THE ROLE OF ECM IN BRINGING ABOUT POLLUTION PREVENTION

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In an R&D environment, Environmentally Conscious Manufacturing (ECM), which focuses on specific materials processing and manufacturing operations, can be used to bring about a broader objective: pollution prevention. Decreasing the impact a product or process has on the environment is quickly becoming the way to do business. In the past, the impact on the environment was considered separately from manufacturing processes. Now, companies are beginning to see the benefits of designing to minimize environmental impact. Incorporating upfront the process changes that reduce environmental impact offers improved process efficiency and long-term cost savings not only for manufacturing operations but also for R&D. Among the approaches used, all with the same objective of decreasing pollution and environmental impact from manufacturing or other business operations, are Environmentally Conscious Manufacturing (ECM), Design for Environment (DfE), and Pollution Prevention (P2).

Environmentally Conscious Manufacturing
ECM is the improvement of environmental attributes of product manufacturing, ideally without sacrificing quality, cost, or performance. ECM ties strongly to chemistry, chemical engineering, materials science, and process engineering. ECM focuses on individual manufacturing steps with the objective of decreasing environmental impact of each step or group of steps somewhat independent of the overall product.

Design for Environment
Design for Environment (DfE) requires a systems approach that considers environmental safety and health over the product life cycle. Why a given material, process, or operation is used becomes relevant. The potential for tradeoffs such as changing one material for another, changing materials while also changing processes is considered in a synergistic manner. A qualitative understanding of the relative environmental impacts and benefits of processes, product transportation and use, and D&D is needed. DfE emphasizes the ultimate environmental impact of a given product in the design stage, thus maximizing leverage and minimizing environmental impact.

Pollution Prevention
P2 is the direct actions taken in a company or facility to minimize the total environmental impact from the company's collective actions. P2 includes not only the physical and mechanical operations of the previous two approaches but also the business

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practices and indirect operations, which may include such activities as encouraging carpooling, changing purchase/shipping/receiving practices, working with vendors and/or customers to have specifications changed to minimize impacts.

The above definitions for ECM, DfE, and P2 are subjective. As a simplification of the above: ECM focuses on specific processes or steps in a process; DfE focuses on products; and P2 focuses on the entire manufacturing plant or facility. In practice, the three can merge into the same approach or they can be very distinctive with almost no overlap. In R&D, it is easy to deal with each approach independently; however, overlapping these approaches is ideal. Since there is a tendency to disconnect R&D from manufacturing, it is easy to understand why typically the approaches are dealt with separately; however, the products of the R&D are not necessarily disconnected from manufacturing. Environmental implications of the business operations, resultant from R&D, including the manufacturing and post-service waste streams, are not usually considered in the R&D enterprise.

Many companies can talk about what they design and build. The authors company, Sandia National Laboratories, is not-for-profit engineering R&D organizations and serves as a project integrator for many large and complex engineering projects. Sandia may be responsible for concepts, design, specifications, and product outcomes, but may not have direct control of manufacturing operations. Sandia does have some limited manufacturing operations.

One major problem for an R&D-based company is setting P2 and ECM goals without limiting future R&D directions and projects. Goals should not be based on present directions and modes of operations because directions can shift quickly. Also, success in a given R&D area may lead to increased levels of effort and, therefore, a potential increase in associated waste streams and environmental impacts. There are numerous examples of exploratory efforts that generate such small amounts of waste and pollution that no concerted effort to apply ECM or P2 techniques is deemed practical. Since most R&D starts out with the assumption that it will lead to further development or wider application, it is important that awareness and forethought of ECM and P2 technologies be kept in mind, even if not fully implemented. As a project advances and increases in scale, the amount of waste may increase dramatically and costs may become large enough that the application of formal techniques is applicable and necessary. The project growth may also require additional reporting and handling that could be avoided if P2 and ECM are implemented.

The key to making ECM and P2 work successfully at an R&D facility is the ability to define environmental impacts in a technical framework. Focusing on one specific physical attribute of a type of pollution allows hazardous solid waste, both regulated and not-regulated, to be addressed. Hazardous waste can be identified, tagged, analyzed, and considered as one of the many chemicals and materials that are processed in our labs on a routine basis. If legal and social issues of the waste are ignored, P2 can be redefined as the need to optimize a process such that the desired product(s) are maximized and undesirable by-products are minimized or eliminated. Reducing hazardous waste streams from cleaning operations originally focused on two approaches, one was the substitution of hazardous solvent cleaners with less/nonhazardous solvent cleaners and the second was using the hazardous cleaners in more efficient ways (i.e. spray bottle application instead of submersion in large volume). Both methods lead to reduced waste streams, but from a materials point of view are not the optimum solution. Foreign material contaminants might be detrimental to a given article of interest. Understanding the implications of a given substitution or process change requires research such as that which characterizes ECM. At an R&D facility, research (associated with ECM) minimizes the total environmental impact of the facility and brings about pollution prevention.
The questions of when and how to apply ECM, DfE, and P2 and determining the resultant change also arises in support operations, which is P2, where much of the R&D is ECM. An example is photographic equipment that significantly reduced the hazardous waste from an operation. The equipment was of such improved quality and capability that business that had been done elsewhere, at another company, was now being sent to this new equipment. There was a decrease in the waste per product, but an increase in the total waste of the operation because of increased use.

Implementing ECM, DfE, and P2 is a challenge at an R&D facility because programmatic directions are always changing, environmental impacts may not be known, and benefits are not always apparent to an individual lab owners. However, ECM, DfE, and P2 are technical methodologies that can enable an R&D facility to minimize environmental impact while still producing technically sound research.

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