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Short Communication

Advancement of Green Chromatographic Techniques in Pharmaceutical Analysis

Rouchan Ali[1*], Saina Begum[2]

[1]*Department of Pharmaceutical Analysis, ISF College of Pharmacy, Moga, Punjab, India;* [2]*Department of Botany, University of Assam Down Town, Guwahati, Assam, India*

ABOUT THE STUDY

In several fields, it is crucial to analyze organic molecules in samples with varying matrix compositions. Liquid or gas chromatographic techniques are used to identify organic compounds in a huge majority of cases. Thus, it is crucial that these techniques have negligible effect on the environment. Based on the type of chromatography, several methods are utilized to make chromatographic separations more environmentally friendly. In gas chromatography, helium should no longer be used as the carrier gas since it is a limited resource. Due to the energy savings provided by low thermal mass technology, GC separations can be more environmentally friendly. In liquid chromatography, the goal should be to use less solvent while replacing poisonous and ecologically harmful solvents with safer alternatives.

Making industrial productions as environmentally friendly as feasible is a major need of the modern day that not only supports sustainable growth but also lessens financial burdens by enhancing yield through more economical methods. The analytical and chemical research simply raised serious concerns about the environmental impacts of their methods, notably the utilization and generation of hazardous solvents or reagents. Thus, the evaluation of their greenness is crucial to determining their trustworthiness in developing sustainable techniques. The major goal of green chromatography is to make a technique greener in all the steps of analysis from preparation to its determination [1].

Currently, the most utilized chromatographic techniques like High Performance Liquid Chromatography (HPLC) and Gas Chromatography (GC), both of which are coupled with various detectors, produce the best results for Mass Spectrometry (MS) [2]. Because inert gases are used as the mobile phases in GC, this method is indeed regarded as a comparatively green one [3].

Advancement of green gas chromatography

Sustainability-related initiatives in GC have targeted the miniaturization of certain equipment parts while enhancing the currently available commercially accessible GCs. It is possible to distinguish between traditional bench-top GC and micro-GC (μGC) based on the size and designs of the GC column [4]. From an ecological perspective, it is evident that μGC involves a reduction in the consumption mobile phase and less time of analysis, which results in less energy use. Due to this, several other types of columns, such as Micro Electro Mechanical System (MEMS), metallic-based and open tubular formats, have been suggested for μ GC [5-11]. On the other hand, there are still many technical problems with these μGC columns, including the challenges of coating or packing the columns with stationary phases, the need to increase the achieved separation resolution, and the proper achievement of a particular column geometry with the various suggested supporting materials (metals, glass, polymers, silicon, etc.). These problems have undoubtedly hampered μGC's expected development [4,12].

To minimize the size of the detectors of GC, efforts have focused on the necessity of a better interface with the column to guarantee a high detection capacity while enhancing the potential portability of equipment. In order to meet sustainability standards, new working modes were also developed for the miniaturization of GC systems. As a result, two illustrative instances of such modes are the microcirculatory GC and the micro-comprehensive two-dimensional GC (μGC × μGC) [9,10]. Microcirculatory GC and μGC × μGC make it easier to analyse complex samples, even enabling the resolution of isomeric molecules in comparatively less time.

The faster GC separations are often achieved by adjusting temperature programs, which typically involve increasing temperature ramps [13,14]. This reduces analysis times, but it also increases energy use, which is contrary to principles of Green Analytical Chemistry (GAC). By applying vacuum conditions to the analytical column, low-pressure GC enables a decrease in both the temperatures needed for the analysis as well as the analysis times [15]. In addition, Low Thermal Mass (LTM) technique has enabled the development of effective temperature programs that are characterized by rapid capillary column heating.

Correspondence to: Rouchan Ali, Department of Pharmaceutical Analysis, ISF College of Pharmacy, Moga, Punjab, India, E-mail: rouchanali56@gmail.com
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Advancement of green liquid chromatography

One of HPLC's main sustainability weaknesses continues to be the use of huge quantities of solvents, which is accompanied by a considerable generation of solvent wastes. In order to accomplish these goals, innovative mobile phases for Reverse-Phase HPLC (RP-HPLC) have been developed, such as acetone-water or ethanol-water combinations, which have good miscibility, low toxicity, and high biodegradability, but this method also requires particular stationary phases (polar-embedded) [16-20].

Another well-known, more environmentally friendly HPLC method is Micellar Liquid Chromatography (MLC) [21-23]. Recent research has suggested using Deep Eutectic Solvents (DES's) as a replacement for organic solvents, although MLC only needs a small amount of them to maintain micelles [24,25]. Additionally, DES's often do not produce interferences in the detection of UV-Vis range.

Another environmentally friendly approach for avoiding organic solvents is to utilize supercritical mobile phases like H_2O or CO_2 [26-30]. Supercritical mobile phases are known to have properties halfway between those of a liquid and a gas, including high diffusivity, low viscosity, and low density. Pure CO_2's low eluotropic strength, one of the drawbacks of Supercritical Fluid Chromatography (SFC), necessitates the use of little methanol to successfully complete the chromatographic separation.

Apart from environmental benefits, miniaturization in HPLC has resulted in increased detection sensitivity and efficiency [3,31]. The chromatographic working mode known as capillary LC uses narrow-bore columns to increase separation efficiency while using less solvent. As well as Sequential Injection Chromatography (SIC), a different miniaturized method combines HPLC with inline sample treatment and pre-concentration. In this method, analytes are eluted without sample preparation using an appropriate mobile phase (Figure 1) [32].

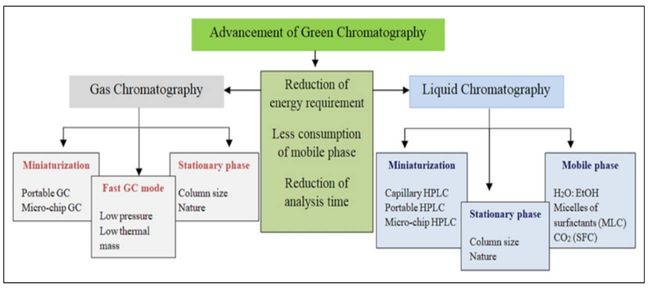

Figure 1: An overview of the key advancements made in chromatographic systems to provide greener techniques.

CONCLUSION

Miniaturization has been the major focus of the developments toward greener chromatographic techniques. There is no doubt that miniaturization results in less energy usage, less consumption of mobile phases, and less waste production. This miniaturization also helped to development of fresh stationary phases for the creation of novel micro columns.

As a result, μGC, portable GC, and μGC × μGC should be emphasized in relation to greener miniaturized GC. Regarding more environmentally friendly miniaturized HPLC, it is important to emphasize Chip-based HPLC, portable HPLC, and SIC. In addition to novel stationary phases and miniaturization, HPLC also includes additional environmental advancements through the use of more environmentally friendly mobile.

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