# Industrial ecology for leverage to let loose less cadmium

Jesse H. Ausubel*

Program for the Human Environment
The Rockefeller University
Box 234, 1230 York Ave
New York, NY 10021–6399, USA
Fax: (212) 327–7519
E-mail: ausubel@rockefeller.edu
*Corresponding author

Iddo K. Wernick and Anthony M. Barrett

Program for the Human Environment
The Rockefeller University
Box 234, 1230 York Ave
New York, NY 10021–6399, USA
E-mail: iddo99@yahoo.com
E-mail: ambarret@andrew.cmu.edu

Paul E. Waggoner

The Connecticut Agricultural Experiment Station
123 Huntington, Box 1106
New Haven, CT 06504–1106, USA
E-mail: agwagg@comcast.net

**Abstract:** Comprehending how humans let toxic cadmium (Cd) loose in their environment demands analysing zinc (Zn) production, the source of most mined Cd. Analysis of unaccounted Cd with the ImPACT identity as a product of population, affluence, intensity of Zn use, and the used fraction of Cd in Zn ore shows that the used fraction exerted the most leverage. A simulation of emission from Zn mining and processing, refinement of Cd and manufacture of its products, and their use, discard, and recycling quantifies opportunities for less unaccounted Cd. Although acting indirectly, recycling Zn has considerable leverage for loosing less Cd into our environment. Making more Cd products last longer and containing exhausted products also helps. Although cutting Cd use and raising recycling lower emission, they increase the unaccounted Cd. This application of industrial ecology supports encompassing a spectrum of impacts lest concentrating on one merely displace harm to another impact.

**Keywords:** cadmium; Cd; zinc; Zn; industrial ecology; materials flow analysis; ImPACT identity.

**Reference** to this paper should be made as follows: Ausubel, J.H., Wernick, I.K., Barrett, A.M. and Waggoner, P.E. (2006) 'Industrial ecology for leverage to let loose less cadmium', *Progress in Industrial Ecology – An International Journal*, Vol. 3, No. 6, pp.522–537.

**Biographical notes:** Jesse Ausubel's work seeks to elaborate the technical vision of a large, prosperous economy that emits little or nothing harmful and spares land for nature.

Iddo Wernick has worked for 15 years to measure and characterise materials flows at the national level.

Anthony Barrett, who is a graduate student in Engineering and Public Policy at Carnegie-Mellon University as well as a Research Assistant at The Rockefeller University, focuses on risk assessment of environmental and other hazards.

Paul Waggoner has worked on simulation models in agronomy and analytic tools for industrial ecology.

## 1 Introduction

Among the heavy metals in groups IIA through VIA of the periodic table, some like copper and zinc have a physiological role that redeems their toxicity. Because others such as lead and cadmium do not, campaigns to keep them out of the environment prevail. Influenced by these campaigns, the use of Cd has declined despite its practical uses. Between its peak year 1969 and 2004, US Cd consumption dropped 93%. Although world production peaked later and fell less, Cd consumption nevertheless fell enough to drop the 2004 Cd price to 6% of its 1998 peak in an apparent victory for environmental care.

This seeming victory and the flow of a metal invite industrial ecology. Analogous to ecologists who study networks in nature, industrial ecologists delve into the network of industrial processes as they interact with each other and live off each other, especially in the sense of direct use of each other's material and energy wastes and products. Industrial ecology seeks joint economic and environmental optimisation of the use of materials from cradle to rebirth, from virgin to finished material, including components, products, so-called waste and ultimate disposal. Industrial ecology offers frameworks for improving knowledge and thus sparing resources, using materials, and curtailing waste and pollution.

Industrial ecologists have recommended studying the forces changing the use of individual elements. They have recommended investigating the flows and balances of elements to learn the structure and webs of economic and material relations among actors in industry (Ayres and Ayres, 2002). If leverage is an advantage of effectiveness and practicality for lifting the burden of pollution, then the goal of industrial ecology's recommended studies is finding the most powerful levers. Specifically, where is the leverage to let loose less Cd around us?

Worldwide, the annual production of most toxic heavy metals, including cadmium, lead, mercury, arsenic, zinc, and copper has risen during the past one to three centuries by two or three orders of magnitude (Pacyna, 1986). Notwithstanding impressive gains containing them, significant emissions still let Cd loose around us, creating chances for unintentional ingestion and parallel opportunities for improvement (Ayres, 1996).

Several characteristics make Cd an absorbing illustration of the analytic potential of industrial ecology:

- Cd accumulates in a person's body and may affect behaviour or cause cancer, so avoiding exposure to even a little Cd is wise (Jarup, 2003). Breathing or swallowing much Cd can kill (ATSDR, 1999). While growing species of 'bio-accumulator' plants in Cd-contaminated areas and then disposing them as toxic waste or the extreme measure of soil removal may reverse Cd contamination in some locales, these options are slow or costly at best. Cd is thus a good candidate for *zero emissions*, watchwords of industrial ecology.
- Although some of Cd's uses have declined, its advantages persist for such batteries as those that power portable tools. By 2000, the fraction of Cd use in batteries had grown to three-quarters of all Cd use. Because the fraction of Cd use in batteries is large, the proposed European Union ban on them would affect Cd use profoundly. (Plachy, 2005).
- As an element, Cd cannot be created or eliminated like polychlorinated biphenyls (PCBs) or organic pesticides. Instead, people mine it and concentrate it and cannot simply destroy it, as by incineration, at the end of its use. Its flow chart must balance.
- Because Cd is captured as a virtual by-product of mining and processing other metals, notably Zn, even primary production of Cd represents a recovery of a waste – and a toxic one at that. At least 80% of worldwide Cd metal output is a by-product of primary Zn production, with about 3 kg by-product Cd per ton of Zn produced (Llewellyn, 1994).

Here, we focus on the course of Cd use and its parallel in Zn production, especially the global courses that are not complicated by international trade. Focusing on flow, we diagram the flow of Cd in the 1990s. On that foundation, we then investigate the forces that drive Cd production and search in a simulation for the leverage that could let less Cd loose into the human environment.

## 2 Courses of Cd and Zn in the 20th century

As customary of industrial ecology, Figure 1 shows the global course of Cd and Zn production. With correction for change in stocks, these global quantities indicate use as well as production. Correction for stocks is slight because Morrow (1998) estimated stocks were only about 20% of production and their change much less than their total. The courses of Cd and Zn differed markedly. While the production of Cd nearly levelled in the 1960s and its price fell from more than $10,000 per ton to almost worthless in the 1990s, the price of Zn stayed around $1,000, while Zn production climbed relentlessly. Although the use of Cd in pigments, stabilisers, coatings, and alloy declined and its use in batteries did not make up the lost quantity, the use of Zn, notably for galvanising, continued undiminished. Remembering that about 3 kg of Cd accompanies each ton of Zn produced and that 80% of Cd metal is a by-product of Zn production makes the diverging courses arresting.