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GREEN CHEMISTRY AND WORKERS*

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What follows is a summary of remarks presented by panelists participating in a workshop entitled, "What Green Chemistry Means to Workers." The session examined the connection between green jobs—including those connected to the emerging field of green chemistry—and occupational, public, and environmental health. It was coordinated by Paul Renner, associate director of the Labor Institute, in collaboration with the Tony Mazzocchi Center for Safety, Health and Environmental Education, a project of the United Steelworkers and The Labor Institute. It was moderated by Joseph "Chip" Hughes, Director, Worker Education and Training Program, National Institute of Environmental Health Sciences. Panelists included Julie Zimmerman, PhD, Assistant Professor of Environmental Engineering, Forestry and Environmental Studies, Yale School of Engineering and Applied Science and Assistant Director for Research, Green Chemistry and Green Engineering Center, Yale University; David LeGrande, Occupational Safety and Health Director, Communications Workers of America; Mike Wilson, PhD, MPH, Environmental Health Scientist, Program in Green Chemistry and Chemicals Policy, Center for Occupational and Environmental Health, Berkeley School of Public Health, University of California; and Sharon D. Beard, Industrial Hygienist, NIEHS Worker Education and Training Program.

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Chip Hughes

Our green jobs community needs to better understand the science and implications of global climate change and prepare for both the dire emergencies and the opportunities for potential innovation which likely will result. Alternative energy sources, such as biofuels and hydrogen, will likely provide new opportunities for preparing an emerging work force in focused occupational and environmental safety and health training. New chemicals, materials, and nanotechnologies will present opportunities for training the work forces involved in production, and in the industrial application of secondary products and ultimately in handling waste disposal by-products.

Changes are occurring in the assessment and remediation phases of Superfund work and numerous facets of environmental clean-up processes. New clean-ups are approached with a focus on green assessment, green remediation, and green construction. The Worker Education and Training Program (WETP) is currently assessing the need for safety and health training in these burgeoning areas and building advanced curricula and a training delivery cadre.

We will meet the emerging threats to worker safety and health posed by issues, such as the changing climate, alternative energy sources, clean-up of deadly legacy wastes, and rapidly penetrating new materials and technologies into the emerging green workplace. Green chemistry represents an emerging innovative approach which can reduce both worker and environmental health risks.

While harvesting green research insights in the laboratory, multi-disciplinary teams can apply them to clean technology innovations for both the workplace and the environment. Exploring these issues and building a dialogue is the purpose of our workshop today.

We must build strong linkages between scientists involved in the development of green products and processes, workers and communities involved in emerging green industries and the multiple stakeholders and policy-makers who must create a fair, just, and health-protective framework to regulate the emergence of a green economic infrastructure.

WHAT GREEN CHEMISTRY MEANS TO WORKERS

David LeGrande

Green Chemistry is a fundamentally different approach to manufacturing and using chemicals and chemical products that seeks to design out human and environmental hazards through the replacement of hazardous chemicals, processes, and products. This approach differs markedly with current chemical production and management practices that focus upon reducing not preventing chemical toxicity.

Several academics, practitioners, and workers have provided us with specific reasons why we are in the present situation and what we need to consider in advancing and implementing green chemistry. For example, Michael Wilson has pointed out the overarching problems with the regulatory and legal requirements of federal and state laws. These problems are characterized as the "data gap," "safety gap," and "technology gap."

Together, these three policy gaps have resulted in a flawed market for chemicals and products in which:

- The health effects of most chemicals are poorly understood;
- Hazardous chemicals and products remain cost-competitive;
- The costs associated with human and environmental health effects are borne by the public;
- There is minimal public/private investment in green chemistry research and development;
- Government regulation does not provide the necessary protections to workers, consumers, and the community; and
- There is inadequate attention placed upon green chemistry in academic institutions.

Clearly, workers and their unions should advocate for and support the development and implementation of green chemistry as part of an organized effort to overcome these deficiencies. Such actions would include:

- Activities associated with the development and growth of green chemistry focused upon closing the aforementioned policy gaps with the intention of developing and maintaining sustainable technologies and environments as well as related reductions in the cost of energy;
- Development and implementation of green chemistry as it produces green, sustainable union jobs;
- Provision by employers of more safe and healthful workplaces as well as related reductions in air, water, and soil contamination;
- Provision of and accessibility to employer-provided toxicity data regarding chemicals and products manufactured and used within their communities and broader geographic areas—for workers, consumers, and community members;
- Initiatives focused on the comparative identification and reduction of occupational and environmental illness and disease among workers, consumers, and community members associated with exposure to hazardous chemicals and products and their replacement with green chemistry chemicals and products; and

- Measures to have manufacturers and downstream employers/users held fully responsible for the human and environmental health problems associated with the life-cycle of chemicals and products.

When addressing "What Green Chemistry Means to Workers," we should consider the concerns of workers as one component of much larger, macro-societal issues. In moving forward, we should envision and remember the positive economic, political, and social impacts the increased development and implementation of green chemistry will have upon all of society—not only in the U.S., but throughout all industrial and developing nations.

APPLYING THE PRINCIPLES OF GREEN CHEMISTRY AND GREEN ENGINEERING

Julie Zimmerman

By applying the principles of green chemistry and green engineering and by considering the fundamental concepts of sustainability, designers can contribute to addressing the challenges traditionally associated with economic growth and development. This new awareness provides the potential to design a better tomorrow—one where our products, processes, and systems are more sustainable, including being inherently benign to human health (including occupational health and the environment), minimize material and energy use, and consider the entire lifecycle.

As these next-generation technologies are considered, designed, and pursued, a broadened definition of performance will be necessary to support these efforts. For products and processes to perform successfully, the definition must evolve from function, cost, quality, and safety to include energy and materials consumption, ecosystem function at the source and sink, life-cycle impacts, and human-health outcomes as well as quality of life.

At the design stage, engineers have the ability to select and evaluate the properties of the final outcome. This can include material, chemical, and energy inputs, effectiveness and efficiency, aesthetics and form, and intended specifications such as quality, safety, and performance.

The design stage also represents the time for innovation, brainstorming, and creativity offering an occasion to integrate sustainability goals into the specifications of the product, process, or system. Sustainability should not be viewed as a design constraint. It should be utilized as an opportunity to leapfrog existing ideas or designs and drive innovative solutions that consider systematic benefits and impacts over the lifetime of the design.

To begin to design for sustainability in this systematic way, there are several key concepts that are critical: Inherency; life cycle; systems; resiliency; and integration.

Inherency

As is shown in the risk equation below, risk is a function of hazard and exposure: Risk = f (hazard, exposure).

In green chemistry and green engineering, risk is minimized by reducing or eliminating the hazard. As the intrinsic hazard is decreased, there is less reliance on exposure controls and therefore less likelihood for failure. The ultimate goal would be completely benign materials or chemicals such that there is no need to control exposure. That is, the chemicals and materials would not cause harm if they are released to the environment or humans are exposed to them. The advances being made in moving toward inherently benign chemicals through green chemistry are significant and dramatic.

It is also critical to note that other characteristics of a product, process or system (besides toxicity) can be designed to be inherent. A design can be inherently more reliable, more durable, more resilient, and more efficient. The intention is to design the desired properties intrinsically rather than controlling or maintaining them through external circumstances.

Life Cycle

Life-cycle considerations take into account the environmental performance of a product, process, or system through all phases, from acquisition of raw materials to refining those materials to manufacturing to use to end-of-life management. There is a need to consider the entire life cycle because different environmental impacts can occur during different stages. For example, some materials may have an adverse environmental consequence when extracted or processed, but may be relatively benign in use and easy to recycle. Aluminum is such a material. On one hand, smelting of aluminum ore is very energy-intensive (one reason aluminum is a favored recycled metal). However, an automobile will create the bulk of its environmental impact during the use life stage, primarily because of combustion of fossil fuels but also because of runoff from roads and the use of many fluids during operation.

Systems

"Systems thinking" considers component parts of a system as having added characteristics or features when functioning within a system rather than when isolated alone. This suggests that systems should be viewed in a holistic manner. Systems as a whole can be better understood when the linkages and interactions between components are considered in addition to the individual components.

The nature of systems thinking makes it extremely effective on the most difficult types of problems to solve. For example, sustainability challenges are quite complex, depend on interactions and interdependence, and are currently managed or mitigated through disparate mechanisms.

Resiliency

Resilience is the capacity of a system to survive, adapt, and grow in the face of unforeseen changes, even catastrophic incidents [1]. Resilience is a common feature of complex systems, such as companies, cities, or ecosystems. These systems perpetually evolve through cycles of growth, accumulation, crisis, and renewal, and often self-organize into unexpected new configurations.

By the laws of thermodynamics, closed systems will gradually decay from order into chaos, tending toward maximum entropy. However, living systems are open in the sense that they continually draw upon external sources of energy and maintain a stable state of low entropy [2]. This enables resilient systems to withstand large perturbations without failure or collapse. That is, these systems are sustainable in terms of long-term survival and can adapt and evolve to a new equilibrium state. Given the uncertainty and vulnerability around sustainability challenges such as climate change, water scarcity, and energy demands, it is likely sustainable designs will need to incorporate resiliency as a fundamental concept.

Integration

Any design is implemented within a context of material and energy flows, some of which may exist beyond the facility but still within the local or regional community. By utilizing readily available material and energy and integrating them into the process or system, a designer can increase overall system efficiency, reduce costs by using waste as a feedstock rather than virgin material, and reduce impacts of human health and the environment. Does this type of waste-feedstock sharing arrangement have environmental benefits? What about economic benefits? The answer is yes to both questions.

The Industrial Ecology Model

There is, perhaps, no better current example of a large-scale cross-process design for integration of material and energy flows than the eco-industrial park located in Kalundborg, Denmark [3]. This arrangement represents the manifestation of industrial ecology whereby entire industries and commercial applications are interconnected such that local materials that are the waste of one process become a value-added feedstock for a nearby process. In this case, what would normally be considered an environmental emission and liability—sulfur dioxide—is now a value-added feedstock for manufacture of gypsum (calcium sulfate) wallboard. The same is true for fly ash generated by the power station that is sold to a cement manufacturer. Similarly, sludge produced from pharmaceutical manufacturing processes, normally a disposal cost and environmental burden, is now sold to a fertilizer company as value-added feedstock. The same is true with energy flows that are shared beneficially between various industrial and residential sectors of the community. Of course, this type of arrangement also has job security benefits because these businesses are now inextricably linked to their neighbors and their local community.

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THE ROLE OF CHEMICALS POLICY AND GREEN CHEMISTRY IN THE CLEAN-ENERGY ECONOMY

Michael P. Wilson

The rapid development of clean-energy technologies—of the green economy in general—is critical to responding to two of the greatest challenges of the 21st century: environmental damage and economic inequality. These technologies, however, are not by definition safer or cleaner for ecosystems, communities, or workers.

As the U.S. prepares to spur a new era of economic growth in clean-energy technologies and energy efficiency, it has an opportunity to generate important co-benefits by simultaneously reshaping outmoded policies governing industrial chemicals. Doing so will:

- Reduce worker, community, and ecosystem harms caused by chemical exposures and pollution;
- Build a sustainable footing for the clean-energy sector; and
- Open new opportunities for investment and employment in the design and use of safer alternatives, based on the principles of green chemistry.

Chemical Production

Over the course of about 50 years, synthetic chemicals have come to constitute the material base of society [1]. In 2005, U.S. chemical manufacturers reported producing or importing about 74 billion pounds per day of chemicals used in products and industrial processes, 90 percent of which were produced using oil [2]. If converted to gallons of water, this mass of material would fill a line of tanker trucks about 10,000 miles long, each carrying 8,000 gallons. At some point in its lifecycle, all of this material enters finite ecosystems, and much of it comes in contact with people through the use of products, in the workplace, and in air, food, water, soil, and waste streams.

The great majority of the tens of thousands of chemicals in commerce, however, have never been sufficiently evaluated for their effects on humans or ecosystems [3]. This is a legacy of weaknesses in the U.S. *Toxic Substances Control Act* of 1976 (TSCA), which has produced a chemical data gap, safety gap, and technology gap in the U.S., with their attendant health and environmental consequences [4].

Globally, chemical production is projected to continue growing about three percent per year, with a doubling rate of 24 years, rapidly outpacing the rate of global population growth [5-7]. This growth will distribute globally both the benefits and the health and environmental effects of industrial chemicals.

Problems with Existing Chemicals and Materials

In 2002, the U.S. Centers for Disease Control and Prevention (CDC) looked for—and found—148 synthetic chemicals and pollutants in the blood and urine of a representative sample of the U.S. civilian population [8]. There is evidence that many of these substances pass through the placenta, entering (and, in some cases, accumulating) in the fetus, suggesting they could pose significant risks to human development [9].

Occupational Disease

Workers are at particular risk from chemical exposures because, depending on their occupation, they are more highly exposed to hazardous substances compared to the general public [10]. Estimates for the state of California suggest that in 2004, workplace chemical exposures resulted in about 200,000 cases of cancer, chronic obstructive pulmonary disease (COPD), asthma, pneumoconioses, chronic renal failure, and Parkinson's disease.

Hazardous Waste

The management and clean-up of hazardous waste is another externalized cost attributable to existing chemical technologies. Each year, the U.S. spends more than $1 billion managing Superfund sites; future costs are estimated at $250 billion [11,12]. On the current trajectory, the EPA anticipates the need for 217,000 new hazardous waste sites over the next 25 years [11].

Electronic Waste

At home and abroad, the proliferation of obsolete, broken, stored, or discarded electronic devices (known as electronic waste or e-waste) poses a mounting, long-term threat to public and environmental health. More than 10 billion pounds of electronic products were discarded in U.S. landfills in 2000 [13]. Electronic waste contains many known toxic substances, including arsenic, nickel, cadmium, lead, mercury, phthalates, volatile organic compounds, and brominated flame retardants [14].

Gaps in U.S. Chemicals Policy

Many of the health and environmental problems attributable to the production and use of industrial chemicals stem from the U.S. chemical data gap, safety gap, and technology gap that have grown out of weaknesses in the *Toxic Substances Control Act* of 1976 [14].

Data Gap

EPA is virtually unable to assess the potential hazards of nearly all chemicals in commerce. More than 99% of the highest production-volume substances used today are among the 62,000 chemicals that TSCA "grandfathered" into use in 1976 without further evaluation [15-17]. Meanwhile, there are no minimum toxicological data required for introducing new chemicals [18].

Safety Gap

TSCA sets a high evidentiary bar before EPA can take action to control hazards, but data gaps and the complexities of characterizing exposure make obtaining this evidence—and building such a case—all but impossible. As a result, EPA has been able to formally regulate just five existing chemicals or chemical classes since 1976 [16].

Technology Gap

As a result of the data and safety gaps, TSCA has failed to motivate broad industry investment in cleaner chemical technologies, known collectively as green chemistry [19]. National research and education agendas have neither prioritized the science of green chemistry nor prepared the next generation of scientists to lead the chemical enterprise toward sustainability.

As a result of the three gaps, the U.S. chemicals market has undervalued the safety of chemicals relative to their function, price, and performance, with the result that hazardous chemicals have remained competitive and in widespread use [4].

Hazardous Materials in the Solar Technology Sector

To create a future characterized by improving social, environmental, and economic conditions, industrial activity will need to solve, not exacerbate, the mounting health and environmental problems facing the planet today. The growth of the multibillion dollar "clean and green" technology sector is a hopeful sign that industrial activity can indeed follow this trajectory, creating both green solutions and new opportunities for employment, including for those most in need of pathways out of poverty. In California, for example, investments in clean energy technologies that were anticipated to seed between 52,000 and 114,000 new jobs statewide by 2010 had created about 105,000 jobs in fifteen different classifications by 2007 [20, 21].

The photovoltaic (PV) industry is at the leading edge of the clean-energy sector. Yet it relies on an array of hazardous substances, and its products could contribute to the wave of electronic waste flowing into Asia and Africa. This opens the possibility that this important industry could face the same problems with occupational exposures and environmental pollution that have accompanied the growth of other industry sectors. To date, the health and environmental impacts of the PV industry have not been adequately characterized, but they are potentially large.

Fortunately, we are not destined to repeat previous mistakes. We have an opportunity to craft policies that will move the industry to 1. reduce and eventually eliminate the use of toxic materials; 2. assure proper testing of emerging materials; 3. expand responsibility for the lifecycle of PV products; 4. design products for easier recycling; 5. protect worker health and safety and provide a living wage throughout the global PV industry; and 6. protect community and environmental health and safety throughout the global PV industry.

Grappling with these six measures will require that the PV industry conduct an assessment of the lifecycle of materials and products it uses. This assessment should include occupational exposures, environmental pollution, and the generation of hazardous waste that occur both domestically and overseas. This is an essential step in prioritizing and mitigating health and environmental problems in the industry.

In taking this step, however, the PV industry will face the same chemical data gaps, safety gaps, and technology gaps that face other downstream users of chemicals and materials in the U.S. Like these businesses, the PV industry will soon find itself facing:

- the lack of standardized, robust information on chemical hazards in their supply chains (the data gap);
- the fact that hazardous chemicals are readily available on the market and often relatively inexpensive (the safety gap); and
- a lack of safer alternatives to hazardous chemicals (the technology gap).

A comprehensive chemicals policy that closes the three gaps will therefore play a key role in building the foundation for a sustainable U.S. PV industry.

To "reduce and . . . eliminate the use of toxic materials . . . ," for example, new policies will be needed that require chemical producers to disclose information to downstream users—including the PV industry—on the hazardous properties of chemicals, thereby closing the data gap. Policies to phase-out the use of the most hazardous chemicals on the market (closing the safety gap) will spur investment in safer alternatives (closing the technology gap).

These measures will require new public policies, including chemicals policies, that include market incentives, direct regulation, and support for research and training. Changes resulting from these policies will help place the PV industry on a sustainable trajectory.

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EXPANDING GREEN JOBS AND SUSTAINABILITY INITIATIVES WITHIN NIEHS' WORKER EDUCATION AND TRAINING PROGRAM

Sharon D. Beard

The National Institute of Environmental Health Sciences (NIEHS) is the federal government's premier environmental health biomedical research institute. The institute also has an education and prevention program, where the Worker Education and Training Program (WETP) has been vigorously developing safety and health training to protect workers.

Since 1987, the federal WETP has provided an effective, accountable structure for training workers who handle hazardous materials, hazardous waste, or respond to emergencies involving these materials. Many of the more than two million workers trained since the program began have been associated with the clean-up of this country's hazardous waste or Superfund sites. Many are also involved in the clean-up of the Department of Energy's nuclear weapons sites. Such work has long been recognized as protecting the environment and the health of surrounding communities. In today's terminology, these are "green" jobs. Proper training assures that green jobs are safe jobs.

The training program administered and funded by WETP consists of a national network of non-profit educational organizations with proven access to training audiences. Organized into 19 consortia that include universities, community colleges, and the training arms of national labor unions, these organizations provide safety and health and skill-based training in every state, Puerto Rico, and the Pacific territories. The organizations are held accountable, through published criteria and required evaluations, for providing the best possible training, utilizing skilled professional and peer trainers, up-to-date curricula, and high-quality training centers and equipment. (NIEHS Green Jobs Concept Paper, 2009)

The WETP sponsored a national conference entitled Implications for Safety and Health Training in a Green Economy, held on October 16-17, 2008, focused on examining the current state of health and safety issues around the green economy, including green jobs and industries, green remediation, and green chemistry. As a result of this conference, WETP made several key findings that will be used to push our priority of making green jobs safe jobs. Key findings include:

- Effective implementation of green job training is a public health imperative. Reducing greenhouse gasses and carbon emissions by creating greener processes, technologies, and jobs will greatly assist in improving public and worker health.
- Green chemistry and effective worker health and safety are highly correlated because both seek to reduce or eliminate the use and generation of hazardous substances and their effects on human health and the environment. Workers must understand green chemistry and organizations must work to infuse the principles of green chemistry into their training programs.
- Research on green remediation and construction must be conducted to address the impacts of green work on worker safety and health; and partnerships to ensure safety must remain the top priority, along with remedy protectiveness with companies considering all environmental effects during each phase of any clean-up.

As our country invests more in green jobs programs, the WETP program should play an ongoing role. The program has the mechanisms in place for quickly getting funding and other resources to its awardees and into the field. It also has a process in place for the evaluation of its efforts including the effectiveness of its training. In addition, it has the partnerships with federal, state, and local agencies, as well as contractor and labor organizations, to make such a program responsive and successful in meeting national priorities.

The WETP programs are documented models of effective training interventions that can be expanded or duplicated according to the needs of our country, its employers, and the work force. For example, the United Steel Workers are conducting workshops and developing training modules based on their work with green chemistry researchers. And the United Auto Workers are conducting workshops aimed at greening their communities.

Another example of the integrating of green initiatives within the WETP is the expansion of the Minority Worker Training Program (MWTP). The MWTP is a carefully designed intervention aimed at increasing the number of underrepresented minorities in the construction and environmental remediation industries. It provides pre-employment literacy and life-skills training, construction skills training, and environmental worker training. This program has achieved great success in moving young workers into long-term employment including, most recently, in the area of energy retrofitting and solar panel installation. Since 1995, these programs have trained more than 7,400 students and employed approximately 68 percent of those students in jobs directly related to their training with career opportunities continued through local apprenticeship and community college programs. To effectively address local health and safety issues and the development of appropriate green-collar job programs, NIEHS awardees worked to establish partnerships in many communities. We hope to use the NIEHS model of training and expand opportunities in green jobs.

An example of this effort is JobTrain, a member of the Center for Construction Research and Training (CPWR Consortium). JobTrain operates an MWTP initiative called Project Build in East Palo Alto, CA. After a year of extensive research and development, JobTrain, launched a new initiative to expand training and employment opportunities for MWTP trainees in the green jobs market by piloting a solar panel "photovoltaic" training project in 2008. This project required significant partnership-building with local and national companies, local governmental agencies, and other community-based organizations. The workshop covered the educational requirements of the new program, what employers were looking for in potential employees, and what training facilities would be needed. Students who completed this course received certification in the installation of solar panels. The pilot program was so successful that the program became incorporated into JobTrain's menu of courses offered to community residents. The program also included a number of internships with a local solar company, Akeena Solar, which provided additional hands-on experience.

As the WETP continues to seek ways of incorporating the green paradigm into its programs and operations, protecting workers engaged in greening our economy remains a priority. We want to share our models and our materials with the greater worker safety community. Thus, any hazardous materials training tools and resources to protect workers developed under our programs are available to the public and other hazmat training organizations via our website. These documents, contact information on current NIEHS awardees and program staff, as well as hazardous materials curricula can be found at www.niehs.nih.gov/careers/hazmat and on the web site of the National Clearinghouse for Worker Safety and Health Training at http://tools.niehs.nih.gov/wetp/index.cfm