

Extraction Techniques Used for the Removal of Pharmaceuticals from Environmental Samples

Mustafa Soylak^{1,2,3}, Muhammad Saqaf Jagirani⁴

¹Faculty of Sciences, Department of Chemistry, Erciyes University, Kayseri, Turkey.

²Technology Research and Application Center (ERUTAUM), Erciyes University, 38039, Kayseri-Turkey.

³Turkish Academy of Sciences (TUBA), Cankaya, Ankara, Turkey.

⁴National Center of Excellence in Analytical Chemistry, University of Sindh 67080, Sindh, Pakistan.

Article History:

Received: 4 June 2021

Accepted: 15 June 2021

ePublished: 6 July 2021

Introduction

At present time the pharmaceutical products play a significant role in modern life. They are used to treat diseases of humans and animals. The existence of pharmaceuticals in the environment is life-threatening and one of the big problems. There are different sources of pharmaceuticals in the environment such as untreated garbage of pharmaceutical companies, hospitals, waste, and untreated municipal wastewater, and agricultural land. A variety of input sources continuously release these contaminants into the local habitat as substances, metabolites/degradation products, or kinds. Manure, when used as fertilizer in the crops, the potential to pollute soil and, as a consequence, natural water via runoff or leaching. Human medicines are similarly discharged into the environment by urine and feces, entering the sewage network, and having wastewater treatment systems. The pharmaceuticals-based pollutants in the ecosystem are nowadays widely accepted as an environmental issue in several countries.

Pharmaceuticals Considered "Distinctive" Micropollutants

The pharmaceutical traces have been detected from different matrices of the human and cattle. The release of these substances into the environment via anthropogenic sources carries a risk to flora and fauna life. This has led to the emergence of a wide research area, as identification and quantification of chemicals; interpretation of transformation pathways when existing in the wastewater-treatment plants or ecological matrices; evaluation of their possible biologic consequences and the development and relevance of sophisticated procedures for removal and/or mineralization of them. Pharmaceuticals are an exclusive class of pollutants, to their unique characteristics. When pharmaceuticals are recognized as pollutants discharged into the ecosystem,

*Corresponding Author: Mustafa Soylak, E-mail: soylak@erciyes.edu.tr

etc. to overcome these limitations the science community focus on the development of new highly selective, sensitive and fast sample preparation and pre-concentration method for the extraction of pharmaceuticals from environment such as physicochemical treatment including activated carbon-based adsorption, nanofiltration, reverse osmosis, membrane filtration, and coagulation-flocculation.²⁻⁵

Extraction Methods

Extraction methods play a significant role in analytical chemistry. Several laboratories mostly use extraction processes that have been in use for decades. However, the emergence of instrumental analysis approaches has increased exponentially, particularly with the introduction of supporting technologies such as transistor and microprocessor control, and it continues to increase. Analytical chemistry and the areas it supports evolve as a result of the information and consequent knowledge obtained through well completed analytical studies. Spectroscopy and chromatogram gave this information and advancement in these techniques improve the worth of this information. Extraction, on the other hand, is often relegated to a supporting function, and it has only been in the last 15 years or so that the relevance of extraction technology has been acknowledged for its role in the development of high-quality analytical data.⁶⁻⁹ Extraction operations are often classified as “pre-treatment.” That is, extraction serves to separate analytes from potentially interfering reaction mixture while also preparing these analytes for assessment. Extraction methods are cost-effective, highly selective, and sensitive, and also beneficial for humans because they use for the extraction of pharmaceuticals residue from real samples. It is very necessary to eliminate pharmaceutical residue to save human health and prevent the toxic effects of pharmaceutical-based pollutants. Most pharmaceuticals are found in the environment at trace levels (sub-mg/L), making quantification challenging. Some analytical techniques have low sensitivity to directly quantify the pharmaceuticals from the environment, requiring pre-concentration and sample preparation procedures before analysis. Since about the beginning of the century number of publications is available to describe the extraction process of pharmaceuticals from the environmental samples before the analysis. The preparation of the sample is a significant part of the pharmaceuticals analysis from the environmental matrix. In the sample preparation, the filtration is the first step of wastewater samples using <1- μm glass-fiber filters are used to avoid during extraction interferences due of the existence of suspended solid materials extraction of targeted pharmaceutical samples is the next step. Different conventional and advanced extraction techniques have been reported for the analysis of pharmaceuticals such as Liquid-Liquid Extraction (LLE), Solid Phase Extraction (SPE) and different advance extraction techniques, Ultrasonication Assisted Extraction (UAE), Soxhlet Extraction, Microwave-assisted Extraction (MAE), Pressurized Fluid Extraction (PFE) Supercritical

Fluid Extraction (SFE), Matrix Solid-Phase Dispersion (MSPD), Accelerated Solvent Extraction (ASE), and Shake Flask Extraction, Solid-phase Microextraction (SPME), and Liquid-phase Microextraction (LPME).² Commonly the SPE and SPME and other extraction methods have been used include LPME and lyophilization. The SPE is widely used for the extraction of targeted analytes from the complex matrix just in one step. In another process, the combination of two SPE materials has been used for the extraction of targeted compounds from the environmental matrix according to their physio-chemical characterizes. Hydrophilic-lipophilic polymeric and silica-based materials with higher hydrophobicity are the constituents extensively used for the sample preparation and pre-concentration of the targeted analyte. Recently, there has been a lot of studies done on evaluating SPE stationary phases. Stronger cation-exchange resins and mixed-mode polymeric sorbents or polystyrene–divinylbenzene resins functionalized with different functional groups are two other stationary phases that have been used for sample preparation and preconcentration and extraction of pharmaceuticals in water samples. Methanol, acetone, and ethyl acetate are the most widely utilized elution solvents. The automation of SPE techniques, which can increase the accuracy and fast analysis of pharmaceuticals, is an intriguing component of the operations. Automated SPE allows for the direct insertion of untreated samples, as well as the automatic conduct of preparing, washing, and elution procedures, fast less amount of solvent, enhancing repeatability, lowering LODs (limits of detection), and limited health concerns throughout the analysis. Currently, SPME has paid more attention to sample preparation and pharmaceutical analysis from an aqueous environment. The basic principle of SPME is the elimination of the targeted analyte from a complex sample onto an adsorbent layer that is coated with the fabric material. The extracted compound quantity by the fiber is proportionate to its absorption in the sample, as long as equilibrium is attained or, for short-term pre-equilibrium, with the help of agitation or convection. After the extraction step, the fiber is moved to the Gas Chromatography (GC) injection port where the target analyte is desorbed. In the SPME, very less amount of solvents has been used and the isolation and enrichment have been done in one step. The detection of polar compounds has been also performed by the SPME derivatization, using coated, direct, or fiber derivatization. After the derivatization-based extraction, the pharmaceutical samples have been analyzed by the GC-MS.

Current Information and Future Prospects

Pharmaceuticals are physiologically active substances that are frequently quite strong. They are also formulated to be resistant to biodegradation, as metabolic stability enhances the desired pharmacological activity. On the other hand, promotes their environmental persistence. Pharmaceuticals have physio-chemical features that enable them as distinct pollutants. As a consequence, their

characteristic cannot be replicated or attributed to that of other drugs. In terms of pharmaceutical study, in the present time, innovative analytical techniques have been established and optimized, with the improving sensitivity and selectivity, to enable the perfect recoveries of trace levels of pharmaceuticals in an aqueous sample. Different analytical techniques have been used for traces analytes. Several methods and materials have been used for the sample preparation and pre-concentration. The SPE is the most significant and well-organized sample preparation method with good selectivity and sensitivity. Currently, the SPME has been used because it has a number of benefits over the SPE in terms of minimization of solvents and sample handling. However, the existing approaches and improvements, fast, accurate determination of trace amounts of pharmaceutical materials in a complex matrix represent an exciting challenge for several scientists work in the areas. Furthermore, the identification of unknown substances, including conversion of by-products, is still a work in progress. More research is required to improve accuracy and sensitivity of the technique's. Also, there is a need to improve current scientific studies on the aquatic ecosystem's impact of medications, metabolites, and transformation products. More data and risk assessment refinement are needed to quantify the acute and/or chronic impacts of these substances and by-products. Furthermore, additional research on the eco-toxic potential of these mixes is essential. The current therapeutic consensus in scientific community is that no single technique could eliminate pharmaceutical materials.

Acknowledgements

Dr. Muhammad Saqaf Jagirani is thankful to TUBITAK for funding this project through 2221 Research Fellowship Programme for Foreign Citizens. Dr. Mustafa Soylak thanks to Turkish Academy of Sciences (TÜBA) for their financial support.

Author Contributions

MS and MSJ contributed in writing of manuscript and they agreed to the published version of the manuscript.

Conflict of Interest

The authors declare there is no conflict of interest in this study.

References

1. Homem V, Santos L. Degradation and removal methods of antibiotics from aqueous matrices– A review. *J Environ Manage.* 2011;92(10):2304-47. doi:10.1016/j.jenvman.2011.05.023
2. Fatta-Kassinos D, Meric S, Nikolaou A. Pharmaceutical residues in environmental waters and wastewater: current state of knowledge and future research. *Anal Bioanal Chem.* 2011;399:251-75. doi:10.1007/s00216-010-4300-9
3. Soylak M, Yilmaz E. *New Generation Green Solvents for Separation and Preconcentration of Organic and Inorganic Species.* Amsterdam: Elsevier; 2020.
4. Soylak M, Elci L, Dogan M. Flame atomic absorption spectrometric determination of cadmium, cobalt, copper, lead and nickel in chemical grade potassium salts after an enrichment and separation procedure. *J Trace Microprobe T.* 1999;17(2):149-56.
5. Soylak M, Elci L. Solid phase extraction of trace metal ions in drinking water samples from Kayseri-Turkey. *J Trace Microprobe T.* 2000;18(3):397-403.
6. Soylak M, Ozalp O, Uzcan F. Magnetic nanomaterials for the removal, Separation and preconcentration of organic and inorganic pollutants at trace levels and their practical applications: A review. *Trends Environ Anal Chem.* 2021;29:e00109. doi: 10.1016/j.teac.2020.e00109
7. Raynie DE. Modern Extraction Techniques. *Anal Chem.* 2006;78(12):3997-4004. doi: 10.1021/ac060641y
8. Yilmaz E, Soylak M. Latest Trends, Green aspects and innovations in liquid-phase-based microextraction techniques: A review. *Turk J Chem.* 2016;40:868-93. doi:10.3906/kim-1605-26
9. Alshana U, Hassan M, Al-Nidawi M, Yilmaz E, Soylak M. Switchable-hydrophilicity solvent liquid-liquid microextraction. *Trend Anal Chem.* 2020;131:116025. doi:10.1016/j.trac.2020.116025