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Environmental sustainable practical actions in industrial processes: Application to drying

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GUEST EDITORIAL

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Diverse series of sustainable principles have been established in the Chemistry and Engineering disciplines, one of the best known is that of Anastas and Zimmerman.[1] Based on the environmental sustainability criteria introduced in the previous article[2] and editorial[3] and by extending them significantly, we propose a series of practical actions (not exactly principles, which are more oriented to a general formalism) to be considered by the industry and research disciplines. We apply the suggested actions to a specific example in drying. The proposed scheme for environmental sustainability actions is the following (from design to the end of life of the developed product/process):

1. Sustainable design: (a) system selection. Define system boundary, subsystems, components and input and output flows carefully, bearing in mind sustainability; (b) resource selection. Select natural and artificial resources (raw materials, substances, water, air, soil) carefully, analyzing their impact on the environment and reducing the total used mass to its possible lower limit (including the null limit if some components or subsystems could be avoided). Try to produce with the designed product/process a positive effect on ecosystem/nature (like bees that use pollen for the production of its food, honey, but also contribute to plant sexual reproduction); (c) energy source selection. Select renewable energy (solar, air, water, ground, biomass/biofuel/biogas, hydrogen, compressed air, etc.) as much as possible and minimize or eliminate nonrenewable energy. Increase energy efficiency and reduce energy intensity; (d) product and by-products identification. Analyze in detail the process to be selected, mainly if obtained products have the expected quality and if the by-products do not pollute (air, water, soil and nature). If they pollute, minimize (or even better eliminate) contamination, reducing the environmental impacts. Evaluate, reduce and compensate the carbon footprint; (e) recycle or reuse. Design considering, as much as possible, the recycling or reusing of products and useful by-products; (f) when searching for new actions try, as one of the possibilities, to mimic the nature (to simulate animal and/or vegetable behaviors) and even improve it, if possible[4]; (g) use a technique well adapted to the improvement of the product/process, for example, Total Quality, Re-engineering, Lean, etc. In particular, consider for the evaluation of continuous improvement, to define and measure a suitable indicator during the initial period as a basic information for an extrapolation to the future to detect if the defined objective will be attained in the previously fixed end time[5]; (h) if the product/process is very complex, its engineering needs to combine different disciplines and its implementation should depend on a complex set of physical and functional interactions between separately designed elements, consider to use system engineering[6] and/or holistic engineering[7]: (i) try to incorporate in the design as much as possible the United Nations objectives of sustainable development (ODS) (http://www.un.org/sustainabledevelopment/); (j) consider the following ISO series for the management of: quality (ISO 9000), environment (ISO 14000) and energy (ISO 50000). If ISO 50000 could be applied worldwide, as much as 60% of the total energy used could be reduced; (k) perform sensitivity analyses for the determination of uncertainties associated with the product/process, since from a physical point of view the measured quantity is as important as the uncertainty.
2. Sustainable production/operation process: (a) production/operation optimization. Define indicators to control the production/operation process. Establish an objective to be achieved at a given time; (b) include sensors to monitor the indicators and all other valuable information. Incorporate all possible sensors for significant variables, based on the selected indicators. In this way, the evolution of the process can be followed and corrective actions can be introduced. Continuous improvement must be an essential theme to be considered near the end of the process.
3. Sustainable maintenance process: (a) maintenance optimization. As in production/operation optimization, indicators and corresponding sensors need to be selected; (b) predictive maintenance. Consider

the industrial internet of things, which enables one to shift from product-based to product and service-based supplies. In this way, fails/problem detection can be made before failures/accidents happen.

4. Sustainable use and end of life of the product and by-products: Make a life cycle analysis (LCA) of the product and by-products. This analysis permits to assess environmental impacts associated with all the stages of the product/process life, from raw material extraction through materials processing, manufacture, distribution, use, maintenance (and repair if needed), recycling, reusing or final disposal, determining the material flows and assessing how these flows affect the environment. Also, LCA permits to make a preliminary evaluation of the potential environmental impacts related to the product/process, to analyze possible final results and to make an informed decision.

Application to drying: We will consider as an example the case of a solar grain dryer that we developed in the 1980s. It is still working at the experimental farm of the Faculty of Agricultural Sciences, National University of Rosario, Zavalla, Santa Fe Province, Argentina. At that time, the only basic criteria considered in the design of the system were the use of solar energy (quite abundant at the location), simplicity of the (bare) solar collector subsystem and possibility to dry different type of grains, typically produced in the nearby region (soybean, corn, wheat, sunflower, and even rice). Sustainability was a concept not used at the design time (it was introduced by the UN Brundtland Commission on Sustainable Development in 1987). Onwards, we present the (virtual) design of a solar grain dryer, considering a series of practical actions introduced in the above Item 1: (a) system selection. The system includes a cylindrical silo with a hollow-based plenum at bottom, a bare solar collector subsystem, ducts and a very efficient electric motor. The system also includes the products to be dried (well characterized grains in relation to their physical–chemical–biological properties), incoming air, by-products (evaporated water, particulate matter, and greenhouse gases), and environmental boundary conditions (terrain at a given geographical location, solar radiation, and meteorological variables). The natural flows are from the sun and wind, whereas the artificial flow is from electricity used in the air pumping motor: (b) resource selection. The selected raw materials are steel and wood to build the storage silo and solar collector. This type of simple design collector does not use a cover glass (compensating for the less efficiency with an increase in the collector surface area), eliminating in this way the hail destruction risk. The positive effect on nature (and on the owner's economy) is the extension of the use of the solar heat produced by the solar collectors to other applications (when the silo is not working for drying), such as heating of greenhouse, building (house, deposit), animal nursery, etc.; (c) energy source selection. Solar energy is used to heat the incoming air by several degrees, reducing significantly its humidity. High-efficiency electric motor is considered; (d) product and by-products identification. Grains physical–chemical–biological characteristics and quality must be analyzed in detail before and after the drying process; same is true for the by-products (evaporated water content, possible air contamination by gases and aerosols). The carbon footprint needs to be evaluated and, eventually, the greenhouse gas emissions compensated; (e) recycle or reuse. Steel and wood can be recycled or reused if properly maintained (applying paint periodically to avoid steel corrosion and wood degradation), extending their life cycle; (f) the nature is mimicked since the natural (ambient) drying process before the grains crop is well simulated by a solar silo, quite different with respect to a conventional high-temperature dryer; (g) the total quality technique is used for the improvement of the product and drying process. Also, the continuous improvement concept suggested above is considered in detail; (h) the recommendations of Grasso and Burkins[7] for holistic engineering approach is followed due to the complexity of the system, which combines a particular type of grain silo, electric motor, solar collector subsystem and variable climatic conditions; (i) the following United Nations ODS is considered: OSD 2: Hunger (reduction) and Food Security and ODS 13: Climate change (mitigation); (j) mainly the ISO 14000 and 50000 series are considered; (k) error theory is applied for the determination of the uncertainties of the main variables (ambient and grain temperatures and grain water content).

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