

Role of High-Performance Liquid Chromatography in Pharmaceutical and Environmental Monitoring

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ABSTRACT

High-Performance Liquid Chromatography (HPLC) is one of the most extensively employed analytical techniques for the separation, identification, and quantification of components in complex matrices. The method operates on the principle of differential partitioning of analytes between a stationary phase and a liquid mobile phase under high pressure, enabling high resolution, sensitivity, and rapid analysis. Owing to these advantages, HPLC has become indispensable in pharmaceutical, biochemical, clinical, and environmental applications. A typical HPLC system comprises a solvent delivery unit, sample injector, chromatographic column, detector, and data acquisition system. Based on separation mechanisms, HPLC techniques include normal-phase, reverse-phase, ion exchange, size-exclusion, affinity, and chiral chromatography, with reverse-phase HPLC being the most widely adopted due to its versatility and broad applicability. Operationally, HPLC may be performed in analytical or preparative modes and may employ either isocratic or gradient elution strategies. Method development requires systematic optimization of critical parameters such as mobile phase composition, pH, flow rate, column chemistry, and detection wavelength to ensure adequate resolution and acceptable retention behaviour. Furthermore, method validation in accordance with regulatory guidelines confirms method reliability through assessment of accuracy, precision, linearity, specificity, robustness, limit of detection, and limit of quantification. Recent technological advances, including high-efficiency columns and hyphenation with mass spectrometry, have further expanded the scope of HPLC. Despite higher instrumentation costs and technical demands, HPLC continues to remain a cornerstone technique in modern analytical science.

Keywords: *High-performance liquid chromatography, chromatographic separation, stationary phase, mobile phase, method development.*

