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How Ecofriendly is your Process? A Brief Review of Evaluation Methods

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Editorial

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Editorial

Green chemistry has emerged since 1990´s decade as a guide to minimize environmental impact of chemical processes based on Paul Anastas´ twelve principles, such as atomic economy, minimizing generation of hazardous residues and energy efficiency [1,2]. However, as researchers carry out ecofriendly processes based on these principles, a question arises…how can researchers evaluate the environmental impact of the processes they develop? This review attempts to summarize different ways to evaluate such impact.

Methods for the Evaluation of the Sustainability or Greenness of Chemical Procedures and Products

A first example is the Environmental Impact Assessment (EIA), which emerged between the decades of 1960's and 1970's, was designed as a methodology to prevent environmental damage which must include alternatives as well as contingency plans to lessen further problems that could arise from the development of a proposal; the EIA has different levels of development worldwide depending on the zone, where North America and Western Europe are the most advanced in the development of such EIA's followed by South America [3]. Other points that EIA must include are the positive and negative impact to health and environment, clear information in order to make informed decisions, reversibility of the damage to the environment and protection plan of resources and ecosystems [4].

There are other EIA's methods such as Strategic Environmental Assessment (SEA), which allows to complement the EIA integrating public participation and consultancy, and Integrated Environmental Assessment (IEA), which involves policy on the relation between the ecosystem and development of human activities [4].

The GREENSCOPE methodology (Gaugin Reaction Effectiveness for the Environmental Sustainability of Chemistries with a multi-Objective Process Evaluator) [5], is used to assess sustainability of different chemical processes based on the four E´s: Efficiency, Environment, Energy and Economics. These parameters take reference to a specific property; for example, efficiency denotes the selectivity of the process, which could be linked to the green chemistry principle of atom economy; in the case of energy a process where its use is minimum is of importance; regarding environment with the waste reduction algorithm (WAR) evaluates at the same time impact on human toxicity by different routes, toxicity in aquatic in marine and terrestrial environments and global warming, among others; and last economics based on annual profits. A similar evaluation method is the Life Cycle Assessment (LCA), which measures the environmental impact on four stages that comprehend the overall life of a product since the conception of the project to the disposal or recycling in terms of use of total mass, emission of greenhouse gases, and total carbon originated in waste with repercussion on economic impact [2].

To evaluate chemical synthesis there are methods such

as Ecological-Footprint (EF) which evaluates the interaction between the ecosystem and the waste generated during the synthetic procedure, a lower EF value means a more ecofriendly method. E-Factor is a faster and easier evaluation method which measures the total waste generated per Kg of obtained product where a value closer to zero means a more ecofriendly process due to the reduction of waste. Other parameters used to assess the environmental impact of a synthetic reaction are Carbon Efficiency (CE), Effective Mass Yield (EMY), Mass Intensity, Reaction Mass Efficiency (RME), Atom Utilization (AU), Solvent and catalyst environmental parameter (f) and Stoichiometric Factor (SF) with different interpretations considering as parameters carbon count, equilibrium of masses, recovery of reaction solvents, waste production, reactants and solvent recycling and stoichiometric reactions [6].

Environmental Assessment Tool for Organic Synthesis (EATOS) is an evaluation method generated as a software for synthetic reactions at laboratory scale which involves since the use of solvents to waste and by products generation throwing the Potential Environmental Impact (PEI) as the main parameter to defining an ecofriendly reaction. Other scale used on this type of reactions is the Eco Scale based on complementary procedures and results such as yield, cost, safety and purification steps [6].

Evaluating the environmental impact is not only focused on the process or the obtained products, but also on the tools to analyze them. The National Environmental Methods Index (NEMI) as a qualitative evaluation method because it is calculated based on a symbol and its scales, which have been further modified by adding, colored pictograms. Other evaluation method designed by Sheldon RA, et al. [2] is based on five categories which integrates the principles of green chemistry in colored scales which goes from green to red depending on the environmental impact. Analytical Eco-Scale is another methodology for the evaluation of green analytical techniques based on a maximum score of 100 where a penalty system is implemented; however, information regarding on the origin of the environmental impact is not sufficient. A more recent method was proposed as the Green Analytical Procedure Index (GAPI), which allows a complete evaluation in every step of the analytical method with the combination of previous methods, by the following criteria: time lapse from the sample collection to results obtention, sample conservation, transport, preparation and quantification [7]. It is to be noticed that the evaluation of analytical methods is based on the twelve principles of green analytical chemistry [1].

The environmental impact of solvents is important, where High-Performance Liquid Chromatography-Environmental Assessment Tool (HPLC-EAT) could be used as complementary tool for the overall evaluation of the analytical methods, which measures their impact based on the amount of solvent used during the analysis [7].

Conclusion

With green chemistry arising as a need to become socially responsible with the minimization of environmental impact, it has been necessary to evaluate the greenness or sustainability of a chemical procedure, product, or analytical technique. Even though several efforts have been carried out to evaluate such greenness, there is still a need to develop a more objective evaluation method that allows a better assessment of the greenness of chemical development at every stage that implies as well as the use of different resources and materials.

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