Interaction between Green Chemistry, United Nation Sustainable Development Goals (SDGs) and Public Health

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Abstract The topic of sustainability has never ever been popular like today when people realized its significance. Launch of the United Nation Sustainable Development Goals built the blue print in environment, wealth, education and public health with sustainability, and development of green chemistry in concept and principles formation, research and innovation provided technical support in realizing these goals, and simultaneously tackle issues in public health. Three objects interact organically and form an integrated system.

Contents

Introduction

Green chemistry

Green chemistry is “design products and process to reduce even eliminate the use or generation of hazardous substances”. [1-2] This field has been widely researched from all main developed and developing countries initially from 1990s nearly 30 years ago.[3] The booming interests originate from the fact that green chemistry not only changes the public attitudes towards chemistry, what’s more, this new field try to solve the chemical exposure hazards which related public health issues and chemical pollution to the environment from atom level. In the past, chemistry was considered as “toxic science” from common perspective since no matter for environment pollution or some disasters cannot leave from chemistry. For example, the inadvertent discharge of toxic chemical substances from chemical factories resulted in significant and severe adverse effects on environment and ecology, which not only led death to marine livings, land pollution that resulted in crops death or even, the direct exposure for human beings which increased risks of some diseases including cancer. And another example included the report of long-term exposure of some specific chemical substances in the laboratory may increase the risk of infertility of researchers, etc. [4] The development of green chemistry will potentially change this situation and correspondingly change people’s attitude towards chemistry.

The initial intention of green chemistry is to realize sustainability from atom level. It changed scientists’ traditional thoughts on controlling exposure hazards and pollutions of chemical substances, manufacturing process to an insightful direction, which reducing or eliminating above adverse consequences from the source. Before installation of green chemistry concept, scientists focused on how to protect related people to decrease exposure with indirect methods like increasing the function and quality of protectors, or novel methods to govern and regulate pollutions after some chemical related pollutions happened. To some respective, such practices did play a role, however, considering the associated high cost, and actions after adverse consequence has happened, it is not economic. Green chemistry is focused on molecular design and careful planning of synthetic pathways and therefore reducing or even eliminating adverse consequence. [5] It makes it possible to achieve environment and economic goals simultaneously, which is a win-win strategy. Proposed by professor Paul Anastas (Teresa and H. John Heinz III Professor and director of Yale center of green chemistry and green engineering), The "Twelve principles of Green chemistry" [5] has been widely adopted by green chemical scientist as designing rules. It now has applied into wide industry sectors from aerospace, automobile, cosmetic, electronics, energy to household products, pharmaceuticals and agriculture.[6]

Green chemistry emphasized the importance of all stages of the chemical life-cycle and designing the inherent nature of chemical products and processes to reduce the intrinsic hazard and therefore limiting the risk of accident and damage. Hazards are defined as adverse consequences which may originate loss for people no matter for property, health even death. It included toxicity, physical hazards (explosion, flammability), etc. Risks intrinsically may come from the nature of raw material in chemical transformation, the intermediate process of reaction or even the final products. Therefore, green chemistry design based on twelve principles aims to realize green in each level, from original properties of raw materials, the intermediate chemical reactions and to final products, in order to reduce the hazards to the minimal level.

Twelve principles include "Prevention", "Atom Economy", "Less Hazardous Chemical Synthesis", "Designing Safer Chemicals", "Safer Solvents and Auxiliaries", "Design for Energy Efficiency", "Use of Renewable Feedstocks", "Reduce Derivatives", "Design for Degradation", "Real-Time Analysis for Pollution Prevention" and "Inherently Safer Chemistry for Accident Prevention". [5] The explanation of atom economy means all materials in the chemical reaction can be incorporated to the final products, and no other by-products are originated by the reaction. The idea of "Safer Solvents and Auxiliaries" originates from the fact that in majority of chemical reactions, especially organic chemical reaction, organic solvents are widely used as chemical reaction medium or eluant during chromatography purification. Main organic solvents include ethyl alcohol, ethyl acetate, methylene dichloride, hexane, etc. Considering hazards of such organic solvents, like potential health risks for exposed researchers or workers, the environment pollution if discharged incorrectly, and high cost on dispose, this principle aims to develop chemical reaction with least use of organic solvents or even transfer to water. For degradation, when the product is at the end of its function, it can be degraded to innocuous products and do not persist in the environment. The economic effect disclosed by when traditional products run to the end, they need to be disposed artificially, like burning or buried. On one hand, this procedure increases the devotion of money and time, on the other hand, burning leads to air pollution, which furtherly deteriorated environment. If products can be degraded on its own, the benefits will not simply for environment, but also for saving costs. As for Real-time analysis for pollution prevention, this is the only principle which focused on analysis and monitoring during process.

Sustainable Development Goals

The Sustainable Development Goals (SDGs) were proposed by the United Nation at year of 2016. If we observe the whole development of human beings from agricultural to industrial era, pursue of economic priority and competitions among developed and developing countries always made people forget the importance of sustainability. The pollutions like smoke of burning coals, waste water containing toxic substances, etc., were discharged to the environment, which not only ruin the habitats of other creatures, what's more, lives of human beings are also threatened. The number of lung diseases patients increased year by year because of air pollution. People gradually realized the importance of sustainable development since it is not only for current generation but also for the next. Sustainability means when people conduct industrial manufactories which are related to whole scale economy, they try their best to control the environmental pollution, reduce the destruction of animals' habitat, etc. simultaneously. In other words, develop economy without sacrifice the environment. In order to make the sustainability more specific, the United Nation published SDGs. SDGs contain seventeen points which is similar with a to do list to be finished in year of 2030, and the main contents of SDGs include "No poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, Industry, innovation and infrastructure, induced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life blow water, life on land, peace, justice and institutions, parentships for the goals". [7]

Interaction

The interaction between SDGs and green chemistry

It is quite difficult to realize these goals without the help of green chemistry, especially for some points like climate change, clean water, clean energy, food production, etc. Take water purification as an example, making more people in the world have an access to the clean and purified water to drink is definitely sustainable, however, if the purified process utilized lethal chemical substances like chlorin, by-products originated during purification is not only unfriendly to the environment but also leave the risk of health side effects to people, which "do the right thing wrong". [8] The innovation of green chemistry aims to tackle such challenges like reducing the usage of toxic substances and finding or creating other substances which have functions of purifying water but with a little or even without any toxicity. Considering energy consumption, since all of industrial productions and activities cannot leave from energy consumption, however, current energy structure still relies heavily on traditional energy source including coal(30%), natural gas(24%), Oil(33%) and limited space for renewable energy source like Hydro(7%) and others(2%) released by BP in year of 2016.[9] On the one hand, the consumption of traditional energy cannot avoid creating carbon dioxide, which reinforce the greenhouse effects and global climate change. On the other hand, the huge amount of toxic substances including Sulphur Dioxide, Nitric Oxide are produced during traditional energy consumption process like burning. In the past, such toxic substances were directly discharged to the nature through chimney until some disasters happened, like London's killer fog, which happened in year of 1952 and killed about 12,000 people. [10] When people gradually realized that if we do not control our behaviors and continually pollute the environment, the planet of our home will be deteriorated, and final victims will be definitely human beings. Countries in all over the world realized the common agreement to protect our planet for current and next generations (which means sustainable development) with reducing or even eliminating environment pollution. However, traditional methods mainly focus on how to control pollutions after pollution happened. For example, when sulfide dioxide and nitric oxide originated after burning coals, toxic gases were treated or purified by some facilities or processes to absorb them or transferring other low toxic substances and then discharged to the nature. Even such activities played a role in controlling pollution and protected environment, and did disclose conscious of sustainability, however, it maybe not economic considering cost devoted to the intermediate process. The launch of green chemistry provided new perspectives. Instead of controlling pollutions after it happens, technology of green chemistry aims to reduce or eliminate pollutions from origins, which means reducing or even eliminating toxic or polluting substances originated during consumption process through changing molecular structure, reaction conditions, reactants, etc., in order to reach sustainability and economic efficiency simultaneously. What's more, the green chemistry technology pushed the development of renewable energy exploration and use, like the development of metal-organic framework, which can store and stabilize hydrogen atoms or methane to play as fuel. [11]

The intersections between green chemistry and sustainable development goals are not simply limited to technology side, but also non-technology side. For non-technology, it mainly focuses on challenges the green chemistry meets, including economics, equity and regulatory framework. For economics, new huge investments need to be injected to transform original infrastructure which with less sustainability, and how to persuade investors to invest since for them, it is logic to focus on investment returns and consider that chemical industry and products are capital intensive. for equity side, the development of green or sustainable chemistry cannot leave from local political and economic attributes. For example, if simply putting green chemistry technology designed for industrial system of developing countries and emerging economics, considering its current reliability on power, the extent of import/export infrastructure, the relationship between labor and merchandised productivity, it will be ineffective for these countries. [8]

The interaction between UN Sustainable Development Goals and Public Health

Public health is a broader topic and fundamental to each human being. From the academic perspective, it mainly focused on the prevention of diseases, the symptom and characteristics of chronic disease epidemiology, epidemiology of microbial diseases, and using biostatistics methods to make quantitative research and monitoring the incidence, the relationships with one specific disease and one factor, etc. The environmental health science also evaluates some environment factors like exposure to some chemicals, air pollutions, water pollutions etc., and the associations between these exposure and human health, risk assessment, toxicology, etc. Public health research is to identify factors which related to diseases and therefore helping us to prevent the incidence of some specific diseases intentionally through reducing or even eliminating the exposure of such factors, and the final result is to make human beings live healthier by understanding diseases and the associations between people and the environment we live in. One of the UN Sustainable Development Goals mentioned good health and well-being, which happens to the key incentives for the development of public health. And what's more, the clean water, clean energy goals are trying to reduce or eliminate the pollution, which has significant associations with human beings' health. For example, it has been proved that exposed by BPA, which is widely utilized in plastic bottles, medical devices as plasticizer, may enter into human bodies when people use the products and increase the risk of side effects on the brain, behavior, and prostate glands in fetuses, etc. [12] Public health researches disclose such association and provide insights to policy makers, producers, and try to eliminate such effects by decreasing exposure or other substitutes, which aims to make people more health, and happened to meet the SDGs.

Innovation

Innovations on green chemistry which contributes to SDGs and Public Health

Based on the twelve principles, the scientific research and industrial application gradually push the development of green chemistry, and the result furtherly facilitates the realization of SDGs and make people more health. The practice of green chemistry focused on waste reduction, atom economy, optimizing synthesis pathway, molecular design, reducing toxic solvents, derivatives, biodegradation etc.

Waste

Preventing formation of waste is far more efficient than cleaning it up after formation from economic and environment perspectives. During the reaction process, a proportion of raw materials may transfer to wastes with the same time of producing what we want, and the scale of waste proportion depends on the combination of raw materials, reaction conditions, etc. The aim of green chemistry is to find the optimized reactants and reaction conditions to reduce the proportion of wastes to the smallest scale and obtain the products we want. The classic example is the improvement of ethylene oxide. The environment factor of former two step with chlorohydrin intermediate is 5, which means when 1 kilogram of ethylene oxide is produced, 5 kilograms wastes will be originated and need to be disposed during the whole process. However, the improved method which utilize molecular oxygen will reduce the E-factor to 0.3kg, which is more economic and environment friendly. [5]

Molecular Design

General principles of designing chemicals are focused on their functions and usages from medicine to materials, with less attention on the reduction of its internal hazards by designing the appropriate molecule structure. (Structure determines properties). Current research on this field aims to understand the relationship between hazards and structure, like bioactivity (related to biotoxicity), explosion, corrosive etc., and design appropriate structure. This field has transformed from descriptive subject to more mechanic. For example, in drug design, the combinatorial chemistry and high-throughput screening, and a series of in silico approaches to toxicity prediction including

Quantitative structure activity relationships (QSARs), TOPKAT, CASE etc., make it possible to identify the toxicity of molecules even before synthesis. [13]

Pharmaceutical Industry

Another significant progress in green chemistry is in pharmaceutical industry. Pharmaceutical industry is fundamental for each human being in the planet since no one can avoid risks of getting some diseases or even born with severe genetic diseases from perspective of public health, and the innovation of drugs helped people to combat diseases and developed generation by generation. However, during the process of research and industrial production, the huge amount of raw materials has to be devoted and meanwhile, by-products originated during the intermediate synthesis may originate environment issues, which has to enhance the cost furtherly to deal with such by-products. Therefore, utilizing more environment-friendly staffs, designing efficient synthesis steps to reduce intermediate products and enhancing production rate of target compounds became the goals of scientists. Leading pharmaceutical companies have provided some green chemistry innovations in this field. Zoloft is a type anti-depressant drug, which was distributed and manufactured by Pfizer. It was prescribed more than 115 million times in the United States as of February 2000. Pfizer streamlined original three synthesis steps into one step, which cut the use of three starting materials between 20-60%. Meanwhile, the reduce of synthesis steps eliminated the need to use, distill, and recover four toxic solvents, and reduced generation of caustic waste by 100 metric tons, acidic waste by 150 metric tons waste, and solid titanium dioxide wastes by 440 metric tons per year. [14]Environment benefits are analyzed before. For economic benefits, the expense cut on raw materials devotion and by-products dispose reduced the manufacturing cost, which furtherly facilitated price of drugs to go down and popularized in patients group.

Conclusion

The interaction of green chemistry, UN's sustainable development goals and public health inter-connected tightly. UN's SDGs plays like a goal, which aims to make people live in the earth more sustainable, and public health is a critique theme in SDGs. Green chemistry plays like an efficient tool to realize SDGs and solve problems in public health from technical side.

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