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The ethical dimension of green chemistry and sustainability

Ying Jian Chen

Research Center for Strategic Science and Technology Issues, Institute of Scientific and Technical Information of China, Beijing, China

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ABSTRACT

Green chemistry is an important tool in achieving sustainability. It provides solutions to such global challenges as climate change, sustainable environment, energy, toxics in the environment, and the depletion of natural resources. The ethical dimension of green chemistry and sustainability is not an add-on, but rather an inherent component of these concepts. In this paper, we first discuss the definition and meaning as well as the ethical assumptions of green chemistry, and then the ethical implications of sustainability are argued. Finally, the potential links between ethics, intrinsic value and innovation are expounded.

Key words: ethics, green chemistry, sustainability, innovation

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INTRODUCTION

The roots of the current preoccupation with *green chemistry* and *sustainability* can be traced back to the environmental movement of the 1960s–1970s. The publication of Rachel Carson's Silent Spring focused public attention on the negative side effects of a multitude of chemical products on our natural environment. These problems were in turn a direct consequence of economic growth which can be traced back to the industrial revolution which created a need for new chemicals and materials to meet the growing demands of an industry largely fueled by coal.

With the advent of the petrochemicals industry, the basic feedstock changed to crude oil and natural gas. This industry had its heyday in the 1950s–1960s when predictions of future growth rates tended to be exponential curves. This simplistic and optimistic view of the future was disturbed in the early 1970s by the publication of the report for the Club of Rome on the *Limits to Growth* which emphasized the finite nature of nonrenewable fossil fuel resources. The Oil Crisis of 1973 subsequently highlighted the vulnerability of an energy and chemicals industry that is based largely on a single fossil fuel.

The environmental movement did not have a broad industrial or societal impact, however, probably because emphasis was placed largely on the environmental problems rather than devising technological solutions. The prevailing opinion was that chemistry is the problem rather than the solution. A turning point can, in hindsight, be traced back to the publication, in 1987, of the report *Our Common Future* by the World Commission on Environment and Development which recognized that industrial and societal development must be sustainable over time. The solution is clearly not no chemistry but new and better chemistry, that is cleaner, greener chemistry – *green chemistry* [1].

THE DEFINITION AND MEANING OF GREEN CHEMISTRY

Green chemistry can be succinctly defined as "*the invention, design and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances for workers and consumers*". The implication of *green* in green chemistry means *young*, *fresh* and *new* [1].

The definition of Green Chemistry starts with the concept of invention and design. This means we, scientists and technologists, must take into account from the start what we are looking for, what kind of product, how we are going to design its manufacture and its use. The impact of chemical products and chemical processes must be included as design criteria. Hazard considerations for initial materials and final products must also be included in the performance criteria.

Another aspect of the definition of green chemistry is in the phrase "*use and generation of hazardous substances*". We must think in advance if use of the product is going to be dangerous (workers, consumers) or if it is going to generate environmental pollution through their use or after their practical application (as waste). Rather than focusing only on those undesirable substances that might be inadvertently produced in a process, green chemistry also includes all substances that are part of the process. Also, green chemistry recognizes that there are significant consequences to the use of hazardous substances, ranging from regulatory, handling and transport, production of waste and liability issues.

It is important to stress that green chemistry addresses both chemical products and the processes by which they are manufactured. The emphasis is clearly on *design* of greener products and processes. Green chemistry embodies two components: (1) efficient utilization of raw materials and the elimination of waste, and (2) health, safety and environmental aspects of chemicals and their manufacturing processes. Green chemistry eliminates waste at source. It is primary pollution prevention not end-of-pipe solutions. Waste remediation may be useful and necessary in the short term but it does not constitute green chemistry.

Green chemistry can be considered as *a series of reductions*, including *waste, cost, materials, energy, non-renewables* and *risk*. These reductions lead to the goal of triple bottom-line benefits of economic, environmental and social improvements. Costs are saved by reducing waste (which is becoming increasingly expensive to dispose of, especially when hazardous) and energy use (likely to represent a larger proportion of process costs in the future) as well as making processes more efficient by reducing materials consumption. These reductions also lead to environmental benefit in terms of both feedstock consumption and end-of-life disposal. Furthermore, an increasing use of renewable resources will render the manufacturing industry more sustainable. The reduction in hazardous incidents and the handling of dangerous substances provides additional social benefit – not only to plant operators but also to local communities and through to the users of chemical- related products [2].

The Twelve Principles of Green Chemistry Green chemistry aims not only for safer products, less hazardous consequences to the environment, saving energy and water, but includes broader issues which can promote in the end *sustainable development.*

The most important aims Green Chemistry were defined in twelve principles [1]. The number twelve is highly significant and symbolic (like the twelve months of the year) as a complete sum of the most important things that we have to do to accomplish a multiple task.

1. ***Prevention.*** It is better to prevent waste than to treat or clean up waste after it is formed.
2. ***Atom Economy.*** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. ***Less Hazardous Chemical Synthesis.*** Whenever practicable, synthetic methodologies should be designed to use and generate substance that possess little or no toxicity to human health and the environment.
4. ***Designing Safer Chemicals.*** Chemical products should be designed to preserve efficacy of the function while reducing toxicity.
5. ***Safer Solvents and Auxiliaries.*** The use of auxiliary substances (solvents, separation agents, etc.) should be made unnecessary whenever possible and, when used, innocuous.
6. ***Design for Energy Efficiency.*** Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. ***Use of Renewable Feedstocks.*** A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.
8. ***Reduce Derivatives.*** Unnecessary derivatization (blocking group, protection/ deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9. ***Catalysis.*** Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. ***Design for Degradation.*** Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.
11. ***Real-time Analysis for Pollution Prevention.*** Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.
12. ***Inherently Safer Chemistry for Accident Prevention.*** Substances and the form of a substance used in a chemical

process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Ethical Assumptions of Green Chemistry Green chemistry rests on a set of principles, and the principles, in turn, rest on certain ethical assumptions [3]:
• Environmental and economic goals are mutually compatible.
• The achievement of these goals will contribute to sustainable development.
• Preventing pollution is better than treating it after the fact.
• If pollution must be formed, that which does not persist in the environment is better than that which persists.
• Waste is bad; efficiency is good.
• Using the resources of the Earth is legitimate.
• Non-depleting resources are better than depleting resources.
• The welfare of the people who work with chemical products and processes is at least as important as the welfare of the environment.
• Reducing the inherent hazards of chemical products and processes is a superior way of reducing risk (to both people and the environment) than reducing the probability of exposure.
• The profit motive is legitimate.

THE DEFINITION AND MEANING OF ENVIRONMENTAL SUSTAINABILITY
The most widely quoted definition of sustainability and sustainable development is that of the Brundtland report to the United Nations on March 20, 1987 [4]:

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

The report highlighted three fundamental components to sustainable development: environ- mental protection, economic growth and social equity and was primarily concerned with securing a global equity, redistributing resources towards poorer nations whilst encouraging their economic growth. The report also suggested that equity, growth and environmental maintenance are simultaneously possible and that each country is capable of achieving its full economic potential whilst at the same time enhancing its resource base. The report also recognized that achieving this equity and sustainable growth would require social and technological change.

According to Kidd [5] modern era sustainability stems from six distinct roots:
• Biosphere
• Resource / environment
• Ecological / carrying capacity
• Critique of technology
• No growth / slow-growth
• Eco-development

Thus, the modern term sustainability refers overall to three fundamental relationships of the human being which is called *sustainability relations* [6]:
① The relationship between humans and their contemporaries,
② The relationship between currently living humans and future generations,
③ The relationship between humans and nature.

It is important to recognize the three basic characteristics of this relationship:
First, the sustainability relations have factual and normative aspects. For instance, relations ① and ② are the subject matter of several scientific disciplines such as economics, politics and sociology. In regard to relation ③, biology, genetics and ecology analyze biological mechanisms that define our relation with nature. However, there are also normative aspects concerning the three sustainability relations. We can understand, design and actualize these relations in different ways.

Second, the sustainability relations cannot be completely established and realized by the individual alone. For instance, the way we organize and institutionalize the generation, storage and transfer of knowledge sets up to a large extent our relationship with future generations. It is through science, education, technology, art, etc., that we are related in certain ways to future generations, and also to other contemporaries and nature.

Third, it is important to understand that each of the sustainability relations shows very different fundamental characteristics. Relation ① refers to relationships between currently living humans, which–at least potentially–could approach each other, recognize each other, and communicate with each other. Relation ② shows an abstraction and asymmetry, in so far as these options of direct approach are not fully given–at least if we consider generations of the more distant future. We could merely communicate with them in one way, for example, by bequeath messages, knowledge, artifacts, etc.； and we might try to imagine some of their thoughts, feelings or values. Relation ③ is even more difficult. For instance, a communication with non-human nature, if it is possible at all, differs much from a communication between humans.

In short, the core meaning of the modern concept of sustainability encompasses three aspects: *continuance, orientation*, and *relationship*. To express this by one definition, one may say that sustainability is the ability to establish continuance as a means for orienting human actions and life toward the threefold relatedness of human existence to contemporaries, future generations, and nature. In other words, sustainability addresses our ability to recognize and realize ourselves as fundamentally relational beings, as beings embedded in the threefold relationship with others, future generations and nature. It addresses the human being as a timely, socially and naturally contingent being and the implications of this threefold contingence for human self-identity, life and actions.

Meaning of Environmental Sustainability First of all, it should be noted that *sustainability* is about *continuity* and *development* is about *change*. There are many things about life that we want to sustain and many that we want to change. So it makes sense to create the notion of "sustainable development"' that combines desired change and desired continuity. For example, we might change exploitation, unhappiness, poverty, destructiveness, etc. and sustain the rest of nature, trust, tolerance, honesty, happiness, health, etc. Treated in this way sustainable development doesn't have to be an oxymoront.

Use of the word "environmental" quite often tends to be associated with some kind of human impact on natural systems. This context distinguishes it from the word "ecological," which can be characterized as a concept of interdependence of elements within a system. Hence, it seems reasonable to view "environmental" as a subset of the broader concept of "ecological," i.e., the intersection of human activities and ecological systems [7-9].

Then, environmental sustainability becomes a subset of ecological sustainability. Broadly speaking, this concept of "environmental sustainability" might be seen as adding depth to a portion of the meaning of the most common definition of sustainable development, i.e., "meeting the needs of the current generation without compromising the ability of future generations to meet their needs," by taking on the general definition "meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them." [4]

More specifically, environmental sustainability could be defined as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity.

The Ethical Implications of Sustainability By its very meaning, the modern concept of sustainability has an inherent ethical dimension. This dimension is related to the orientational aspect of the term – to its normative and evaluative meaning. Orientation means to give a direction, to guide one's actions, to distinguish between what is right and wrong, to say how one ought to act and live. Generally, orientation can be given by different means, such as power and leadership or religious faith.

The respective academic discipline that deals with orientation in this way is philosophy. Normative and evaluative issues are traditionally the subject matter of the philosophical sub-discipline ethics. Ethics deals with the analysis of normative and evaluative issues, with the questions of how one ought to live and how one ought to act.

Ethics is the systematic reasoning about the question: How ought one to live? Considering the specific relational meaning of the modern concept of sustainability, the basic ethical question in regard to sustainability then is: How ought one to live in regard to the sustainability relations? An alternative formulation would be: How ought one to live in regard to one's embedment in the threefold relationship with contemporaries, future generations, and nature? Sustainability ethics must be able to analyze this question in a systematic way. This is a demanding and difficult philosophical task for several reasons. One main reason is that this basic ethical question comprises three very different ethical sub-issues in regard to the three sustainability relations:
①The *moral* relationship between humans and their contemporaries,
② The *moral* relationship between humans and future generations,

③ The *moral* relationship between humans and nature.

Sustainability ethics must be able to deal with three very different relationships that show very different characteristics and ethical aspects. Sustainability ethics must be able to simultaneously address ethical aspects of all three sustainability relations and their constitution. It must be an integrated analysis of the ethical aspects of the threefold embeddedness of human beings in the sustainability relations. Particularly, sustainability ethics should enable us to identify and analyze ethical conflicts and trade-offs among the three sustainability relations, and should provide ways to adequately integrate them.

ETHICS, INTRINSIC VALUE AND INNOVATIOIN

Ethics is a field of knowledge that deals with human behavior from the point of view of how – through our actions – we can become better people. There are many fields that – like ethics – study human behavior. They differ, however, in the lens through which human behavior is analyzed. For example, physics analyzes activity through the lens of movement; physiology does so through the lens of how organs function; economics through the lens of efficient use of resources; and sociology through the general patterns of collective behavior. Ethics is also concerned with human behavior, but its focus is on how actions influence the way we are. It is quite obvious that we do things through our actions. What isn't so clear, however, is this other dimension, which relates to an effect that remains within the subjects themselves: our own actions change us [10-11].

It is often said that human beings are, at birth, the most helpless of all species. Yet throughout our lives we acquire a degree of development that puts us in prime position among all living creatures. Throughout our lives we acquire a body of knowledge, a series of technical skills and character traits that make each one of us the person we are. We can therefore say that, although we all belong to the same species and have a common backdrop that unites us, we are all different, unique and unrepeatable.

Realizing that our actions not only transform the world but also transform who we are is how we introduce ethics into the evaluation of our actions. What ethics is interested in, therefore, is the impact of actions on our way of being, as those actions make us better or worse people.

From this perspective, ethics is not just a list of prescriptions or rules that point to what we should do and forbids what we shouldn't. Ethics, like all other sciences, has a normative aspiration, and a practical orientation. Ethics not only reflects on what it means to become better human beings, it also gives us pointers on how to achieve it.

On the other hand, humans tend to give their own species greater intrinsic value. This gives them power to advance their selfish ends. The moral duties we have towards the environment are derived from our direct duty to other inhabitants we co-exist with [12].

The instrumental and intrinsic value of items in the environment therefore generates moral duty on the part of moral agents to protect it or at least to refrain from damaging it. Many ethical perspectives assign a significantly greater amount of intrinsic value to human beings than to any non-human things such that the protection or promotion of human interests or wellbeing at the expense of non-human things turns out to be nearly always justified. Such destruction might damage the well-being of humans now and in the future, since our well-being is essentially dependent on a sustainable environment.

Environmental ethics poses a challenge to traditional anthropocentrism. Firstly, it questioned the assumed moral superiority of human beings to members of other species on earth. Secondly it investigated the possibility of rational arguments for assigning intrinsic value to the natural environment and its non-human content.

As the relationship between ethics and innovation, at first glance it might seem that innovation and ethics are two opposing concepts. Ethics has a prescriptive element. It sets out what we can and cannot do, and therefore limits our scope of action. By contrast, innovation leads to doing things differently, breaking the mold, overcoming barriers. In this sense, there may be those who would believe that ethics could limit innovation.

But that view misinterprets what ethics is all about. Ethics cannot be reduced to a legalistic view of human behavior, much less to a negative view that defines ethics as a list of prohibitions. A positive, comprehensive view of ethics will make us realize that ethics and innovation are closely related: that innovation – like any other human activity – is deeply rooted in ethics, and that ethics inspires and encourages innovation [13-14].

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