Life Cycle Assessment of Multi-Product Plants

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In the future, pharmaceutical products, like many other products in the food, nutrition, cosmetics or special chemicals sector, will find themselves rated based on an ecological footprint such as specific CO_2 production or cumulative energy demand. In order to properly assess and quantify the ecological impact of a product it is imperative to assess the respective production process. For the development of new processes this should be in corporate at a very early stage of process design to support the development of ecologically beneficial processes. Examples for critical aspects are the selection of solvents, decisions on the deactivation and purge of a catalyst vs. its separation and recycling or the selection of purification and polishing steps in downstream processing. For the improvement and retrofit of existing processes and production facilities similar information is required although the identification of potential areas of improvement builds on the existing process topology and equipment.

In most cases pharmaceutical manufacturing facilities are operated as multi-product plants. Individual production processes for different products are set up modular by combining the relevant unit operations in the process. Typically the equipment and unit operations portfolio of a multi-product plant is fixed and new production processes have to fit into this portfolio. Compared to a dedicated plant for a single product this situation gives rise to numerous chemical engineering challenges of which two are of special relevance for the Life Cycle Assessment of pharmaceutical production processes:

I. The proper allocation of the ecological damage resulting from the use of a given equipment and infrastructure portfolio to the different products manufactured in the same plant.
II. The identification and quantitative assessment of potential ecological improvement for a specific product if the constraints from using the existing equipment and infrastructure were neglected.

This contribution will present an approach to assess the ecological footprint of an individual product manufactured in a multi-product plant relative to its ecologically best process. It bases on the concept of a “best unit” representing the optimal realization of a given unit operation, such as solvent evaporation or chromatographic purification, with equipment and infrastructure resulting in the least environmental damage. This is matched to the used equipment, infrastructure and service media resulting in an ecological potential analysis for each unit operation of the process. The application of this concept will be demonstrated for typical unit operations in pharmaceutical production such as evaporation or chromatography. The approach supports an integrated development, assessment and optimization of new products and the corresponding manufacturing processes as well as the identification of optimization potential in existing plants and processes for a sustainable pharmaceutical production.