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Chapter

Modern Sample Preparation Techniques: A Brief Introduction

Mona Sargazi, Sayyed Hossein Hashemi and Massoud Kaykhaii

Abstract

Due to fast growth in microprocessors, analytical instrumentations in spectroscopy, chromatography, microscopy, sensors and microdevices have been subjected to significant developments. Despite these advances, a sample preparation step is indispensable before instrumental analysis. Main reasons are low sensitivity of the instruments, matrix interferences and incompatibility of the sample with the analytical device. Most of the time spent and most of the errors occurring during a chemical analysis is on sample preparation step. As a result, any improvements in this essential process will have a significant effect on shortening the analysis time and its precision and accuracy and lowering the cost. This introductory chapter intends to draw the readers' attention to the importance of sample preparation, the procedures of sampling and the source of errors that occur in the course of sampling. The chapter then continues with a heading on sample preparation techniques, including exhaustive and non-exhaustive methods of extraction. Microwave, sonication and membrane-based extraction techniques are more emphasized as exhaustive methods and under a new title, miniaturized methods are discussed. Automation, on-line compatibility and simplification is an important aspect of any sample preparation and extraction which is discussed at the end of this chapter.

Keywords: sample preparation, matrix interferences, microextraction, automation

1. Introduction

Over the last two decades, efforts in sample preparation have been done to eliminate organic solvents and perform rapid analysis of combinatorial chemistry and biological samples, which require a high level of automation. These new developments in sample preparation, as a result of miniaturization of the extraction process, were a reason to extend new solvent-free approaches. Also, a fundamental understanding of extraction principles has been very important in the development of novel approaches, which results in new trends in sample preparation, such as microextraction, miniaturization, and integration of the sampling and separation. The sampling and sample preparation process, which is similar to engineering approaches on a smaller scale nevertheless is different from those related to chromatographic separations or other traditional disciplines of analytical chemistry, consists of extraction of components of interest from the sample matrix to an extracting phase. So, the procedure of extraction has a variety of selectivity, speed, and convenience as a result of the approach and condition

used and geometric configurations of the extraction phase [1]. Modernization of analytical methods and instrumentation made it possible to measure smaller concentrations of even the most complex molecules and species in complicated matrices. In addition, improved measurement techniques and tools allow, or often require, the use of smaller analytical test portions to determine analyte concentrations. Using small test portions face with difficulty in achieving representativeness of the population, especially in the analysis of trace components, since the quality of any analytical result, depends on sample representativeness and integrity. Similar to all measurements, which are accompanied by errors, some typical errors often occur during sample collection prior to trace analysis [2] but many sources of error in an analysis can be controlled through the use of blanks, standards, or reference samples. Neither blank nor standard can repair the damage caused by an invalid sample [1]. Errors are an integral part of all measurements, which cannot be eliminated completely but it is possible to estimate the magnitude and nature of them in order to validate results [3].

In this chapter, an attempt has been made to define the principle of sample preparation and its importance prior to chemical analysis. The following sections are dedicated to different methods of sampling and the errors that occur during sampling and focus on the different techniques in the science of sample preparation. This chapter is not intended to provide a comprehensive review of the topic of sample preparation, but it is helpful for learning more about it.

2. What is sampling and sample preparation?

Successful quantitative analysis starts with the sample collection, which is a first operation in an analytical procedure. The sample in sample collection should be representative of the bulk material and various sample collection techniques can be employed depending on the nature of the matrix. For example, in the field of environmental samples, such as soil, air, and water, consideration of representative sampling right at the point of collection is of great importance because it needs to consider the intrinsic heterogeneity of most materials. These considerations are highly important especially in performing analysis of trace and ultra-trace components, which require sample-specific strategies to obtain a clear and unbiased overview. After sample collection, it needs to be decided whether the entire sample or a portion of the sample requires to be analyzed [4]. It should be noted that sampling depends on the location, depth, and time of the year, which affects the concentration of the sample. Once the sample is ready for analysis, sample preparation is the next step [3]. Sample preparation is a crucial step of the analysis process with the ability to detect an analyte at a level that is appropriate for detection by the instrument. Matrix interferences in this step can interfere with the detection and measurement of analytes in a way that often requires to complete separation of the sample matrix from the analyte(s) of interest. So, the nature of the analyte and the matrix determine the choice of sample preparation. **Figure 1** shows various sample preparation steps that may be employed in sample preparation in which most analysts use one to four steps for sample preparation, although, in some cases, more than seven steps may be used [4].

Nowadays, efforts have been done to hyphenate sampling and sample preparation steps but there are challenges such as multistep procedures involving organic solvents. So, it is difficult to develop a method to integrate sampling and sample preparation with separation methods, for the purpose of automation. Therefore, over 80% of analysis time is currently spent on sampling and sample preparation steps for complex samples [1, 5].
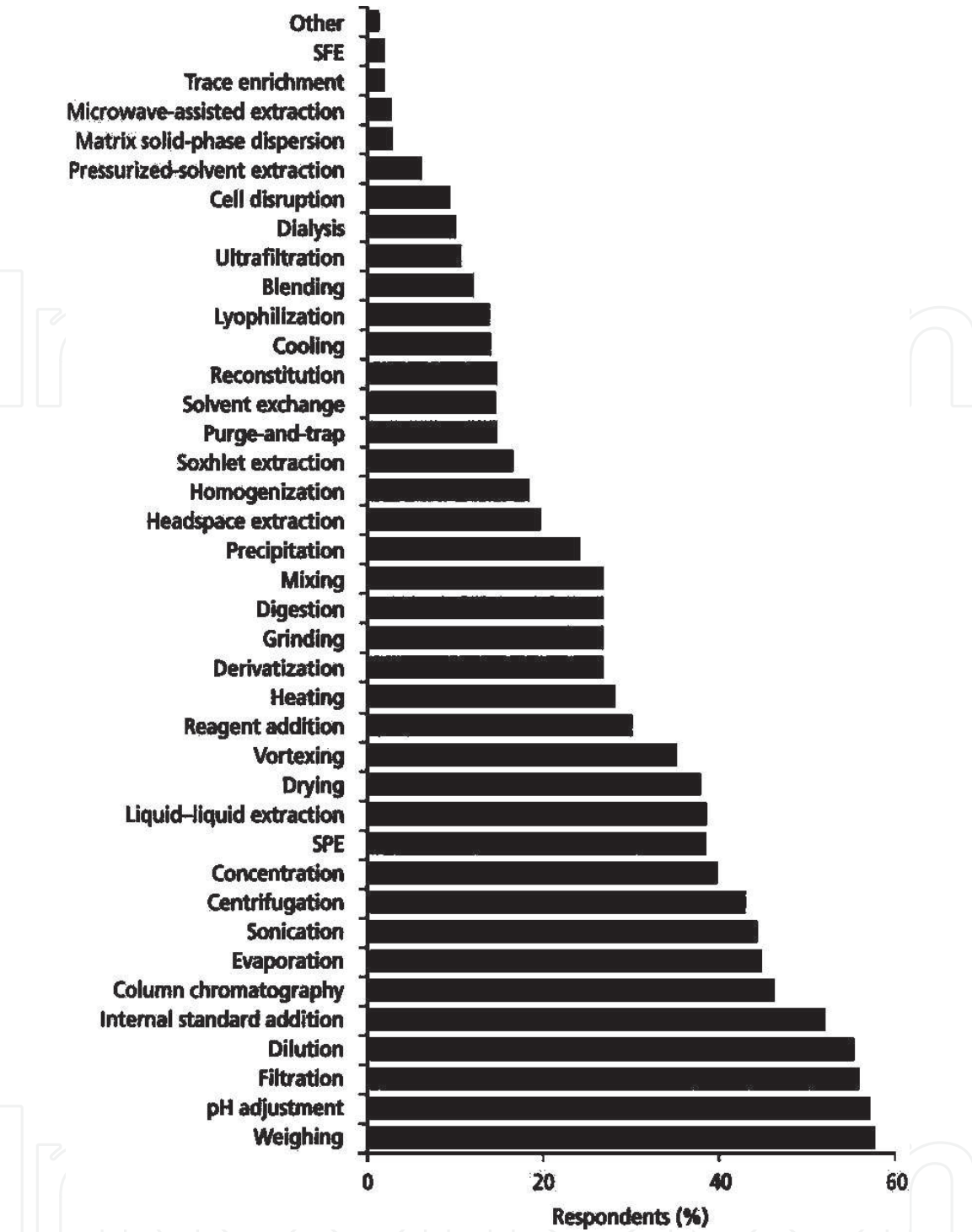
Figure 1.
Sample preparation procedures commonly used [4].

3. Importance of sampling and sample preparation

One of the most important parts of the analytical process is sampling, which is highly dependent on the properties of the analyte and the nature of the sample. Obtaining correct and informative results from the analytical procedure is a main purpose of this step. Inappropriate sample collection causes irreparable impairment that cannot be compensated even by quality assurance measures. Sample contamination during sample collection is one of the main sources of acquiring invalid data [6]. The decision of where to collect samples, which represents the whole sample, how to characterize the problems, and choosing a right method of obtaining the right

amount of samples, are the critical issues in the sampling step. The purity of the sample should be ensured before taking a measurement to obtain the optimum results when using any instrument, irrespective of the technology. For this reason, sample preparation often involves a cleanup step for "dirty" samples besides extraction procedure. Sample preparation also includes all treatments to decompose the structure of the matrix in order to perform the fractionation, isolation, and enrichment of the proposed analytes. These treatments, which adapt the tested analytes with the detector to enhance the sensitivity of the detector, are also considered part of the sample preparation protocol. Emerging some challenging problems with the sample matrix led analytical chemists to turn to non-traditional technologies, which meet the need for solvent-free approaches, automation, and miniaturization. These developments reach some benefits such as *in situ* analysis of sample, which consequently reduces the time and errors and thus leads to more accurate, precise, and faster data. In parallel with the development of new technologies, the fundamental of extraction principles has advanced, which is in high importance in the development of novel sample preparation trends. In the case of complex samples, the analytical procedure consists of several steps including sampling, sample preparation, separation, quantification, statistical evaluation, and decision making. These analytical steps follow one after another, and the slowest step determines the whole speed of the analytical process. Since direct analysis cannot produce real results because of interferences of a matrix of the sample that causes low sensitivity, therefore, modification of the sample to obtain better analytical results is very important [7, 8].

4. Sampling methods

The aim of sampling methods is to choose a "sample" that represents the population. Attempts in sampling methods are ensuring about an equal chance of each part of the population to be selected for analysis, which requires a random element in the sampling strategy. These strategies include simple random sampling, systematic grid sampling, stratified, cluster, and two-stage sampling.

In simple random sampling, the population is divided into a set of units and a sample is selected unit by unit with an equal probability of selection for each unit at each draw. In systematic grid sampling, samples are collected from grid areas, which are as a result of dividing the population into two or three-dimensional grids. When the purpose of sampling is increasing the probability of locating possible hot spots in a population, systematic sampling is used.

In two-stage sampling, elementary units are randomly selected within the population and sample increments are taken from locations within each unit. The locations may be selected systematically or randomly.

Stratified random sampling is composed of the division of a population into sections called strata. By designing an efficient and cost-effective sampling plan, the number, size, and shape of strata are important. When the purpose of sampling is to estimate more precisely analyte concentration in the population, the uniformity of each stratum is necessary. So, the number of sample increments needed to define analyte distribution within each stratum will be reduced. By using systematic sampling, the units occur at the same relative position in the stratum, while in stratified random sampling, the position in the stratum is determined separately by randomization within each stratum.

In survey sampling, a group of distinct and identifiable units in the population is called a cluster and choosing a group of units as a single unit is called cluster sampling. In cluster sampling, the population is divided into small groups with each group serving as a sample unit. The formation of clusters means forming groups of a heterogeneous nature [6, 9].

5. Sampling errors

Sampling as the most crucial step of each analytical procedure is of high importance and should be done with the utmost care and expertise. Nevertheless, there are some typical errors (systematic and random) that can occur from a small percentage to several orders of magnitude [2]. The sampling error is the error caused by observing a sample instead of the whole population. The sampling error is the difference between a sample statistic used to estimate a population parameter and the actual but unknown value of the parameter. One of the most important systematic errors, which can occur in the sampling process, is sample contamination. Contamination can exceed the true levels of the compound analyzed and consequently causes to obtain invalid results. Therefore, one of the concerns of sampling is to avoid introducing contamination into the sample. The equipment for sample collection is one of the main sources of contamination in sampling so a proper sampling device and container are of great importance for accurate analysis. For example, in the sample storage step, by storing samples in containers a wide range of chemical or physical changes can occur such as chemical reactions within components of the sample or sample components reacting with the containers [6]. Another source of error in sampling is selecting species, which is representative of the sample. In many environmental samples, the concentration of analytes is relatively high, for example, at the mg.kg^{-1} level and selecting species considered as bioindicators or biomonitors is decisive term. Also, some errors are caused by the homogenizing process to reduce initial values of species into manageable amounts in order to consider them as representative analytical subsamples. There is a relation between the sampling error and particle size of the sample as shown in **Figure 2**. As it can be seen, a larger sample size reduces error significantly; however, working with a large amount of sample is not logical. According to the figure, sampling error for a normal sample is likely to be between 0.1% and 1% of the whole sample. The sampling error can be minimized by grinding the particles into fine size with this assumption that there are no issues relating to the stability of the analytes. It is important to mention that the place of sampling is very closely linked to a proper sampling strategy. Carefully choosing of a statistically relevant number and mass of individual samples greatly depends on the distribution and concentration of the analyte in the collected material [2, 4].
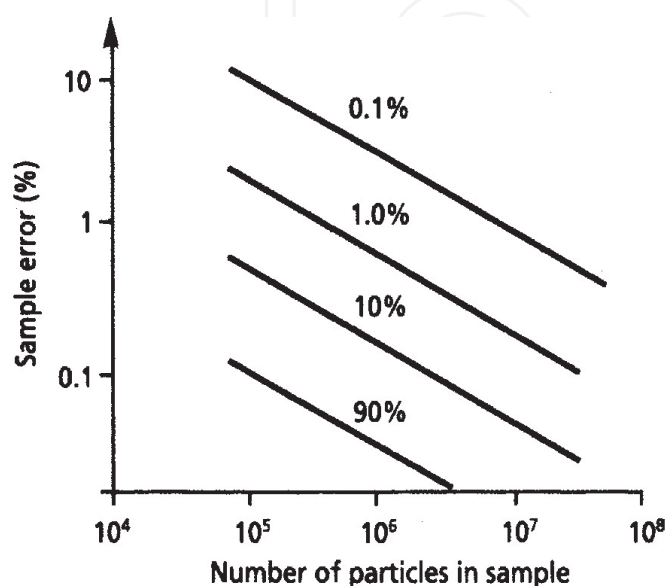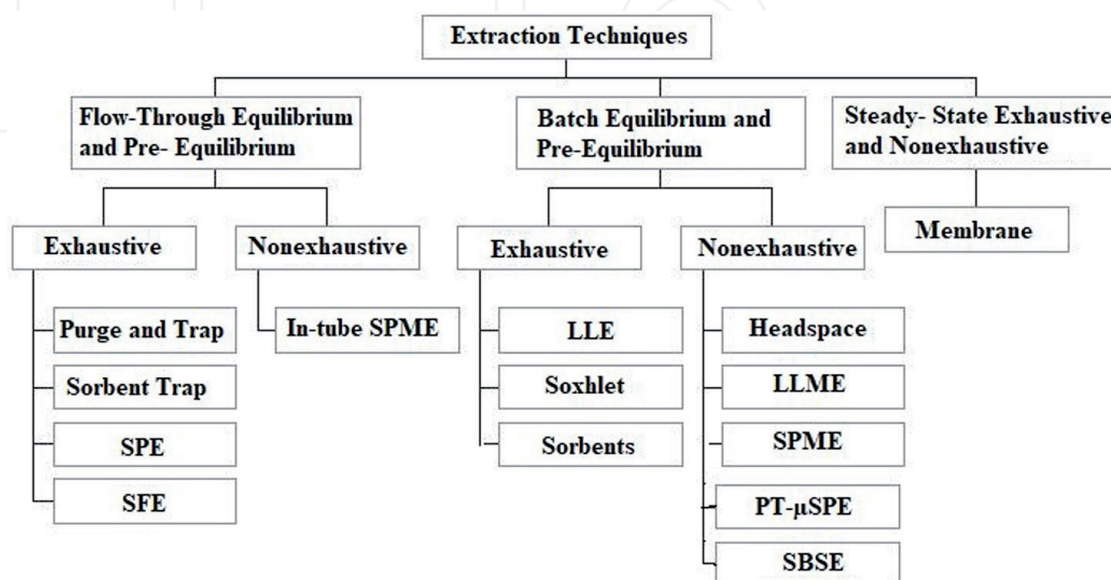

Figure 2.
The relationship between sample error, the number of particles in a sample, and different percentages of original material sampled [4].

6. Sample preparation techniques

Signal detection of the analytical instrument of the target analyte at a low concentration is always challenging because of the highly complicated media and different interferences from the matrix of any real sample such as biological, food, water, and environmental samples [10]. Accordingly, it is a need to develop a novel, effective, fast, inexpensive, and simple sample preparation technique to isolate analyte components of the samples and preconcentrate them to a detectable limit [11]. Several pretreatment techniques including solid phase extraction (SPE) [12], dispersive solid phase extraction (DSPE) [13], solid phase microextraction (SPME) [14], magnetic solid phase extraction (MSPE) [15], liquid–liquid extraction (LLE) [16, 17], molecular imprinted polymer (MIP) [18], stir bar sorptive extraction (SBSE) [19], pipette tip microsolid phase extraction [20], molecularly imprinted stir bar sorptive extraction (MIPSB) [21], microwave-assisted extraction (MASE) [22], membrane extraction [23], solid phase extraction (SPE) [24], supercritical fluid extraction (SFE) [25], and silver nanoparticle stir bar sorptive extraction [26] have been used widespread application for preconcentration and isolate trace level compound of complicated matrices. Before talking in detail about these mainly miniaturized techniques, first some details about the classification of extraction methods are explained.

7. Exhaustive and non-exhaustive extraction methods

Figure 3 represents the classification of extraction protocols. In exhaustive extraction methods such as solid phase extraction and liquid–liquid extraction, analytes are completely transferred to the extraction phase. These methods have been widely applied as a sample preparation technique in the separation and enrichment of inorganic and organic analytes of water media. Exhaustive extraction methods do not need calibration because almost all target molecules are transported into the extracting solvent because of their large volume. Flow systems replaced batch equilibrium techniques to reduce the consumption of solvent and time. For example, in dynamic extraction with solvent (Soxhlet extraction) in which extraction is performed at the solvent boiling point, circulation of the extractant enhances the extraction power significantly.

Figure 3.
Classification of extraction methods. Copyright Wiley-VCH, 2010. Reprinted with permission [1].

Non-exhaustive methods including SPME and liquid phase microextraction (LPME) are based on the principle of equilibrium, pre-equilibrium, and permeation. Although non-exhaustive methods (equilibrium method) such as SPME are similar to exhaustive equilibrium techniques, the amount of extraction phase is much smaller than equilibrium exhaustive techniques and is generally used to separate a small fraction of the analyte from the sample matrix [1].

8. Microwave and sonication extraction

Abu-Samra et al. [27] had already utilized the microwave method to promote the extraction techniques of liquid phase extraction (LPE). Microwave-assisted extraction can enormously decrease the extraction time (around 10 min) because microwaves directly heat up the solutions (sample and extraction solvent) instead of containers. The protocol also reduces the solvent consumption and allows multiple samples. The microwave-assisted extraction (MAE) effectiveness was proved with compared by general extraction techniques including high-speed homogenization and mechanical shaking protocols. MAE utilizes a household microwave oven that can reduce the cost of purchasing a dedicated tool for extraction, including a polytron-type extractor or an automated pressurized liquid extraction (PLE). If a flammable organic solvent including acetone is applied as an extraction solvent and a household microwave is utilized to MAE, sparks that may occur within the range can cause a fire or explosion. So, it is necessary to take suitable measures including as preventing the solvent from leaking into the extraction container to minimize fire and explosion danger [28, 29].

Ultrasonic-assisted extraction (UAE) or sonication extraction (SE) is a mature extraction methodology that accelerates the process of entering goal analytes in the solvent by utilizing ultrasound during liquid phase extraction (LPE). Indeed, ultrasonic extraction is based on mass exchange from the sample into the extraction phase using ultrasound radiation. Sonication extraction is done by high-frequency sound waves introduced into a liquid medium and it is associated with the formation and collapse of tiny bubbles or cavities in the liquid. It has been demonstrated that the UAE can improve the recovery compared to normal solvent extraction due to its physicochemical effects such as similar sonication cavitation, disturbance, fragmentation, emulsification, and erosion [30–32]. The extraction performance of UAE, MAE, and Soxhlet extraction was compared and the result showed the better performance of UAE [33]. The technique is a simple and cost-effective method [28].

9. Gas extraction techniques

Purge and trap protocol or dynamic headspace analysis or gas extraction technique is usually applied as an extraction method for the trace level determination of volatile analytes present in a liquid sample. The main advantage of the protocol is its capacity to accept large volumes of sample including the high sorption capacity of traps; hence, a lower detection limit for volatile organic analytes can be obtained. In the protocol, the sample is purged using inert gas for a specified time and the purged compounds are trapped applying an adsorbent trap as shown in **Figure 4**. Thermal desorption is utilizing to transfer the target molecules to a next step. Often before GC detection, an analyte accumulation step, depending on the cry-focusing unit, is applied. A short capillary is cooled to a sub-ambient temperature usually with liquid nitrogen or a Peltier system. The step allows to focus the compounds in a narrow band that is rapidly transferred to GC column using fast thermal

desorption. This created a good peak shape and efficiency of separation, so it increases the resolution as well as the sensitivity of the procedure [34, 35].

10. Membrane extraction

Membrane extraction is an extraction technique that utilizes a microporous membrane to separate the analytes of the extractant. The materials in the matrix to be tested pass *via* the microporous membrane, which are then extracted using the extractant. Based on the physical and chemical properties of the matrix, the extractant can be adjusted and selected to achieve better detection results [36]. The concept of membrane extraction is shown in **Figure 5**.

Membrane extraction with a sorbent interface (MESI) is considered as an efficient extraction technique since it has not only the ability to isolate the compound of the real sample, but also indicates advantages such as high selectivity, removal of the extraction solvent, reduced analysis time, compatibility by gas chromatography (GC), and applicability to continuous monitoring and automation of industrial processes. So, the utilization of a MESI method for isolation and enrichment of target compounds is an area of growing research interest. The membrane extraction includes two simultaneous steps: the isolation of target compounds of the sample media using the membrane probe and the stripping of target molecules of the other side of the membrane utilizing a flowing stripping gas. The membrane acts as a selective barrier as it allows some compounds and prevents others from passing *via* the membrane wall to the analytical sample. MESI-GC has been used to isolate different samples in various media. A custom-made tools for heating the polymer and collection, isolate of the degradation products present in the sample's headspace was applied (**Figure 6**) [37]. The treated polymer film was sandwiched as a thin layer between two aluminum foils near the heating element, which was also covered by an aluminum foil. The temperature of the heating element was controlled with an automatic temperature controller. Also, the temperature of the heating element was determined precisely with a thermocouple wire, which was in contact with the aluminum foil and connected to the digital thermometer. A polymeric membrane
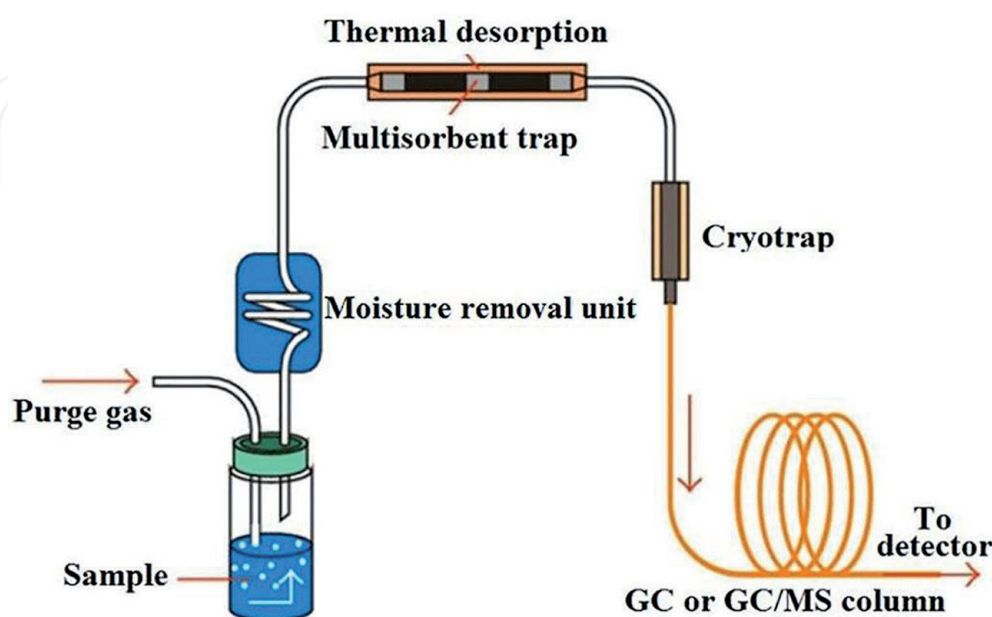
Figure 4.
Schematic diagram of purge and trap method (adapted from Ref. [34]). Reprinted with kind permission from Ref. [34] copyright 2020 Taylor & Francis [34].
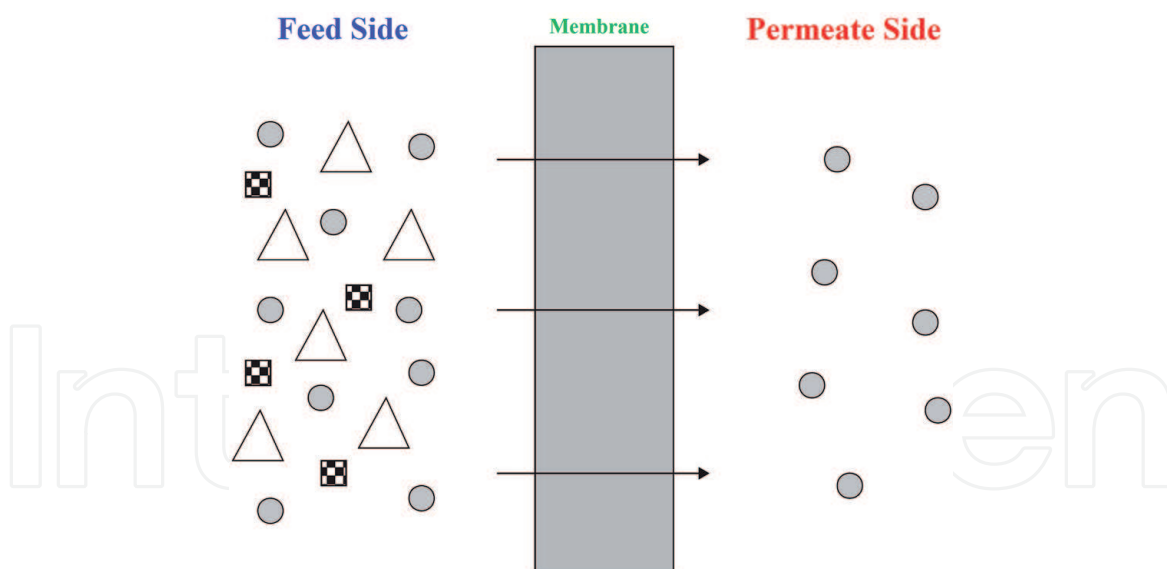
Figure 5.
The concept of membrane separation; the analytes are depicted by the circles [37]. Copyright Wiley-VCH, 2003. Reprinted with permission [37].
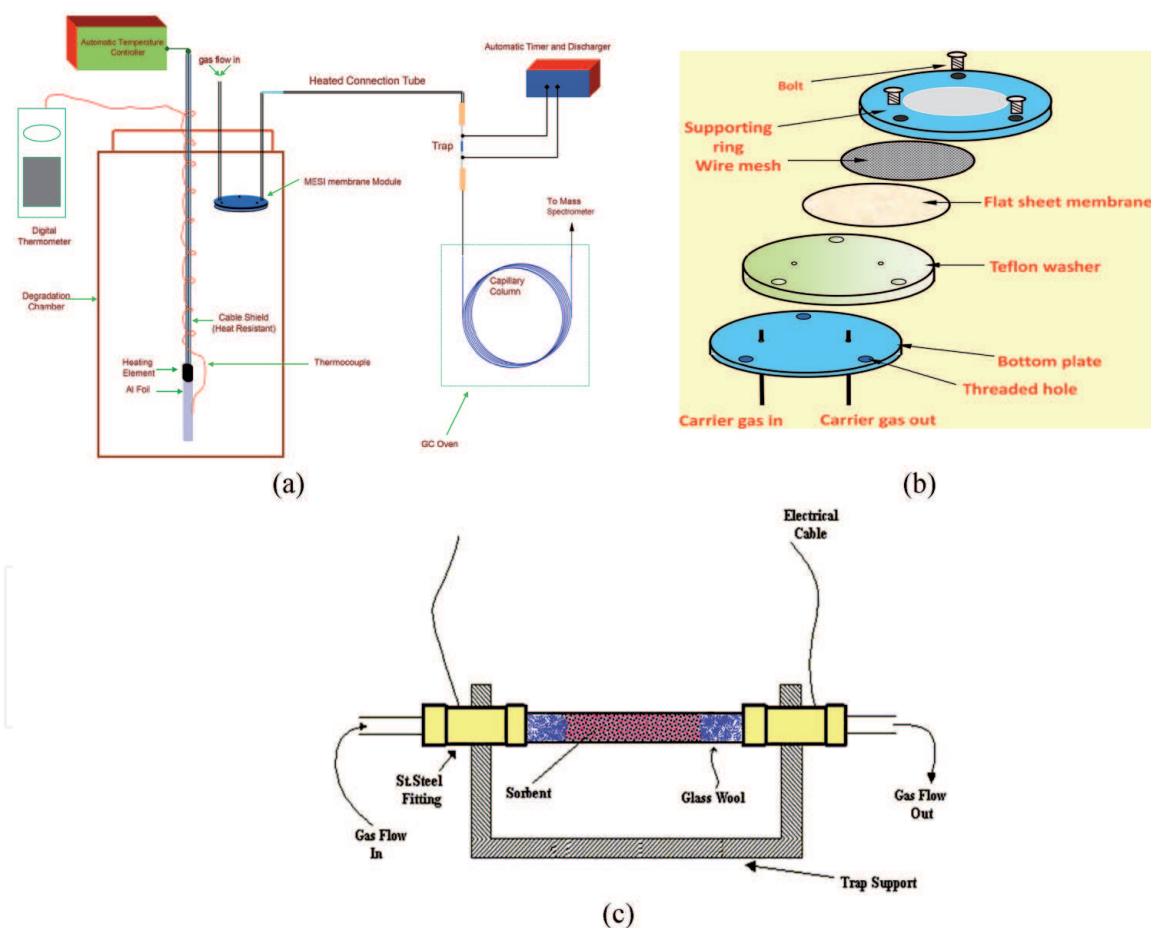
Figure 6.
Schematic diagram of MEAI-GC system applied for the polymer degradation and (a), details of the membrane module (b), main components of the MEAI trap (c). Reprinted by kind permission from Ref. [38]. Copyright 2002 Royal Society of Chemistry.

first extracts the compound from its media. By a porous adsorbent, the analytes are trapped on a polymeric trap. The extraction membrane acts as a selective barrier and is generally non-polar, then keeping water away from entering the system. It also acts as a selective element, since the permeation rates of various analytes vary

by the membrane particle. Once the molecules cross the membrane, the carrier gas stream transports them to the adsorbent interface, where concentration occurs.

The MESI system was included of a membrane extraction probe, an adsorbent trap, and a capacitive discharge power supply. **Figure 6b** shows a scheme of the membrane module. A flat sheet membrane is not self-supportive and so needs a holder to support it for contact by the system. One side of the membrane was contacted to the sample and the other to the carrier gas. There are polytetrafluoroethylene (PTFE) washers and stainless steel plates on both sides of the membrane. In a stainless steel plate, one side of the membrane was supported with a mounted fine stainless steel wire mesh. Both plates were fastened using three bolts. *Via* small diameter PTFE tubing, the carrier gas was combined to the module, which fits tightly into the PTFE washer. The carrier gas pressure lifted the membrane and allowed free passage of the gas to the outlet tubing on the opposite side of the membrane surface. After leaving the membrane, the carrier gas and target molecules proceed to the small trap. The connecting tubes between the membrane module and the GC injector were deactivated stainless steel tubes. To delete the signal determined with the detector that could come of the compound absorbed on the walls of the tubes, the connectors were heated to approximately 120°C applying a heating tape. In **Figure 6c**, the design of the micro-trap was presented. The micro-trap was made by packing a section of stainless steel tubing by the polymer adsorbent. Using passing an electrical current directly *via* the wall of the tubing for a few milliseconds of the discharge, the trap was heated. The temperature was modified with an electrical potentiometer charged utilizing the capacitor and utilized to the ends of metal tubing. The cycle of trapping and heating was repeated automatically using a timer. The temperature of the trap was set producing minimal decomposition of the adsorbent [38].

11. Miniaturization in sample preparation and extraction

Miniaturization techniques are of increasing interest in almost all aspects of chemical analysis and especially in sample preparation. They lead to a significant decrease in analysis time, sample and solvent volume, and consumption of chemical reagents. Reduction in the quantity of chemical reagents and matrix samples applied per assay enables higher-throughput assays due to massive parallelization and multiplex determination versions and after that promulgates the creation of new procedures using easier handling protocols. Miniaturized SPE and LLE have been applied for enrichment and isolation of various analytes and have many advantages including low consumption of solvent, eluent, and sorbent, good extraction efficiency, simple operation versatility. These advantages led to the invention of miniaturized modes of SPE and LLE including SPME, SBSE, μSPE, hollow fiber-based liquid phase microextraction (HF-LPME), LPME, and DLLME [39–41].

Liquid-phase microextraction was first introduced by the Cantwell group and Dasgupta group in 1996 [42, 43]. As a sample preparation technique derived from LLE, LPME overcomes the drawbacks of solvent consuming and integrates sampling, enrichment, and extraction in one step. Compared with LLE, LPME has a much higher preconcentration factor and the method minimizes the solvent in scale of microliters. Various types of LPME have been employed to meet the requirements of determination such as HF-LPME, DLLME, and electromembrane extraction (EME). In HF-LPME, a porous hollow fiber by the immobilized solvent is placed between sample and acceptor solution for extraction, which provides high enrichment and extraction efficiency. The technique has advantages such as high sensitivity and sample cleanup [44].

DLLME has excellent enrichment characteristics and is fast. In DLLME, target compound extraction is practically instantaneous due to the enormous contact surface between the receptor and donating solvents. To obtain analyte dispersion, a third solvent should be applied. In DLLME, after adding a proper volume of extraction and dispersive solvent in the aquatic sample, a cloudy solution consisting of three solvents (water solution, extraction solvent, and dispersive solvent) is formed. After extraction of the target analyte from the water phase in fine droplets of extraction solvent, the organic phase can be separated by centrifugation [45, 46].

In EME, target molecules at aqueous media are electrically migrated across a solvent immobilized porous polymeric liquid membrane called supported liquid. They can later enter to the acceptor solution with the application of direct current electric potential. Furthermore, utilizing a transparent liquid free membrane as an alternative of SLM enables visual screening of the extraction methods. The EME is a promising procedure for wider applications in analyte analysis and efforts have been made to improve this extraction method [44].

Solid phase microextraction, as an effective and simple sample preparation, has been generally used for different real samples since it was proposed by Pawliszyn et al. in 1990 [47]. The extracting phase attached to the coated fiber has key effects on the extraction process of the method since the mechanism of the technique is mainly depending on the absorption equilibrium of the target compounds between the fiber coating particle and sample solution. Up to date, scientists have employed a number of coating particles to develop the usage of SPME including graphene oxide, covalent organic framework, polymer, molecularly imprinted polymer, ionic, and metal–organic frameworks (MOFs) [17].

Stir bar sorptive extraction is another interesting extraction method. Stir bar coated by poly-dimethylsiloxane (PDMS), for preconcentration and separation of the analytes, was first introduced in 1999 with Sandra et al. and called stir bar sorptive extraction (SBSE) [48]. The technique depends on sorption that makes target compounds partitioning between retaining sorbent (polymer) and liquid or vapor sample media; hence, originating bulk retention. SBSE is dipped in the sample and stirred for a defined time. After extraction of the target molecules, it is taken out of the sample and immerged in a vial including elution solvent and stirs again. In final, the elution solvent is removed and send to a proper apparatus for determination. Sampling is carried out with direct insertion of SBSE in liquid or headspace (HS) sample [49–51]. The mechanism of SBSE is shown in **Figure 7**.

Pipette tip microsolid phase extraction (PT-μSPE) is one of the most important extraction techniques of miniaturized SPE that has become a simple and suitable device for the extraction of different analytes. The pipette tip is proper to be applied
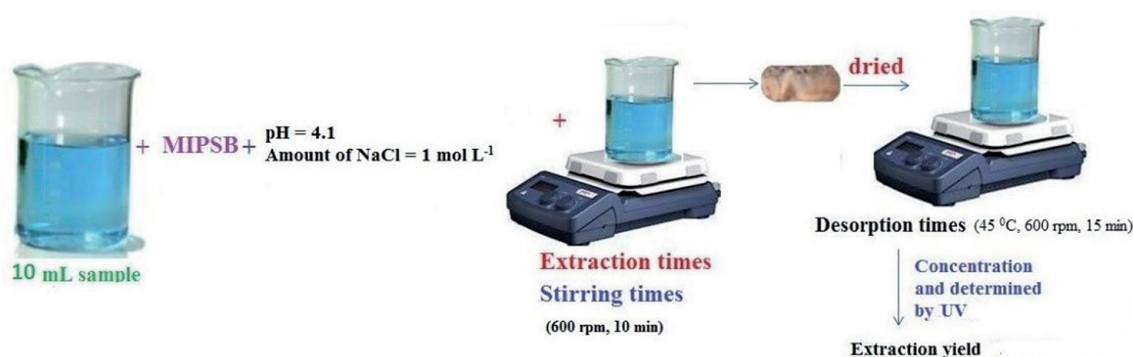
Figure 7.
Schematic of MIP-coated SBSE for naphthalene sulfonates. Reprinted by kind permission from Ref. [52]. Copyright 2018 Taylor and Francis.
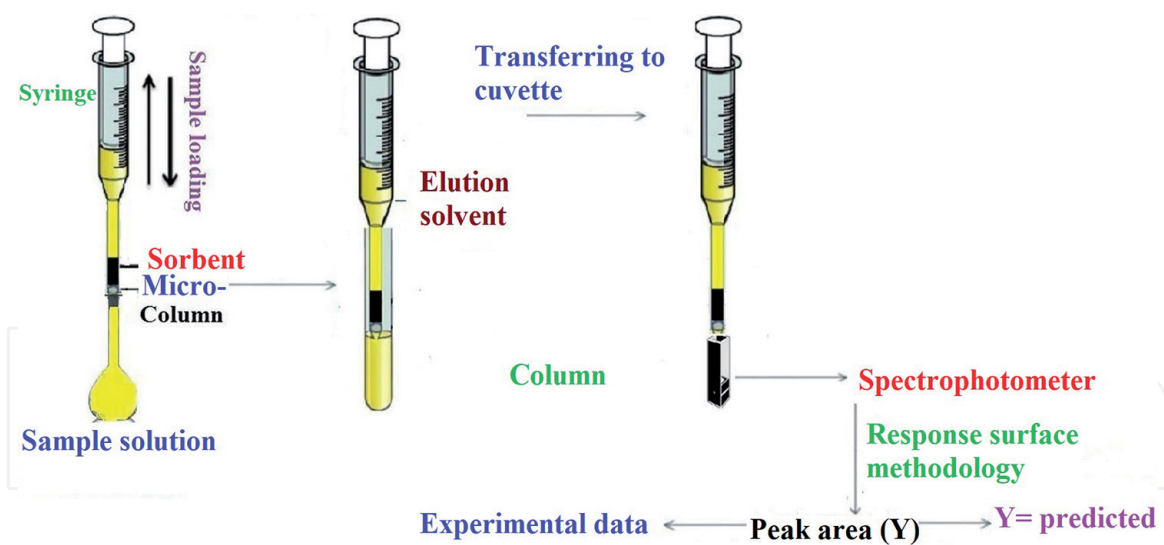
Figure 8.
Schematic of PT-µSPE for nalidixic acid and acetaminophen [40]. Reprinted by kind permission from Ref. [40]. Copyright 2020 springer.

Method	Extraction phase	Sample phase	Sampling mode
SBSE	Sorbent coated on stir bar	Environment or water sample	Direct
SDME	Single drop	Environment, water, and gas sample	Direct or headspace
DLLME	Organic solvent	Environment or water sample	Direct
LPME	Liquid phase	Environment or water sample	Direct
SPME	Polymeric extracting phase coated on a fused silica fiber	Environment, water, and gas sample	Direct, headspace, and membrane

Table 1.
Some of miniaturized sample preparation techniques.

as a SPE column due to its special conical shape using various diameters in two ends. Normally, a bigger pipette tip is immersed in a small one to obtain a novel cartridge and used as µSPE [53, 54]. Schematic of PT-µSPE for nalidixic acid and acetamino-phen extraction is depicted in **Figure 8**.

Table 1 shows the comparison of some of the miniaturized sample preparation methods.

12. Automation

The aim of miniaturized methods is a drastic reduction in solvent consumption and samples, based on the green chemistry protocols. However, they sometimes consist of steps such as centrifugation, drawn and drop cycles, and vortexing which are regarded as disadvantages. Hence, even considering all non-automated micromethods benefits, they are still related to multiple steps, increasing the analysis time, complexity, and propensity of analytical errors. So, automated methods are explained basically to be simpler, faster, and further environmentally friendly than traditional and miniaturized methods. For the goal, various strategies for

automation methods have been introduced in the last decades, such as the automation of SPE (online SPE) and with tailoring the microextraction protocols in order toward its automation such as automated SPME, in-tube SPME, automated SBSE, and so on. Fully automated SPME injection systems are commercially available now from different companies. It will be possible theoretically that a technique depending on SPME could be adapted to work by another microextraction technique, for example, by microextraction by packed sorbent (MEPS) once the same adsorbents such as C_{18} or C_8 can be packed inside the MEPS's syringe, which is applied as coated phase on SPME fibers. Hence, after preliminary tests to enough the values of the parameters including extraction cycles and solvent volume, the protocols could be transferred between these two methods and to other sorbent-based techniques as well [55].

13. Conclusion

Evaluating chemical analytes in complex media is a challenging task, which needs highly accurate sample preparation techniques. The development of these methods created miniaturization techniques with features such as providing lower detection limits, wider linear range, and improvement of selectivity and speed. Nevertheless, the intense sample handling remains an important gap that may even impair the performance of the techniques since the equilibrium between analytes can be easily disturbed. In this chapter, we tried to explain some major sample preparation techniques, both exhaustive and non-exhaustive methods. Also, sample collection and pretreatment are discussed as critical steps, which may impair the correct analytes detection despite the sample preparation method applied. Improvement of sample preparation using smaller samples, and the volume of solvent, reduction of analysis time, miniaturization, compatibility to different analytical instruments and automation, is still a major part of research in chemical analysis. Besides automation, the application of "green" solvents such as ionic liquids and deep eutectic solvents likely will find more demands in the extraction. Solventless and flow-through sample preparation methods are also of interest, which is expected to find more importance in the near future. Advances in membrane technology will affect extraction techniques as well. In the next chapters of this book, the reader will find some recent researches currently under investigation to achieve these goals in sample preparation.

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Conflict of interest

The authors declare no conflict of interest.

Author details

Mona Sargazi[1], Sayyed Hossein Hashemi[2] and Massoud Kaykhaii[1*]

1 Faculty of Sciences, Department of Chemistry, University of Sistan and Baluchestan, Zahedan, Iran

2 Faculty of Marine Science, Department of Marine Chemistry, Chabahar Maritime University, Chabahar, Iran

*Address all correspondence to: kaykhaii@gmail.com

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