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Commentary Article

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Green Chemistry for Sustainable Active Pharmaceutical Ingredients Manufacturing

Dylan Arthur*

Department of Pharmacy, University of Turku, Turku, Finland

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DESCRIPTION

Growing environmental concerns, regulatory challenges and the desire for ethical behaviours are pushing the pharmaceutical sector to adopt sustainable methods in the manufacturing of Active Pharmaceutical Ingredients (APIs). APIs are essential components of drugs that have the desired therapeutic benefits and the techniques used in their synthesis can be resource-intensive and harmful to the environment. Consequently, the industry is investigating a range of sustainable production techniques that preserve product quality and efficacy while cutting down on waste, energy usage and environmental impact. The transition to sustainability benefits pharmaceutical businesses' long-term profitability in addition to the environment.

Green chemistry concepts are being applied as one of the main strategies for producing APIs in a sustainable manner. The design of chemical processes and products with the least amount of hazardous materials and environmental effect is the focus of green chemistry. Using renewable feedstocks, decreasing the amount of solvents used and boosting energy efficiency are some of the ways that the twelve principles of green chemistry provide a foundation for bettering API synthesis. For example, a lot of conventional techniques for producing APIs mostly depend on organic solvents, which can be hazardous to the environment and human health. Businesses may drastically cut down on the amount of solvents they use and the waste that goes along with them by using solvent-free processes or greener solvents like supercritical carbon dioxide or water. Furthermore, by improving reaction efficiency and selectivity through the use of catalysis in the production process, less energy and raw materials are required overall.

Biocatalysis and enzymatic reactions are used in another sustainable manufacturing approach. Biocatalysts, including enzymes and entire cells, can promote chemical reactions under moderate circumstances, generally with greater selectivity and fewer by-products than standard chemical approaches. The use of biocatalysis in the manufacture of APIs can result in lower energy consumption and less waste creation, which is consistent with the green chemistry principles. Enzymes, for instance, can be used to transform valuable APIs from renewable biomass feedstocks, providing an alternative to raw materials produced from petroleum. This helps the circular economy by using waste materials as inputs for new processes, while also lessening the environmental effect of API manufacturing. Another essential component of producing APIs in an ecologically responsible manner is sustainable raw material procurement. In order to obtain the natural resources needed for API synthesis, the pharmaceutical sector is increasingly looking towards sustainable agriculture techniques. This involves avoiding synthetic pesticides and fertilisers that might damage the environment and switching to foods that are farmed sustainably or organically. Furthermore, responsible production of medicinal plants is necessary to maintain biodiversity and safeguard ecosystems. Applying agroecological techniques and participating in fair trade activities encourages social responsibility along the supply chain in addition to supporting environmental sustainability. Production of APIs is also made more sustainably by implementing process intensification techniques. Process intensification is increasing productivity *via* the optimization of chemical reactions while consuming less energy and raw materials. Methods like continuous flow chemistry, in which reactions take place in a continuous stream instead of batch operations, might improve the productivity of API synthesis. By lowering the dangers involved with large-scale batch reactions, continuous processes frequently result in quicker reaction times, less waste and increased safety. Furthermore, the exact control over reaction conditions made possible by improvements in micro reactor technology allows for the quick creation and scaling of sustainable and effective production processes. The Life Cycle Assessment (LCA) is a essential instrument for assessing how API manufacturing processes affect the environment. LCA is evaluating the possible effects on the environment that may arise from extracting raw materials through manufacture, usage and disposal of a product. Pharmaceutical businesses are better equipped to pinpoint areas for improvement and make well-informed decisions on the adoption of sustainable practices when they conduct life cycle analyses of APIs. Businesses may select the most sustainable solutions by using Life Cycle Assessment (LCA) to measure the environmental performance of various manufacturing pathways. Transparency in environmental reporting may also boost stakeholder trust in pharmaceutical businesses and improve corporate social responsibility. Initiatives from the industry and regulatory bodies are essential in advancing sustainable manufacturing practices for APIs. The significance of sustainability in pharmaceutical production is being emphasized by several organisations, including the U.S. Environmental Protection Agency (EPA) and the International Council for Harmonization of Technical Requirements for Pharmaceuticals for Human Use (ICH). By setting norms and standards that support the use of green chemical practices and the reduction of environmental effect, regulatory authorities may drive industry transformation. In addition, industry efforts like the Pharmaceutical Supply Chain Initiative (PSCI) encourage cooperation between businesses and stakeholders by supporting sustainable practices and responsible sourcing throughout the pharmaceutical supply chain.