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Environmental Chemistry Lectures Based on System Thinking for University Students

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Abstract

This article introduces practical examples of undergraduate-level chemistry-based environmental science lectures and seminars by Prof. Akitsu. Sustainable and ecological issues are closely related to chemical problems, but there are also features that make each item complicated. We will take a structure that links problems and solutions such as the current status of environmental pollution, changes in fossil fuels, merits and demerits of power generation methods, conversion to renewable energy, new fire safety problems, and examples of further environmental pollution. Furthermore, blind solutions cannot address the "trade-off" relationship with a wide field of view, e.g., social scientific issues (cost, safety, and convenience, etc.). In this report, we describe an example where "system thinking" is desired for environmental problems that cannot be solved in a straight line.

Keywords: Undergraduate/General, Environment chemistry, System thinking, Environment science

Introduction

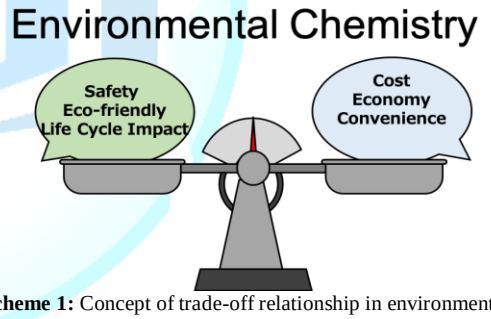
The motivation of this case report environmental problems are a collection of various chemical phenomena [1]. However, when solving ecological issues, it is required to optimize not only the specific optimization (solution) but the whole. In recent years, there has been a growing movement to incorporate system thinking into chemical education (primarily environmental chemistry). The composition of the problem is that the issue is intertwined in a sophisticated manner, so that one solution can cause a new challenge, and that there are disadvantages in terms of social security even if there are scientific and technological advantages, etc. It is one of the areas that can be said to be a good target for system thinking [2].

One of the authors (Prof. Akitsu) gave a lecture on chemistry based on environmental science for three years [3]. Handle various ecological topics (e.g., life cycle assessment, nuclear power, rare metals, etc.). After that, for a small number of chemical students at a seminar, we have been continuing classes for two years to make them think about a solution to the problem where the problems mentioned above contradict each other.

In this article, we introduce the main contents of the lecture (taking complex issues in a chained fashion and considering the “trade-off relationship”, Scheme 1).

Chain Structures of Various Problems

A solution to an environmental problem we will pick up from the lecture and explain various issues related to the global environment,



Scheme 1: Concept of trade-off relationship in environmental chemistry.

which is in a trade-off relationship that causes new disadvantages when trying to overcome the obstacles. Herein we depict the chain of issues discussed in the “Environmental Science” lectures. Each item contains Current status, Merits (if any), Demerits (more than two reasons from a different field) to be overcome.

Atmospheric water environment, material circulation S, N, C

Energy is economically disadvantageous and does not spread, and safety has created new problems. Chemistry of oxides [4] and vibrational modes for infrared (greenhouse effect of CO_2) is associated with this problem. With the industrial revolution, fossil fuels are conventionally used as an energy source for making machines work. The development of the industry has enriched life.

However, CO_2 is generated, causing global warming, acid rain, and air pollution. Therefore, it is necessary to develop renewable energy that does not use fossil fuels such as coal and oil. However, renewable energy is economically disadvantageous and does not spread, and safety has created new problems.

Energy conversion (coal and oil)

Chemistry of oxides and acid-base reactions [4] (and surface chemistry of foam) may be associated with this problem. Air and water pollution can be prevented if there are no harmful components (NO_x, SO_x) in the gas burning fossil fuel. From coal to oil, oil desulfurization technology can be the solution. The ability to do work is energy. The energy that humans can theoretically use is free energy. If the free energy is negative, the reaction proceeds spontaneously. Human beings are mutually converting and using human power in carrying out social life.

Energy, particularly fossil fuel thermal energy, can be converted into various energy. Power plants convert thermal energy into electrical energy. Electrical energy is used in multiple ways.

The use of carbon-neutral bioethanol and biodiesel fuels instead of conventional petroleum fuels has been promoted because of the emission of CO_2 by combustion. No emission methods should be required. However, since oil is flammable, it is difficult to digest it once a fire occurs. Furthermore, when mixed with petroleum, it will defoam the fire extinguisher because of its hydrophobicity and hydrophilicity, which may be a problem with safety [5].

Nuclear power

Chemistry of radio reactions of actinoides4 may be associated with this problem. Nuclear power generation is used as an alternative to thermal power generation that emits carbon dioxide. Heat is released when a large mass nuclide splits into a small mass nuclide. It is a power generation method in which water is heated by the heat to generate power.

Nuclear power generation uses energy from fission. Therefore, it is different from thermal power generation and does not emit CO_2 and gases that cause air pollution during power generation. From these points of view, it can be said that it is an environmentally friendly energy source.

However, the fuel for nuclear power is radioactive. Therefore, safety management and appropriate risk assessment must be conducted. Once an accident occurs, it will cause massive damage like Fukushima and Chernobyl. It can be said that it is environmentally friendly in that it does not emit carbon dioxide in this way, but it must also take into consideration the danger of radiation.

Fuel cell

Chemistry of hydrogen, oxygen, acid-base reaction and electrochemistry (of course materials such as catalytic metals and polymers as electrolytes) may be associated with this problem [4]. A fuel cell is a cell that generates electricity using hydrogen as a fuel. The energy from the reaction of burning oxygen and hydrogen is taken out. It can be said that it is an environmentally friendly power generation method because only water is discharged as a product.

There are problems with hydrogen safety and the way it is generated. Even if compared with other fuels, since the combustion range is as full as 4% to 75%, it can be said that storage and transportation are difficult because it is a flammable gas. Also, when generating electricity with a fuel cell, carbon dioxide is not emitted. Currently, steam reforming, which is a standard method of hydrogen production, emits $CO+H_2O \rightarrow CO_2+H_2$, and carbon dioxide. In this context, solar cells may be proper as renewable energy generation.

Solar cell

Chemistry of solid semiconductor, photo-induced electron transfer, and sensitizer (organic dyes and metal complexes) may be associated with this problem [4]. Solar cells are attracting attention in place of fossil fuels that place a burden on the environment. The light energy of the sun can be used to obtain current by the light power effect. There are commonly used silicon-based solar cells and types and dye-sensitized solar cells at the research stage.

Solar cells are environmentally friendly energy sources because they do not emit CO_2 or air pollutants. Furthermore, since power can be generated where sunlight strikes, it is possible to shorten the distance between the power plant and the consuming place as in the conventional type and it can be said that energy loss is small.

In order to use solar cells, it is necessary to have a large site and a store in rainy weather. For the first time at India Cochin International Airport [6], it succeeded in supplying all the electricity with sunlight. However, in order to operate the airport stably, more than 46000 solar panels are installed. Also, we purchase electricity at night or when it rains. Thus, it is difficult for solar power generation to supply power at this time stably. Also, safety management at the time of the fire of solar cells is also required. Photovoltaic cells generate electricity both during the fire and while receiving sunlight. This makes it difficult to extinguish the fire [7].

Environmental hormones and flame retardants

Chemistry of polymer combustion, halogen compound [8] and biochemistry may be associated with this problem. We need a way to ensure the security described above. One way is to raise the flame retardancy. It is to increase the flame retardancy of the material itself and to make it hard to burn. Specifically, a flame retardant is added. A halogen type flame retardant is mentioned as 1 type of flame retardant. When a halide is added, the radical trapping effect stabilizes the active OH radical.

However, environmental pollution due to flame retardants has been reported. Mainly, soil contamination in the pasture around the Great Lakes of the United States is severe. Flame retardants released into the air, contaminate the soil and are absorbed by plants. Dairy cows consume contaminated grass and are contaminated with baby milk. In other words, human beings are damaged by bioconcentration. Also, the environmental impact of flame retardants was pointed out, and the use was restricted. After that, new flame retardants were developed and repeated [9].

Atmospheric water environment (again)…

Environmental pollution problems are repeated for different substances and elements in this way.

Conclusion

It can be said that conventional chemical education alone, which tends to be a problem, is not enough to solve such problems in terms of both environmental problems and safety/harmfulness without leaving such problems. There is the great hope for its use in system thinking, which is a methodology that combines various theories and principles throughout and harmonizes. However, environmental problems range widely, and the relationship between victims and perpetrators is complicated. In particular, it is difficult to solve with mere science and technology alone, and it is necessary to take into consideration the relationship between science and technology and society, such as the economy and politics. In other words, it is required to look around and optimize the whole society. For that purpose, it is also necessary to change chemical education with the times. In the past, education was given independently in each field, such as organic chemistry, inorganic analysis chemistry, physical chemistry, biochemistry, and the like.

Indeed, this approach can be used to deal with pollution problems. From now on, in order to aim for the solution of complicated environmental problems, it is essential to make the education to connect the fields which acquire knowledge to be able to return chemistry to actual social problems across fields.

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