Review Article

A review on Chromatographic Techniques for the Determination of Pharmaceuticals in Environment

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Abstract

The past several years have seen an increase in awareness of the pervasiveness of medications as pollutants in the aquatic environment. The main reason for concern regarding the release of pharmaceuticals into the environment is the possibility that biological agents may become opposing to them. The development of precise and reliable analytical techniques for pharmaceutical determination in a range of samples is necessary for their safe use in the pharmaceutical industry and medical treatments. This review offers a summary of chromatographic techniques for identifying and quantifying the examination of pharmaceuticals in a range of environmental samples. Both the general public and the scientific community are currently very interested in the topic of pharmaceutical-related environmental contamination. The current review also provides an overview of the more chromatographic techniques coupled to mass spectrometry that have been created and applied for the determination of pharmaceuticals in the environment such as GC-MS, LC-MS and LC-MS/MS.

Keywords: Chromatographic methods, pharmaceuticals, environment, review

1. Introduction

Environmental contamination by pharmaceuticals is a topic of great interest to both the scientific community and the general public at present [1]. Emerging contaminants, such as pharmaceuticals, cosmetics, illicit drugs, and other products of anthropogenic pressure, have recently been found to be present in aquatic ecosystems [2–6]. All pharmaceuticals can be categorized using bioactive compounds, whether they are synthetic or natural. The fact that there is disagreement in the scientific literature regarding what constitutes a bioactive substance should not be ignored [7]. Because of the extensive pharmacological spectrum of those with anti-cancer activities, they are crucial to the creation of new drugs [8]. Environmentalists may find it challenging to identify novel pollutants, such as phenols [9], polycyclic aromatic hydrocarbons [10], and heavy metals [11]. Pharmaceuticals have been found in several surface water bodies around the world, placing environmentalists in a difficult situation [12,13].

Recent decades have seen a sharp rise in the production and use of pharmaceutical products as a result of medical advancements [14]. Due to their necessary rise in use and increasing prevalence in a variety of environmental components, pharmaceutical chemicals are currently categorized as emerging environmental contaminants [15]. Previously, no consideration has been given to pharmaceuticals and personal hygiene products as potential environmental contaminants. However, the number of publications describing the extent of environmental contamination brought on by these sources has increased recently [16–18].

Aquatic waste contamination hurts community water sources and may have detrimental health effects [19]. Nutritional products, dietary additives, pharmaceuticals, and cosmetics are all made with synthetic and natural bioactive compounds. Chemical analysis plays a critical role in pharmaceutical preparations by

establishing the quantity and purity of a biologically active ingredient, whether natural or synthetic [20–25].

Accurate and reliable analytical methods for pharmaceutical determination in a variety of samples must be developed in order for the pharmaceutical industry and medical treatments to use them safely [26]. Even though toxins are widely found in the natural environment, it is now possible to identify them because of the advancement of modern detection tools [27] Further information regarding the structure of the degradation process is required to make pharmaceutical products more stable and to determine whether the contaminants and degradation products are hazardous [28]. Although vibrational spectroscopies in particular have produced important data in a variety of contexts, the available information is limited [29].

The process of separating mixtures arising from their various migration velocities along the stationary phase bed is known as chromatography. Since it has its adaptability and excellent resolving capacity, chromatography is a highly valued analytical method utilized in science, industry, and medicine. It is utilized to monitor environmental conditions and the production of the chemical and pharmaceutical industries [8].

This review provides an overview of contemporary methods for identifying and quantitatively determining the complex analysis of pharmaceuticals in various environmental samples.

2. Chromatographic Techniques

2.1. Thin layer chromatography

Thin-layer chromatography (TLC) is a separation method for quantitative pharmaceutical analysis [30]. Because of its affordability, ease of use (requiring less

complex equipment), and minimal sample cleanup requirements, this kind of analysis can be carried out in remote locations [31].

The study by El-Shoubashy and co-workers compares chromatographic methods for the analysis of the ternary mixture in tablet dosage form and pure form. The initial technique is HPLC and an acidic aqueous phase pH 3 (mobile phase composed of acetonitrile). The second method, known as HPTLC, involves applying drug solutions that were developed using a 7.4:2.6:0.5:0.01, v/v mixture of acetic acid, water, and methanol [32]. The study demonstrates the analysis and imaging of ecdysteroids in plant extracts from Silene family members using HPTLC [33].

Giri et al. examined the TLC of eighteen medicinal plants from Nepal using chromatographic plates and solvent systems [34]. They identified the flavonoids, tannins, saccharides, and phenols using UV light and spraying agents. Nugraha et al. found steroids and polyphenols in a range of plants [35]. Belhi *et al.* utilized TLC as the initial technique for phytochemical Limoniastrum feei extracts that were procured from the southwest area of Algeria [36]. RF values were utilized to identify the active compounds, and TLC in combination was employed to disclose the antifungal and anti-cellulase characteristics of the extracts [37].

2.2. High-performance liquid chromatography

With a wide range of uses, high-performance liquid chromatography (HPLC) is an immensely helpful analytical method. A sample is passed through an adsorbent material column (such as silica beads) under pressure in HPLC. The sample mixture's constituent parts will interact with the material in the column in various ways, resulting in varying flow rates for each. As a result, the different parts can be collected separately and will exit the column at different times. Both qualitative and quantitative analysis are capable of identifying each component and figuring out the sample's makeup [38].

A quick assay technique utilizing HPLC has been created to measure dimetindene maleate in environmental water samples and pharmaceutical formulations. Using an acetate buffer pH of 4.0 and acetonitrile as the mobile phase (65:35), the HPLC determination was performed. A recti-line relationship was found between dimetindene maleate concentrations. The suggested technique has been effectively used to measure dimetindene maleate in environmental water samples and pharmaceutical dosage forms [39].

SPE and HPLC were presented by Flores *et al.* for the determination of pharmaceutical products in environmental samples (soil and water), comprising ten antidepressants and three anticancerigenics. Using an ultra-base C18 column, the investigated compounds were separated. It was possible to obtain detection limits ranging from 1 to 50 ng/mL for every target compound. This technique was used to analyze environmental samples, such as soils and waters with varying historical dates [40].

The use of SPE–HPLC analysis to analyze significant veterinary medications across several classes in a complex wastewater matrix was investigated. Three sulfonamides were among the pharmaceuticals that were examined. Utilizing Oasis HLB extraction cartridges, the procedure entails pre-concentration and cleanup via SPE. A DAD in conjunction with HPLC was used to analyze the pharmaceuticals. The recoveries range was between 68.3 and 97.9%. The range of the quantification limits varied depending on the pharmaceutical: 1.5–100 µg/L. The method that is being described was utilized to identify pharmaceuticals present in wastewater samples [41].

The concentrations of some antibiotics in the wastewater from three hospitals were measured using HPLC equipped. The two most significant water pollutants in this study were levofloxacin and tetracycline. Gradient elution was used to separate and quantify these antibiotic residues on a reverse-phase C18 column. After the

extraction, the SPE cartridge was cleaned using a pH 4 citrate buffer. The calibration curves showed excellent linear ties ($R^2 > 0.9998$) [12].

The study developed a method using solid-phase extraction and HPLC-DAD to extract and determine thirteen pharmaceutical compounds from water samples in African nations, including Ethiopia. The method's limits of quantification and detection ranged from 0.2-2.6 µg/L and 0.1-0.8 µg/L, respectively. The method successfully tested environmental water samples from Addis Ababa, Ethiopia, revealing concentrations of trimethoprim, caffeine, and albendazole in hospital wastewater, norfloxacin in the same water, and trimethoprim and ciprofloxacin in the sewage treatment plant [42].

2.3. Combined chromatographic techniques

In pharmaceutical use analysis, the most separation methods are GC-MS, LC-MS, and LC-MS/MS. Many times, particularly in situations where sample screening is crucial, mass spectrometry has been combined with chromatography techniques [43]. An analytical technique was created to detect twenty pharmaceuticals in soils at once, including anti-inflammatory, oestrogenic hormones, and antiepileptic The best procedure involved extracting the sample with ultrasound assistance, cleaning it up on a silica gel column, and derivatizing it. This provides excellent resolution, high sensitivity, repeatability, and immunity to interferences, even from intricate matrices like soils. All target compounds had absolute recoveries greater than 80%, except for diethylstilbestrol and valproic acid. The target compounds in soil samples collected in Poland were successfully analyzed using the developed method. Twelve of the 20 pharmaceuticals had at least one compound found in the soil. For the first time, antidepressants, β-blockers, and antiepileptic medications were also determined [44].

By reducing anthropogenic stress, sustainable human activity development is directly linked to environmental protection. Because of their increasing use in veterinary care,

animal husbandry, cosmetics, and medicine, as well as the fact that they are not fully removed in wastewater treatment facilities, pharmaceuticals are categorized as a class of newly emerging pollutants that have been shown to negatively affect aquatic life. The work aims to analyze the sustainability aspects of analytical techniques in the context of the requirement to find pharmaceuticals in the various matrices. GC-MS was used for identifying pharmaceutical residue in environmental samples. The following topics were included in the analysis: (i) the technique's characteristics, (ii) the cost, and (iii) its applicability across a range of economic sectors [45].

It is possible to identify a large variety of medications from various therapeutic classes. Owing to the generally higher polarity of pharmaceuticals, LC-ES/MS/MS analysis or effective derivatization before GC/MS measurements are typically necessary. Furthermore, utilizing LC-ES/MS/MS resulted in a lower relative standard deviation. Nevertheless, electrospray ionization suppression is likely to happen when analyzing highly contaminated samples [46].

A UPLC-MS/MS was developed to determine the presence of multiclass pharmaceuticals in the water sample. To prepare the sample, an ultrasound-assisted back extraction process was carried out after the floating organic droplets were collected using cold centrifugation. Electrospray ionization in positive mode was used to ionize the sample, and multiple reaction monitoring was utilized to measure the target analytes. The results showed that the relative recovery varied between target analytes, ranging from 93.1 to 109.4%, and the enrichment factor was 172−192-fold. These satisfactory findings demonstrated the specificity and dependability of the suggested approach for use in trace analysis of target analytes in waste samples [47].

Conclusion

A wide range of newly emerging pollutants in environmental matrices are taken into consideration in the studies reviewed here that look at the quantification of pharmaceuticals in environmental samples. Powerful analytical techniques are necessary to ensure low detection limits and prove analyte identities. This paper presented an analytical chromatographic method for identifying pharmaceuticals in a variety of environmental samples. The identification of more types of compounds and, consequently, a more thorough assessment of environmental pollutants have been made possible by the application of advanced technology (GC-MS, LC-MS, LC-MS/MS) methods to ecological analysis. Although the limits of detection attained by the LC-MS/MS techniques were marginally greater than those by the GC-MS, the LC-MS/MS approach demonstrated benefits in terms of adaptability and simpler sample preparation.

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