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Green Analytical Chemistry in Pharmaceuticals: Tools, Metrics, and Sustainable Practices.

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ABSTRACT: JKKM- EP 039

Every stage of the pharmaceutical lifecycle (from raw materials to the end product), requires analytical chemistry for evaluation of safety, quality, and stability. Although, some of solvents used for analysis have a environmental impact. Formulated by Paul Anastas in the 1990s, Green Chemistry, which focused on more sustainable synthesis pathways, renewable resources, and developing safer solvents, more environmentally friendly practices broadened the area of chemistry. In turns it gave rise to Green Analytical Chemistry (GAC), which focuses on incorporating sustainability into the classical analytical techniques of chromatography and spectroscopy, and stability studies (now including the use of water, supercritical CO_2, ionic liquids, and bio-based solvents in place of the toxic solvents). In relation to the 12 principles of GAC, NEMI, GSST, The Analytical Eco-Scale, HPLC-EAT, AMVI, GAPI, AMGS, PMI-LCA, RGB Colour Model, AGREE, Complex GAPI, AGREEprep, iGAL, NQS Index, HEXAGON, RGB 12 Algorithm, BAGI and RAPI are just a few of the numerous green metric tools created are based on the principles of "Green" thinking and to measure and enhance greenness. They include qualitative, semi-quantitative, or quantitative methodologies with some parameters and limitations. The toxicity of the solvents involved, waste production, the amount of energy consumed, the practicality of the analytical method used, the carbon footprint, and the cost. The methods used to represent the outputs are pictogram, colour coding, and scoring etc. These ensure methods optimization and validation of the pharmaceutical processes, enable resource conservation and regulatory compliance, and advocate sustainable innovation in the pharmaceutical sector. These parameters are always evolving to keep pace with global environmental concerns and innovations in the field of science.

KEYWORDS: Green analytical chemistry, Green metric tools, Greenness, Sustainability, Eco-friendly.