CHEMISTRY IN COLLEGE–LEVEL ENVIRONMRNTAL SCIENCE CURRICULA

Henry A. Alegria, PhD
University of South Florida St. Petersburg, Florida, USA
Lembit Nei, PhD
Tartu College, Tallinn University of Technology, Estonia

Abstract

Insufficient proportion of chemistry classes in most of the college-level environmental science curricula is mostly ignored by the relevant scientific publications. Graduates of environmental science programs are often very weak in their understanding of the principles from chemistry underlying environmental science. The need for a stronger environmental chemistry component to be part of environmental science curricula is evident. The role of chemistry as an essential basis for environmental education should find much more attention in the relevant scientific literature.

Keywords: Environmental education, Environmental science, Chemistry, College program

Introduction

Wide and intensive discussion concerning the importance/role of chemistry in college-level environmental science curricula is of utmost importance. It has become evident that the levels and proportions of chemistry material in these programs are extremely uneven. The critical minimum amount and content of chemistry classes offered for environmental students should be agreed upon. The problems related to teaching science and chemistry as components of environmental education are under-represented in the relevant publications. Not much has been published concerning the role of teaching chemistry as an essential part of environmental science college-level programs.

A recent paper published by Turányi and Tóth in 2012 showed that there is apparently a serious problem: in comparison with the students of chemistry, pharmacy and biology, the knowledge of the principles of basic chemistry among environmental students was the weakest. This study showed that many university science students were not able to apply knowledge (e.g., the number of molecules in special volumes of ideal gases) that is part of the basic curriculum in secondary school. The authors of this study pointed out that it has been well known from teaching experiences that there are significant differences between the chemical knowledge of students of chemistry, pharmacy, biology and environmental science (decreasing in this order). Still, they did not expect that such a difference in the number of good answers could be obtained from the different courses for each task. The difference was explained not only by the different amount of previous chemistry study, but also by the low motivation of (especially) environmental students towards studying chemistry.

College-level environmental science studies

There is a large number of degree-granting programs in the environmental sciences or environmental studies at American and Canadian colleges and universities (Vincent and Focht, 2009). The same is true in Europe. The educational endeavor is intensely values laden. Values enter the curriculum development and delivery process at every step. Before a curriculum development process even begins, there are assumptions about what teaching and learning “should” look like and what purposes it should serve (Chapman, 2011).

Environmental science comprises those disciplines, or parts of them, that consider the physical, chemical and biological aspects of the environment (Allaby, 1996). Similar definition is given by McKinney *et al*. in 2007: environmental science involves all fields of natural science as they bear on the physical and biological environment around us. Aspects of biology, geology, chemistry, physics, meteorology, and many other disciplines must be considered when studying environmental science.

Environmental science education and chemistry

Let us now look at how the role of chemistry (and more precisely environmental chemistry) has been determined in environmental science. The National Center for Education Statistics in the United States has defined (in 2000) an academic program in environmental science as follows: environmental science program focuses on the application of biological, chemical, and physical principles to the study of the physical environment and the solution of environmental problems, including subjects such as abating or controlling environmental pollution and degradation; the interaction between human society and the natural environment; and natural resources management. The program includes instruction in biology, chemistry, physics, geosciences, climatology, statistics, and mathematical modeling. Related areas of study include environmental studies. Environmental studies incorporate more of the social sciences for understanding human relationships, perceptions and policies towards the environment (Wikipedia). The field encompasses study in basic principles of ecology and environmental science.

The critical importance of environmental science and environmental studies cannot be disputed (McKinney *et al.*, 2007). Virtually everyone is aware of environmental issues – global warming, the depletion of the ozone layer, the disputes over nuclear power, and the problems with solid waste disposal (McKinney *et al.*, 2007). Due to the rapid increase in urban population, the amount of sewage sludge has increased dramatically in the past 20 years. Environmental pollution caused by sewage sludge has become a global problem, which hinders urban development. It is of utmost importance to find ways to effectively re-use this waste and reduce its impact on the environment (Lu *et al.*, 2009; Lillenberg *et al.*, 2010). Human activities cause environmental pollution with respect to a variety of toxic substances, including polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), pesticides and others. Questions related to the fate and transport of pollutants, and their impact on health and the environment, cannot be handled without good knowledge of chemistry. Meeting global energy needs in a sustainable and environmentally responsible way is one of the grand challenges of our time (Abruña, 2013). Without doubt, chemistry has a significant role in dealing with the problems related to fossil fuel mining and combustion.

Chemistry is one of the most important subjects in dealing with environmental education, showing that the relationship between human life and the environment can be logically explained through scientific/chemical skills and knowledge (Tanaka, 2000). Already in 1889, the Nobel Prize winner Svante Arrhenius pointed out the existence of a "greenhouse effect", in which small changes in the concentration of carbon dioxide in the atmosphere could considerably alter the average temperature of the planet. This clearly highlights that more knowledge of environmental mechanisms is needed to cope with actual problems of pollution (Environmental Chemistry, 2005). Chemistry is often portrayed as the villain of environmental degradation. It is true that chemical products, produced in large quantities and badly misused, have caused vast environmental harm. But it is nonsense to think of a chemical-free environment (Manahan, 1991). All matter consists of chemicals. Any meaningful efforts to solve environmental problems require understanding of chemical processes that occur in the water, air and soil, as well as in living systems. These are the topics addressed to Environmental Chemistry (Manahan, 1991). Environmental Chemistry as a constituent of both Chemistry and Environmental Science provides the chemical basis for understanding our surroundings (troposphere, hydrosphere and terrestrial environment). It deals with the chemical principles operating in the natural and altered environment (VanLoon and Duffy, 2005).

Let us eliminate chemistry!

It has become evident that in several European universities (as for example Estonian University of Life Sciences, Latvia University of Agriculture, Oxford Brookes University, University of Brighton, and many others – according to the information available from the relevant official web pages), this problem has been ignored or solved by eliminating most of the chemistry from the environmental science curricula. The most drastic example can be attributed to the environmental science curriculum implemented by the Estonian University of Life Sciences. In the 4-year BSc program that was started in 1997 the proportion of chemistry was 7% (general chemistry, analytical and environmental chemistry, ecological chemistry, hydrochemistry and hydrobiology); for the freshmen who started in 2005 the amount of chemistry in their 3-year BSc curriculum was 5% (environmental chemistry); the changes made from 2009 left only 3% for chemistry in total (analytical and environmental chemistry). From 2013 the new 3-year BSc curriculum of the Estonian University of Life Sciences does not involve any subjects independently representing chemistry studies. Naturally there is no chemistry incorporated into the succeeding MSc and PhD programs.

In the United States of America, the 4-year environmental science BSc programs are able to accommodate larger "amounts" of chemistry. The BSc curriculum of Environmental Science and Policy at the University of South Florida, St. Petersburg offers both general chemistry and organic chemistry, which together cover more than 10% of the total amount of the studies. The MSc curriculum offers classes of environmental chemistry. As a whole, the situation is still not much better than in Europe. Any quick review of the curricula of environmental science (or environmental studies where the science option is not available) programs at a range of colleges indicates that the norm is to require one or two courses in chemistry at most. In addition, many programs do not require even the standard general chemistry course that science majors take during their first year, but often accept introductory-level (often non-majors type) chemistry courses.

By no means can these conclusions be generalized to all European and American universities, but according to our many years' experience in the field of environmental science/studies, the tendencies shown above are evident and further extensive research and focused discussions concerning the role of chemistry as (by our understanding) a significant and inevitable component of the relevant curricula is needed. According to our best understanding, an environmental science curriculum that lacks a sufficient amount of chemistry, and does not lead to a quantitative approach to most global environmental problems, remains descriptive by its nature. Chemistry as a discipline provides a scientific background for understanding environmental problems, and for successful designing of environmental quality control, monitoring and remediation actions. There is no modern environmental science without environmental chemistry, and there is no environmental chemistry without chemistry.

Conclusion

Chemistry is essential to environmental science. Introductory-level chemistry courses, however, are designed to provide students with a very basic understanding of the subject. Rarely do they provide sufficient coverage to truly understand the chemistry behind environmental processes and issues. It has been the experience of the authors and most colleagues consulted that graduates of environmental science programs are very weak in their understanding of the chemistry principles underlying environmental science. While this is anecdotal evidence, it does highlight the need for a stronger environmental chemistry component to be part of environmental science curricula.

Acknowledgements

Lembit Nei thanks for funding the European Social Fund's Doctoral Studies and Internationalisation Programme DoRa, which is carried out by Foundation Archimedes. The authors thank Andre Litvin for correcting the manuscript.

References:

Abruña, H.D. 2013. Energy in the Age of Sustainability. Journal of Chemical Education 90, no. 11): 1411–1413.

Chapman, D. J. 2011. Environmental education and the politics of curriculum: a national case study. The Journal of Environmental Education 42, no. 3: 193–202.

Lichtfouse, E., J. Schwarzbauer, and D. Robert, eds. 2005. Environmental Chemistry. Green Chemistry and Pollution in Ecosystems. Springer.

Allaby, M. 1996. Basics of Environmental Science. Routlege.

Lillenberg, M., S.Yurchenko, K. Kipper, K. Herodes, V. Pihl, R. Lõhmus, M. Ivask, A. Kuu, S. Kutti, S.V. Litvin, and L. Nei. 2010. Presence of fluoroquinolones and sulfonamides in urban sewage sludge and their degradation as a result of composting. International Journal of Environmental Science and Technology 7, no. 2: 307–312.

Lu, Y.J., X.W. Wu, and J.F. Guo. 2009. Characteristics of municipal solid waste and sewage sludge co-composting. Waste Management 29, no. 3: 1152–1157.

McKinney, M., M.R. Schoch, and L. Yonavjak. 2007. Environmental Science. Systems and Solutions. 4th edition. Jones and Barlett Publishers.

Manahan, S. E. 1991. Environmental Chemistry. 5th edition. Lewis Publishers.

National Center for Education Statistics. 2000. Classification of instructional programs. United States Department of Education, Institute of Education Sciences. Retrieved from: http://nces.ed.gov/pubs2002/cip2000/occupationallookup6d.ASP?CIP=03.0104

Tanaka, H. 2000. Environmental chemistry education for the 21st century. Journal of the Indian Chemical Society 77, no. 11–12: 531–538.

Turányi, T., and Z. Tóth. 2013. Hungarian university students' misunderstandings in thermodynamics and chemical kinetics. Chemistry Education Research and Practice 14, no 1: 105–116

VanLoon, G.W., and J.D. Stephen. 2005. Environmental Chemistry. A Global Perspective. 2nd edition. Oxford University Press.

Vincent, S., and W. Focht. 2009. US higher education environmental program managers' perspectives on curriculum design and core competencies: implications for sustainability as a guiding framework. International Journal of Sustainability in Higher Education 10, no.2: 164–183.