PBTs), (ii) carcinogens and mutagens adversely affecting our reproductive, endocrine, immune, or nervous systems, (iii) acutely toxic, explosive, and corrosive chemicals that have immediate hazards, (iv) persistent organic pollutants (POPs), greenhouse gases (GHG), and ozone-depleting substances (ODSs), (v) healthcare wastes, and (vi) e-wastes. Obviously, the first four types of hazardous wastes are consistently discharged into the environment by chemical industries. Besides direct impact of chemical industry wastes and/or products on our body and mind, it is now well-established that such chemicals have detrimental effect on our environment.

According to the United Nation's fourth assessment report on climate change published in 2007, the average temperature in the Northern hemisphere during the last 50 years is *very likely* the highest recorded in the last 500 years, and *quite likely* the highest recorded in 1300 years. Obviously, rather unprecedented rise in temperature has significant impact on wide range of terrestrial and marine animal and plant species. It is evident that human activities result in emissions of four long-lived GHGs – CO_2, methane (CH_4), nitrous oxide (N_2O) and halocarbons such as gases containing fluorine, chlorine or bromine. The three major sources of growth of GHG are emissions from transportation, energy generation and consumption, and industries, including chemical industries, whereas growth of GHG due to agriculture, residential and commercial buildings is comparatively slower.

Under these circumstances, human civilization, as we know it, driven by progress of science and technology, growth, and prosperity, faces critical challenges in the twenty first century. This monumental challenge has opened up new avenues of research and development, job creation, and wealth generation that promise to be sustainable. This paper attempts to evaluate this enormous opportunity, and provides an overview on solutions to one of the most complex and unavoidable problems human race has ever faced.

CHEMICAL INDUSTRY

Chemical industries includes companies that convert raw materials such as oil, natural gas, air, water, metals, and minerals into products that are central to modern world economy. Plastics and polymers comprise of almost 80% of chemical industry products. Besides, chemical industry products are starting materials or intermediates to processing of numerous consumer goods, and provide agriculture, manufacturing, construction, and service industries with pivotal inputs. To summarize such an extensive list of products, they may be classified into four broad categories –

(i) Basic chemicals (35 to 37% of total output) e.g. polymer products used for packaging materials and containers, home construction and/or appliances, pipes, toys, games, different intermediates of bulk petrochemicals such as ethylene, propylene, benzene, toluene, xylenes, methanol etc., derivatives of these basic chemicals such as rubber, surfactants, dyes and pigments, turpentine, resins, numerous inorganic chemicals such as salt, acids, alkalis, and fertilizers.

(ii) Life sciences (30% of total chemical industry output) e.g. pharmaceuticals, diagnostics, animal health products, vitamins, and crop protection chemicals such as herbicides, insecticides, and fungicides.

(iii) Specialty chemicals (also sometimes referred to as 'fine chemicals'; 25 to 30% of total output) e.g. innovative and useful products such as industrial gases, adhesives, sealants, coatings, industrial and institutional cleaning chemicals, and catalysts, marketed for their use instead of their chemical composition.

(iv) Consumer products (about 10% of the total output) e.g. products ready for direct use such as soap, detergent, and cosmetics.

Global and Indian scenario:

Historically, European countries together form the leading continent, when it comes to chemical industry output, followed by the United States, and Asia. However, by the turn of twentieth century, owing to rapid growth rate of chemical industries across countries like Japan, China, and India, Asia became the 2nd highest in the world [4, 6]. According to the American Chemical Council (ACC), thanks to 11% growth rate of chemical index in the Asian countries, 6.7% in Europe, and only about 0.2% in the United States during the years 2000 – 2005, Asia has surpassed the EU countries in chemical industry output. Among the four major categories of products, basic chemical constitutes the largest proportion, followed by specialty, and knowledge products. However, due to high cost of energy and raw materials required in basic chemical industries, their profit-margins are going thinner, which has driven their growth rates slower compared to those for specialty and knowledge chemical industries.

Until late twentieth century, chemical industry has been consistently front-runner among all manufacturing industries. But, over the last two decades, the Asian crisis, economic meltdown, and higher global oil prices due to political uncertainty in the Middle East have left chemical industries lag behind the rest of manufacturing industries. Although only 2% of the total global output, Indian chemical industries are growing at 10 – 12% annually, and soon becoming a significant force to reckon with in the global scenario of chemical industries. They play a major role in Indian economy, constituting 13% of India's total industrial output, 13% of its total export, and 7% of its GDP. Among chemical industry products, petrochemicals are of most value in India, followed by specialty and fine chemicals, pharmaceuticals, inorganic chemicals, and dyes and paints.

CHEMICAL INDUSTRY WASTES

Waste can be anything owned by a person or an organization including business organization, and which the owner wants to get rid of. That means, if an item is treated as waste by the producer and/or owner, then it is a waste [2]. Taking a different perspective, waste may be defined as that, which represents a loss of valuable resources both in the form of materials and energy, many of which are scarce [3]. According to the Resource Conservation and Recovery Act 1976 of the United States, hazardous waste is a waste that poses substantial or potential threats to public health or the environment if improperly managed (RCRA) [7]. The Environmental Protection Agency, both in Europe and in the United States [3, 14-15], have listed and categorized hazardous waste mostly according to their sources and characteristics. Government of India started enacting Environment (Protection) Act in 1986, as an umbrella Act encompassing Water (Prevention and Control of Pollution) Act 1974 and Air (Prevention and Control of Pollution) Act 1981 [8]. This legal document enlists hazardous wastes as well as some of the chemical industries that may generate them.

Vast majority of the hazardous wastes, as classified by the UN into six categories, are generated by chemical industries. This is evident from the fact that hazardous waste generation in different countries largely depend on its contribution to the global chemical industry out put (Figure 1) [9]. Due to global awareness about hazardous wastes, regulatory enforcements some of these hazardous chemical industry wastes are now well-managed, particularly in developed countries. The problem of accumulation of PBTs and POPs (Figure 2) such as heavy metals, residues of synthetic agricultural inputs, industrial chemicals and unintentional byproducts (e.g. solvents, hexachlorobenzene, polychlorobenzene, dioxins and furans) in the environment and our food chain has been consistently addressed, and progress has been made towards eliminating or minimizing their presence [1].

CHEMICAL INDUSTRY WASTES AND CLIMATE CHANGE

Majority of chemical industry wastes contribute to GHGs in our ecosystem. It has

been documented that total GHG emission has increased by 70% over the last three decades [5]. Emission of carbon dioxide, the major GHG that is responsible for global climate change, has increased by 80% during the same time period. Also, as much as 45% of GHG emission worldwide is due to industries including chemical industries, energy industries being the most significant contributor among them. In an assessment by the Intergovernmental Panel on Climate Change, UN has reported with more than 90% certainty that global increases in CO_2, N_2O, and CH_4 are due to our use of fossil fuel, use of fertilizers in agriculture, and both, respectively [5].

SUSTAINABLE GROWTH OF CHEMICAL INDUSTRIES

The element of uncertainty

The debate between so-called "pro-" and "anti-chemical industry" views on effects of such industries on climate change is raging throughout the world. Published literature have conclusively researched and reported that warming of global climate is due to increased emission of GHGs [5]. Unequivocal data on increases in global average air and ocean temperatures, widespread melting of polar snow-cover, and rising average sea level emphasize this fact. However, all impacts of global climate change such as higher-altitude and earlier-spring planting in agriculture, increased heat-related mortality in Europe, shorter snow-hunting season in the Arctic, losses of coastal wetlands and mangroves, and increased coastal flooding due to rising sea level are not conclusively established through published research.

Approaches to face the challenge

In the midst of many conflicting views, and uncertainties on contribution of chemical industries to global climate change, world leaders in science, research, business, and politics are gradually reaching a consensus that human race can only prosper and grow qualitatively if growth in production, business, and wealth are sustainable. The regulatory mandates on hazardous waste disposal by generating industries including chemical industries are in place, and are being enforced by national and international agencies to the extent they are capable of doing so. Slowly, but gradually the realization is sinking in that tackling a problem of this magnitude and complexity calls for inter-continental, inter-organizational, and cross-border cooperation and collaboration.

The Ozone Action Programme initiated by the United Nations Environment Programme (UNEP) in 1987 and ratified by 187 countries around the world under the Montreal Protocol have been effective in collectively deal with the problem of depleting ozone layer in the stratosphere [12]. The UNEP has started Finance Initiative (FI) involving 180 insurance companies to promote "green investment" and "green growth" among private sector organizations [9]. The UNEP has even been working with organizations such as International Olympics Committee (IOC), which reported successful reduction in emission during 2008 Beijing Olympics, and all the estimates from the ongoing 2010 Winter Olympics in Vancouver, Canada, are expected to tell a similar success story.

Particularly for chemical industry wastes, Basel, Rotterdam, and Stockholm Conventions by the UNEP were attempts to harmonize logistics and improve coordination at regional, national, and global levels to deal with the problems like hazardous waste disposal, and international trade of hazardous chemicals and pesticides [10]. All the parties to Basel, Rotterdam and Stockholm conventions have met for the first time in February 2010. This rather extraordinary and unprecedented cooperation was aimed at joint activities, management, budget, audits, and a uniform review mechanism dealing with chemical industry waste related problems and emerging issues.

In the late 1980s, tightening of environmental regulations in industrialized countries led to significant rise in the cost of hazardous waste disposal. The malpractice of shipping

hazardous wastes to developing countries by some of the waste-generating industries started. When revealed, international outrage led to the drafting and adoption of the Basel Convention, which was signed in 1989, and effective since May 1992 [11]. Each country party to this draft (includes India, China, USA, and UK) is required to annually report its hazardous waste generation and movement in the form of detailed data tables, and graphics. This has led to: (i) successful reduction in quantity and hazardousness of wastes, and (ii) disposal of waste to the nearest possible location from the source of generation minimizing movement of hazardous wastes.

Rotterdam Convention signed in 1998 and effective since 2004, is a step to further strengthen Basel Convention by a multilateral agreement on sharing responsibilities of hazardous waste movement and disposal worldwide by cooperation and information-sharing. Stockholm Convention signed in 2001 and effective since 2004, deals specifically with the problem of POPs. The list of POPs to be either eliminated or restricted has been constantly updated with the latest modifications being added in the 2009 meeting of the convention. It also mandates exceptional situations, when restriction(s) on POP(s) needs to be exempted to effectively tackle a natural calamity or a disaster or an epidemic [13].

Energy industries being one of the significant contributors to hazardous waste generation and associated problems, technologies are being seriously researched and explored to "green" alternatives to fossil fuel. For example, solar cells and wind mills are being improved upon their traditional design to more user-friendly, low-cost versions for large-scale substitution of fossil fuel for energy generation. Biotechnology and molecular biology has opened up numerous technological wonders that may significantly reduce dependence on synthetic agricultural inputs to feed increasing world population. The UNEP is working round-the-clock to train, provide technical know-how, and troubleshoot during application of such state-of-the-art technologies in developing and underdeveloped countries [11]. Human civilization is returning to smarter, common-sense-oriented science and technology to counter some of the challenges posed by wealth- and profit-driven science and technology. The results of such "greener" alternatives has tremendous potential to grow the world economy, generate prosperity, promote health among human and other species that share the earth with us, and create numerous employment opportunities, particularly in young societies such as China and India.

ACKNOWLEDGMENTS

Formatting of this paper was helped by Dr. Birendranath Banerjee, Lecturer, School of Biotechnology and Life Sciences, Haldia Institute of Technology.

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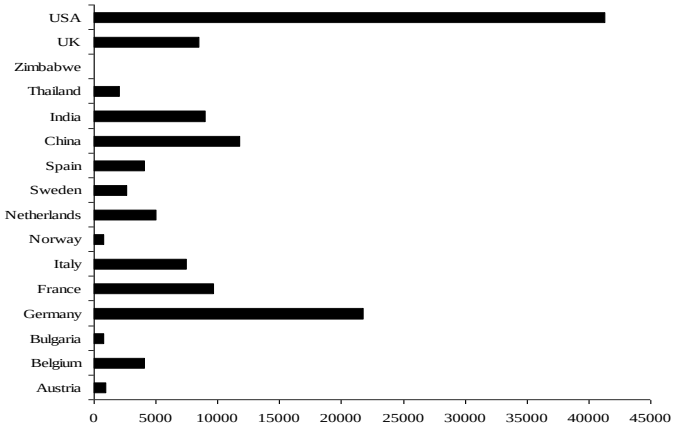

Figure 1: Hazardous waste generation (‘000 tonnes) in different countries in the year 2007

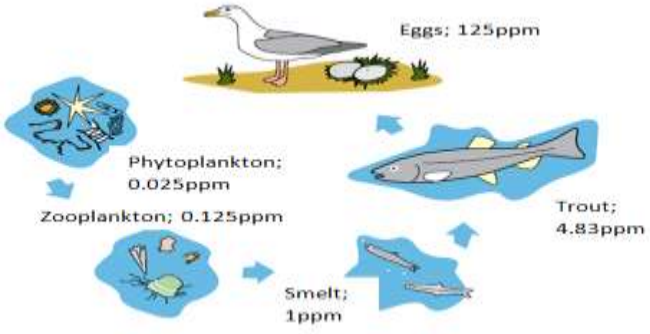

Figure 2: Increasing accumulation of PBT in water and land ecosystems [1]