Focus Review Article

Review of Procedures Involving Separation and Solid Phase Extraction for the Determination of Cadmium Using Spectrometric Techniques

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Abstract:
For the analysis of cadmium, the toxicity of spectroscopic methods is increasing because the measurement of the low level for detection of this element is done in various samples. This review studies the methods of separation and pre-concentration and analyzes spectroscopic methods for detecting cadmium in water samples. Considering the amount of trace cadmium ion in the analysis of aqueous samples, a suitable method should be used. From the past, chemists have been trying to find a solid phase to recover analytes from the water matrix. The experimental method of SPE is a standard method for the analysis of heavy metals such as cadmium ion in aqueous samples. Cadmium is known worldwide as a toxic metal. Therefore, it is often necessary to determine this element in environmental, biological, food and agricultural samples. However, analyses are difficult because the quantities of cadmium samples are relatively small, except for trace amounts. Measurements are made by flame atomic absorption spectrometry and inductively coupled plasma optical emission spectrometry.For this reason, several preconcentration methods for the determination of cadmium ion, including solid phase extraction, coprecipitation and cloud point extraction, has been reviewed.A brief history of using Solid-phase extraction in the analysis of cadmium ion in water samples is presented in this paper.

Graphical Abstract:
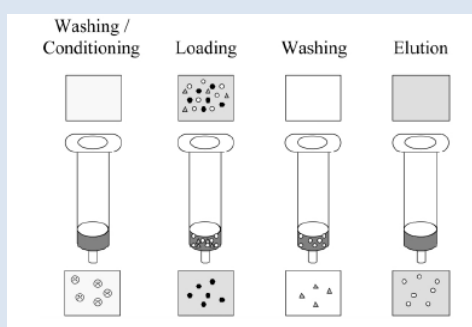
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1. Introduction

Due to the sensitivity and selectivity of techniques such as atomic absorption spectrometers, pre-concentration must be pre-condensed, especially in water samples for cadmium ion, before measurement is trace. In addition, since high-level non-toxic components are usually accompanied by analytes, a purge step is often done. Liquid liquid extraction is a classic method to prevent the removal of metal ions and matrixes. Solid phase extraction (SPE) is another approach that offers a number of important benefits. This reduces the consumption and exposure of solution and also, the cost of disposal and extraction time to prepare the sample. As a result, in recent years, the SPE has been successfully used to isolate and identify sensitive metal ions, mainly in water samples. Following the introduction of the theory of this technique, guidelines are developed Solid-phase extraction-based methods for pre-concentration of small amounts of cadmium ions. Finally, application examples are provided[1-14].The above-mentioned techniques, with FAAS, provide low cost, high-performance, and high-end specimens. The determination of cadmium by an atomic flame spectrometer is free of interference, and this can easily be measured with compressed air-acetylene flame. In the resonance line of 228 nm, the detection limit for cadmium is 0.02 mg L^{-1}.

The analytical line is in the range of 326.1 nm to determine the concentration of Cd higher and the concentration of the characteristic is about 6 mg L^{-1}, so greater than this value should be avoided [15,16]. Cadmium measurement was difficult by ETAAS for a long time, since cadmium is an element that has volatility [17].The SPE technique is similar to the liquid fluid extraction (LLE), which consists of two phases (two incompatible solvents). However, instead of two dispersed liquid phases, as in the LLE, SPE involves partitioning between the fluid (the matrix of the sample) and a solid phase (absorbent). This typical filtration technique provides concentration and enrichment of analytes from the solution by sorption onto a solid sorbent.Accordingly, the liquid sample is transported through a column, a cartridge, a tube, or a absorber disc that absorbs and holds the analytes. After all the sample passes through the sorbent, the stored analytes are used then being recovered upon elution with a suitable solvent. Solid-phase extraction began for the first time fifty years ago [1,2,3]. However, numerous studies have shown that the great potential of this technique can be used for specialized studies. [18,161-177].

1.1. Basic principles

An SPE method is always composed of three to four successive steps, as illustrated in Fig. 1.. First, a solid sorbent should be swirled with a suitable solvent (as a solvent). This step is important because it moisturizes the absorbent and activates the absorbent groups. In addition, the removal of possible impurities that are initially present in the sorbent is eliminated. Also, at this stage, the air contained in the column is removed and the saturated volume of the adsorbent is filled with solvent. Typically, methanol is used to activate the depleting phase (such as octadecyl-bonded silica), followed by water or a water buffer whose pH and ionic strength are similar to the sample. Care should be taken to ensure that no solids are absorbed between the two stages of elution and the passage of the adsorbent sample, otherwise the analytes will not be maintained effectively and poor results will be achieved. If the sorbent is dried for more than a few minutes, it should be re-modified.

The second step is to pass and absorb the sample through a solid absorber. Depending on the system used, the sample size can be from 1 mL to 1 L. The sample may be transmitted by gravity, pumping, vacuum or by an automatic system of adsorbent columns. The flow rate of the sample through the sorbent should be low enough to allow the adsorbent to maintain analytes efficiently. During this step, analyses enriches on the adsorbent. Even if the matrix components are retained by a solid absorber, some of them will pass, so the matrix separation is possible from sample analysis.

The third step (which is optional) may involve solid solvent washing with a suitable solvent having low tensile strength to eliminate the absorbed matrix

components .The absorbent drying step may also be recommended, especially for water matrices, to remove the effects of water absorption from solids. This eliminates the presence of water in the final extract, which in some cases may cause post-condensation concentration in the analysis with difficulty. The final step involves the removal of the desired analyte elements by a suitable solvent and without deleting the matrix components of the preservation. The volume of the solvent must be adjusted to allow quantitative recovery of the analytes by low dilution. Additionally, the stream should be properly optimized to ensure that the analyses are completely out. It is often advisable to divide the volume of the solvent into two parts and remove the analyte from the adsorbent.
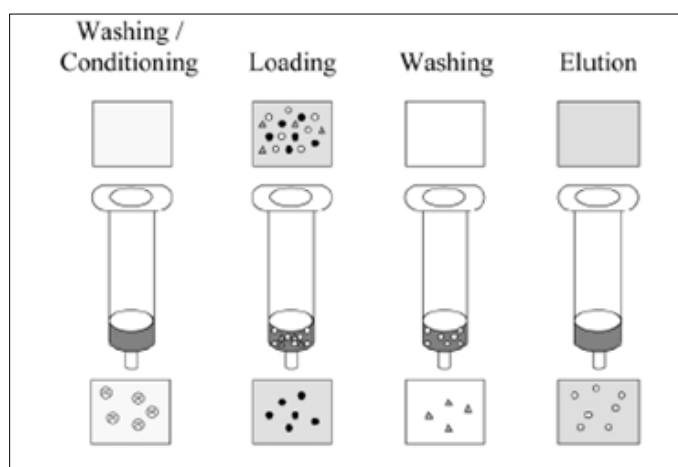

Fig. 1: . Solid-phase extraction operation steps

1.2. Maintenance and Retention of cadmium on adsorbent

Adsorption and absorption of cadmium on solid adsorbent's are necessary for preconcentration (see Fig. 2). The adsorption mechanism depends on the nature of the sorbent, and may include a simple adsorbent, chelation, or an ion exchange. Also, for the trace cadmium inhibition, ion- pair solid phase extraction can be used.

1.2.1. Adsorption.

Trace Cadmium inhibition is usually absorbed in solid phases, through the forces of water retention or hydraulic interaction. Hydrophobic interaction occurs when the solid absorbent is very non-polar (reversed phase). The most commonly used absorbent of this type is octadecyl-bonded silica (C_{18}-silica). Mostly it is activated with water-soluble oxygen, such as methanol or acetonitrile. Such interactions are usually preferred to online systems because they are not too strong .

1.2.2. Chelation

Several atoms of the functional group are capable of chelating with cadmium ion in water. Atoms are often used in nitrogen (e.g. N in amines, azo groups, amides, nitriles) and sulfur (eg S in thiols, Tiocarbamate, teeth). The nature of the functional group shows the selective ligand idea of the selectivity of cadmium ion . In practice, mineral cations may be divided into 3 groups:

a) *hard ,group cations*: It reacts through electrostatic interactions (due to increase in

The entropy is due to changes in the orientation of water hydration molecules); this group consists of alkaline and alkaline- earth metals (Ca^{2+}, Mg^{2+},K^+, Na^+) that comprise the weakly outer crystalline complexes by only hard oxygen ligands.

b) *Boundarine, Cations:* These cations have an intermediate behavior; these groups of cations include Fe , Co^{2+} Ni^{2+} Cu^{2+} Zn^{2+} Pb^{2+} Mn^{2+} . They have a complex for both hard and soft ligands.

c) Soft, cations: These cations tend to produce a medium-magnesium (N) and soft (S) ligand. Therefore, Cd^{2+} and Hg^{2+} have a strong coordinate bond with medium (N) and soft ligands (S)

For soft metals, the order of the donor atom dependence has been observed: 0-N-S. A reversed covalent bond has been observed for hard cations. For a bidentate ligand, the dependence on a soft metal increases with the softness of the donor atom: (0. 0) - (0, N) - (N, N) - (N, S). This order is reversed for hard metals. In general, the competition for a one-way covalence bond of a given ligand consists essentially of the first and second group metals for sites O and metals in group two and the third group for sites N and S. The competition between the metals in group I and the third group is very weak.

Chelating chemical agents that are added directly to the sample to chelate trace cadmium loaded onto a suitable absorbent. One method is to load the chelating group into the sorbent. finally, three different methods are available: (1) the synthesis of new sorbents containing such suitable functional groups; (2) the chemical bond with suitable functional groups on the adsorbent; (3) the physical absorption of the groups in the adsorbent by loading the solid matrix with solution containing a chemical ligand (impregnated, coated or loaded absorbers). The latter is the easiest to use in practice. The main drawback is that there is a probability that the calcite discharges from solid solvent.During the elution, it reduces the lifetime of the saturated adsorbent. Different ligands have been used on various types of solid matrices for condensation, separation and determination of successful inhibition metal ions.

Chemical groups with a hydrophobic group are stored on hydrophobic acids (such as C_{18}-silica). Also, ionic exchange resins with chemicals containing an ionexchange group, such as a sulfonic acid ditizone derivative (i.e., diphenyl tiocarbazone) (DzS), 5-sulfo-8-quinolinol, 5-sulfosalicylic acid, and tistylecyclic acid.

The metal ion cations depend on several factors for the performance of the chelate: (1) the hardness and softness, charge, and size of the metal ion; (2) the nature of the atoms of the donors in the ligand; (3) the buffer conditions that favor the metal cation extraction and bonding with the group Active chelate; (4) the main nature of the adsorbent (e.g., the degree of cross-linking for a copolymer). However, the presence of a solid sorbent may also effect and result in the formation of a complex with a different stoichiometry than that observed in Homogeneous reaction [10,11] In fact, several properties of the adsorbent should be taken into account, namely the number of active groups present in the resin phase [7,10], the resin and the ligand connected [12] Resin hole dimensions [13].
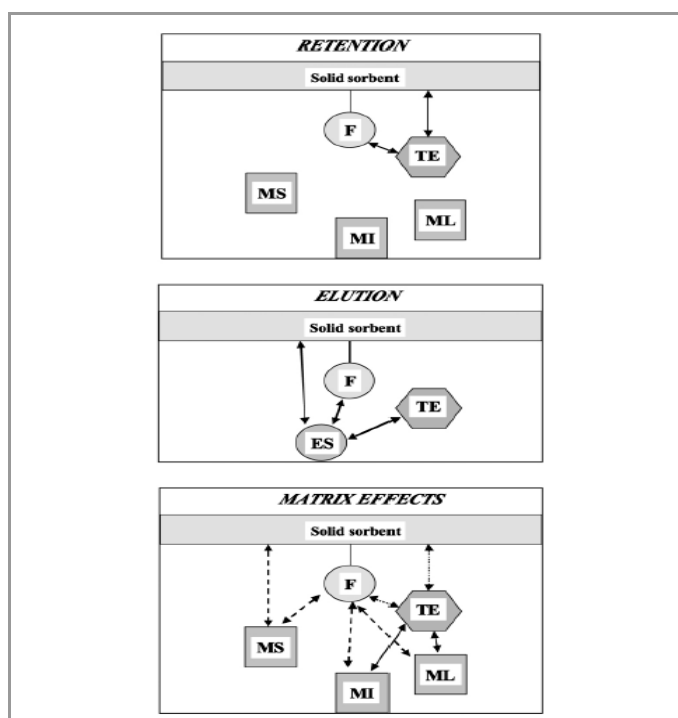
Figure 2. Interactions occurring at the surface of the solid sorbent. F, functional group; TE, trace element; MS, matrix solvent; MI, matrix ions; ES, elution solvent.

2. Measuring cadmium

2.1. Atomic Absorption Spectroscopy (AAS)

The determination of cadmium by the Flame Atomic Absorption Spectrometer (FAAS) is virtually intact, requiring air flames and acetylene [13]. Interference from aluminum and iron can be avoided by adding protective agents such as ascorbic acid, citric acid and EDTA. The technique is very low (LOD 0.02 mg L^{-1}) and is often unsuitable for low-level analysis [13]. In this sense, to determine the amount of cadmium measurement, as shown in the tables in the table below, many preconcentration and preparation methods should be performed [13].

Graphite furnace atomic absorption spectroscopy (GF-AAS) is a good alternative to determining the small amount of cadmium in several samples for sensitivity [13]. However, in some cases, the steps before and after the isolation are performed before the GF-AAS analysis measurements. Using a modifier, fixes cadmium, and allows measurement without effect Matrix and interference species. The Pd-Mg modifier is one of the most commonly used ones, since it produces the best results. This modifier allows for the use of temperatures in the range of 1200 ° C to 1400 ° C, which can further distribute the disturbing elements [13-17]. The stabilizer effect of this modifier also improves its atomic temperature to 2000 ∘C [13]. Ammonium phosphate is another modifier that is often used to determine cadmium by the GF-AAS, which allows its atomic temperature to be reduced to 1600 °C and reaches a detection limit of 15 pg[13,18].

2.2. Inductively coupled plasma optical emission spectrometry (ICP OES)

An induced optical-optical optical spectrometry is an appropriate analytical method that is often used to determine most heavy metals such as cadmium in different types of specimens [19]. However, the small amounts of cadmium in many samples are below the detection limit of this technique. Almost all photomultiplier-based ICP spectrometers use the analytical line Cd 220.353 nm, despite the high background interference and interference between the elements of 220.4 nm alpha and the background change due to iron (Hg). The direct interference of the overlap due to iron in the analytical lines was found to be 226.0 and 284.8 nm[20.21]. Therefore, preconcentration and separation methods are designed to measure the cadmium content in complex matrices using ICP OES. Several tables shown in this paper summarize the use of separation techniques such as liquid liquid extraction, solid phase extraction, cloud extraction, as a preparation for cadmium determination using ICP OES.

3. Separation and pre-condensation of cadmium

Separation techniques [23,50], liquid liquid extraction [57-60], solid phase extraction [69-134], and cloud extraction [139-146,150-160] have been successfully

used. Each technique has advantages and disadvantages and should be selected according to the analytical problem.

3.1. Coprecipitation

One of the most efficient separation and enrichment methods for heavy metal ions is also coprecipitation. In this technique, the collector should be easily separated from the matrix solution. This can be done by filtering, centrifuging and depositing. The advantages of this technique is its simplicity. Inorganic or organic collector used as efficient collectors of fine elements. However, this process is slow [22]. This technique is used to determine the cadmium samples in water. For cations such as aluminum, gallium, cerium (IV), erbium, iron (III), magnesium, samarium and zirconium hydroxide, they have been widely used and successfully applied to trace amounts of cadmium ions used [23.50].In Table 1, several methods for determining cadmium in many samples are described using coprecipitation as a separation and preconcentration method.

3.2. Methods by Liquid–liquid extraction

Solvent extraction is one of the most extensive methods of preparation and separation to determine the small amounts of heavy metals. Its feature is simplicity, convenience, wide scope and, etc.. In this method, the metal is between two non-intermixing liquid phases (usually the water and organic phase). After a complex reaction, the metal ion is extracted from the water solution to the organic phase. To measure, the extracted metallic cation can be measured directly in the organic phase and usually acid is performed [51-53]. Separation and preconcentration methods using solvent extraction generally result in high concentration because of the difference in the volume of water and organic phases. This method is time consuming and retains a large amount of potentially toxic organic solvents as waste. This single operation can be done with a flow injection system (FI) and / or a sequential injection (SI), which, in addition to reducing sample consumption and solvent consumption, automatically manipulates the enclosed[54].

Methods in flow injection systems for separation and pre-concentration using solvent extraction to determine metals such as cadmium and lead are widely discussed in literature [55, 56]. Table 2 shows several analytical systems for separating cadmium and pre-condensation using solvent extraction and determining cadmium by flame atomic spectrometry techniques.

3.3. Methods by Solid phase extraction

The solid phase extraction method is based on the partition between a liquid containing a sample matrix and a suitable solid phase (sorbent). The method is based on the contact of a homogeneous liquid sample through a column, a flask, a cartridge, a tube, or a disc containing a selective absorber holds cadmium ions. After this step, recovered cadmium is eluted by a proper solution with a suitable solvent [68].Sorbents used for pre-concentrate and determining cadmium can be loaded with complex reactions by suitable reagents. Reagents suitable for loading these sorts adsorbents include: activated carbon, natural adsorbents, Amberlite XAD resins [71-75],

polyethylene [76] and others [77]. Many reactants have been used to store cadmium ions, which include: 2-(2-thiazolylazo)-*p*cresol (TAC) [85], 2-propylpiperidine-1-carbohydrate [86], 2- (2 Benzotriazole-zo) -2-*p*-cresol (BTAC) [80,87], red periglolol [81], 1- (2-pyridylazo) -2-naphthol (PAN), [88], dithizone [89,90], and 2- (5-Bromo-2-pyridylazo) -5-diethylaminophenol (5-Br-PADAP) [91]. Reagents can also be used with chemical reactions, which are potent inhibitors for the pre-concentration of cadmium.

Supports includes the Amberlite XAD Series [92,93], Silica Gel [94-96] and Cellulose [97,84]. Several methods for the separation and pre-concentration of cadmium have been proposed using the solid phase extraction method shown in Table 3.

3.4. Automation and on-line analysis

The solid phase extraction isolation technique can be easily automated [123-124]. Also, a larger sample size can be analyzed. In addition, a smaller sample size can also be used. However, in the case of complex specimens, off-line SPE should be used because of its greater flexibility, as well as the possibility of analyzing the same extraction using various techniques to apply.

3.4.1. On-line coupling to liquid chromatography.

On-line systems mainly use a micro-column. On-line systems have been reported with several detectors, such as ultraviolet detectors or plasma mass spectrometers (ICP-MS), which have been inductively coupled, with detection limits in the range of 0.05-50 ppm. Using a photodiode fluorescent detector, detection with a maximum absorption wavelength can reduce the detection limit to 0.50 ppb [125].

3.4.2. Determinates of cadmium with Online coupling to Atomic Absorption

Online spectroscopy in atomic absorption for heavy elements [126] Olsen et al and Fang et al [127,128] were presented for the first time. Then, an absorption extraction system, which was coupled with the GF-

Table 1: Preconcentration procedures using coprecipitation for the determination of cadmium

Sample	Collector	Technique	LOD(μgL^{-1})	R.S.D. (%)	Reference
Ground water	MnO_2	FAAS		3.3-8.3	[23]
Natural water	MnO_2	FAAS			[24]
Rain water	MnO_2	FAAS			[25]
Sea water	MnO_2	FAAS			[26]
Zinc and zinc ~aluminum	MnO_2	ICPOES			[27]
River waters	MnO_2	ICPOES	3.2	5.0	[28]
Sea waters and mineral	Aluminum hydroxide	FAAS	16	2.0-3.0	[29]
Sea waters	Cerium(IV) hydroxide	FAAS	7	8	[30]
Tap water	Erbium hydroxide	FAAS	O.Z4	1-9	[31]
Sea water	Gallium hydroxide	ICPOES	O.IS		[32]
Sea water	Gallium hydroxide	ICPOES	O.IS		[33]
Sea water	Iron hydroxide	ETAAS			[34]
Sodium tungstate	Lanthanum hydroxide	ICPOES	I.JI	3.1-5.5	[35]
Dialysis concentrate	Magnesium hydroxide	ETAAS			[36]
Sea water	Magnesium hydroxide	ICP-MS	$2.7.10^{-4}$		[37]
Urine, sediment	Copper	EAAS	24.0	5.0	[38]
Natural water	Zirconium hydroxide	E,AAS	$4.2.10^{-4}$	<10	[39]
Infant formulas and milk	Ammonium Pyrrolidine	ETAAS	0.04		[40]
Cupric sulfate	Ammonium Iron sulfate	ICPOES		4.4-5.8	[41]
Natural water	Bismuth ditehyldithiocarbamate	ETAAS			[42]
Natural water	Copper ditehyldithiocarbamate	FAAS	1.5	4.4	[43]
Natural water	Copper ditehyldithiocarbamate	FAAS	3.2	2.0	[44]
Cobalt sulfate	Cerium phosphate	FAAS	55.9		[45]
Water	Lanthanum phosphate	ICPOES		1.6	[46]
Sea water	Palladium	ETAAS		3.8	[47]
Natural water	Sodium ditehyldithiocarbamate	ICPOES			[48]
River water	Sodium ditehyldithiocarbamate	ICPOES	10.0		[49]
Sea water	Sodium sulphide	ICPOES		1.9	[50]

**Pg/mL   [a] ng/g

AAS coupling, was proposed for small amounts of cadmium [129]. Since then, numerous articles have been reported by FI. The selected programs are shown in Table 4. This sorbent should be used for rapid analysis of antibiotics in FI systems [130]. In practice, the C_{18} -silica adsorbent is widely used. Selection of the appropriate reactant based on their rapid reaction with metals, such as diethyldithiocarbamate (DDTC) and Ammonium pyrrolidine dithiocarbamate (APDC) [131,132]. Also, both reactants are soluble in water and not absorbed in C_{18}- silica so that they are not loaded with their reactants. However, these reagents are public and non-selective. Although the C_{18}-silica is often used sorbent for preconcentration of flow injection analyses, other sorbents are used for some applications as reported in Table 4, such as reactive activated carbon [134], polyurethane foam PUF) [134] or PTFE rotation [133]. A small reactor (KR) has recently been found which includes a long spiral tube, usually made of PTFE.

3.4.3. Cadmium ion determinates in coupling with ICP-AES or ICP-MS.

The first preconcentration report of FI in line with the ICP-atomic emission spectrometry (AES) appeared about 25 years ago [130]. Since then, numerous studies have been carried out to measure heavy metals, including cadmium, using various adsorbents such as modified ZrO_2 or modified silica gel [136].

3.4.4. On-line coupling of cadmium by spectrophotometry

The benefits of spectrophotometry are cheap and very common tools. In addition, by choosing a redundant reaction, it is possible to determine the number of metal cations [123].

Its coupling with FI analysis is well suited for regulatory purposes, and examples are shown in Table 4 [123]. Solid phase spectrophotometer (SPS) is also provided with FI systems due to its simplicity and low detection limits. Solid sorbents are commercially

available or customizable. FI extraction methods have several advantages: an increase in sample size (with an increase of 1 to 2 times), the consumption of the prototype and the indicator is reduced two to three times, the relative standard deviation of the standard decreases by about 1-2%, low pollution And the method will be automated quickly and easily.

3.5. Cloud Point Extraction (CPE)

The cloud point phenomenon occurs when a non-ionic or amphoteric surfactant react above the critical concentration of micelle (CMC) causes the metal cation or the main solution to be analyzed in two steps, when the temperature specified in the thermometer is called the super-spot cloud Gets At the top of the cloud point, the micelles form the surfactant molecules that act as an organic solvent in the extraction of the liquid liquid, and the analytes are divided between the micelles and the water phase [135-137]. Therefore,

metal cation can be trapped and dispersed into a rich phosphorus phase, which is hydrophobic.The nucleus of the micelle is formed in the form of an accumulated hydrophobic, which is formed between the metal ion and a proper chalky agent in the proper conditions.

Partition evaluate, So the coefficients of the ligands and surrounding complexes create a peripheral Surfactant that changes the ratio of the reaction, the position of the equilibrium, and the parameters of the analysis [140], for example, the cadmium determined prior to centrifugation in a micellar phase of Triton X-114 phase And is determined by GF-AAS using appropriate modifiers. Therefore, at a higher pyrolysis temperature, the removal of the surfactant matrix is achieved prior to the cadmium atomization step without risking the loss of the analite and preventing the absorption of the background. Table 5 shows some of the new CPE methods for determining cadmium and heavy metals.

Table 2 : Preconcentration methods by solvent extraction for determination of cadmium

Sample	Technique	Complication agents	Solvent	Enrichment factor	Reference
Table salt	FAAS	Dithizone	MIBK[a]	99	[57]
Waste Water	FAAS	HBDAP[b]	HNO₃/HCl		[58]
Estuarine water	GFAAS	APDC[c] and DDC[d]			[59]
Urine and CRF	ICP-MS	APDC	MIBK/HNO₃	23.3	[60]
High Purity aluminum salts	ICPOES	APDC	HNO₃/H₂O₂		[61]
Natural water	FAAS	Dithizone	Xylene		[62]
Natural water	FAAS	Dithizone	HNO₃	543	[63]
Aragonite	ET AAS	NaDDC	MIBK		[64]
water	FAAS	APDC	MIBK		[65]
Seawater	ICP-MS	DOC			[66]
Drinking water	FAAS	CMPQ[e]			[67]

[a] Methylisobutyl ketone
[b] NN-bis(2-hydroxy-5-bromo-benzyl)-1-
[e] Ammonium Pyrrolidinedithiocarbamate
[d] Ditehyldithiocarbamate
[e] 5-(2-Cabomethoxyphenyl)azo-8quinolinol

Table 3: Off-line procedures for Cadmium preconcentration using solid phase extraction

Sample	Enrichment factor	Technique	LOD(μgL^{-1})	R.S.D. (%)	Reference
Sea water	-	FAAS	-	3.3	[71]
Enviromental sample	-	FAAS	-	-	[72]
Sea water	150	FAAS	-	-	[73]
Waste water	100	FAAS	0.001	-	[81]
Tap water	-	FAAS	2.00	2.2	[82]
River waters	-	FAAS	5.0	5.1	[83]
Sea waters	12000	FAAS	0.005	2.1-3.2	[88]
Tap water	200	FAAS	-	1.9	[90]
River waters	-	FAAS	4.06	2.9	[92]
River waters	-	FAAS	-	5.0	[93]
Sea water	-	GF-AAS	4.0	8.0	[95]
Tap water	-	FAAS	3.3	3.9	[98]
Sea water	40	ICPOES	53.0	4.2	[99]
Sea water	100	GF-AAS	0.20	5.0	[100]
Natural water	500	ICPOES	0.15	<10	[101]
soil	200	FAAS	2.50	2.4-3.2	[103]
River waters	-	FAAS	-	2.9	[104]
Natural water	250	FAAS	4.00	4.4	[105]
Natural water	375	FAAS	0.25	2.5	[106]
Water	129	FAAS	0.20	-	[107]
Waste water	130	FAAS	6.10	1.6	[108]
Waste water	-	FAAS	15.0	2.8	[109]
Natural water	-	FAAS	-	3.0	[110]
River water	100	GF-AAS	0.04	4.9	[111]
Water sample	-	FAAS	0.70	1.9	[112]
Sea water	50	FAAS	0.10	-	[113]
Sea water	-	FAAS	0.03	2.8	[115]
Sea water	-	FAAS	-	2.0	[116]
Water sample	294	FAAS	3.0	2.78	[117]
Water sample	-	FAAS	0.017	-	[118]
Tap water	115	FAAS	1.0	2.2	[120]
Sea water	-	FAAS	-	1.9	[121]

Table 4: Applications of SPE to FI on-line preconcentration systems

Matrix	Sorbent	Eluent	Analysis method	Recovery%	Preconcentration	Matrix	Sorbent
Certified	C18-silica	IBMK	F-AAS	99.2–101%	60–189	3000	[132]
biological,	C18-silica	EtOH	F-AAS	--	4–1000	300–3000	[134]
vegetable	C18-silica	MeOH	F-AAS	--	14–60	4000-10000	[130]
samples	PTFE turnings	IBMK	F-AAS	95–102	330	800	[133]
Standard	PUF	EtOH	F-AAS	--	4–1000	300–3000	[134]
solutions	Lewatit TP807'84 PAPhA	HCl	Spectrophotometry	80–120	50	2000-5500	[123]

Table 5 : CPE applications for cadmium preconcentration and determination

Sample	Analysis method	LOD(μg.mL^{-1})	RSD(%)	Reference
vegetable	F-AAS	0. 3		[139]
blood	GF- AAS	0.08		[140]
River waters	FAAS	1.10	3.5	[141]
Human hairs	F-AAS	2.86	1.39	[142]
Tap water	ICP-OES	0.077	4.2	[143]
Waters	ICP-MS	0.004		
Waste waters	GF- AAS	0.08	4.8	[144]
			2.8	[145]
Biological sample	GF- AAS	0.040		[146]

Table 6 : preconcentration of cadmium ions using knotted reactors

Sample	Analysis method	Enrich factor	LOD(μg.mL^{-1})	RSD(%)	Reference
Tap water	FAAS	37	7.5	2.9	[150]
Water,tea	FAAS	57	8.0	1.30	[151]
Water and Bioligical sample	FAAS	58	0.2	3.30	[152]
Blood and liver	F-AAS	20	2.0	2.60	[153]
Water samples and soil	GF- AAS	99	1.6	2.70	[154]
Bioligical s and enviromental samoples	GF- AAS	125	4.8	2.0	[155]
Water sample	GF- AAS	142	5.0	4.8	[156]
Blood	GF- AAS	99	1.60	2.8	[157]
Bioligical samople, Urine	ICP-OES	140	0.2	2.70	[158]
Urine	ICP-MS	34	4.7	2.65	[159]
Seawater	ICP-MS	28	0.028	-	[160]

4. Conclusions

The trace of cadmium ions is toxic and carcinogenic. Trace of cadmium ions in various samples pre-concentrated methods are used by separation techniques such as liquid liquid extraction, solid phase extraction, deposition, and cloud extraction. However, each method has its own advantages and disadvantages and should therefore be selected according to the type of sample. Most proposed methods are performed using solid phase extraction. In recent years, online systems have become more important.

5. Acknowledgment

References

[1] Liška, I. (2000). Fifty years of solid-phase extraction in water analysis–historical development and overview. *Journal of Chromatography A*, *885*(1-2), 3-16.

[2] Poole, C. F. (2000). Solid-phase extraction with discs. *Encyclopedia of Separation Science, Academic Press, Oxford*, 4141-4148.

[3] Hennion, M. C. (1991). Sample handling strategies for the analysis of non-volatile organic compounds from environmental water samples. *TrAC Trends in Analytical Chemistry*, *10*(10), 317-323.

[4] Lundgren, J. L., & Schilt, A. A. (1977). Analytical studies and applications of ferroin type

chromogens immobilized by adsorption on a styrene-divinylbenzene copolymer. *Analytical Chemistry*, *49*(7), 974-980.

[5]　Chikuma, M., Nakayama, M., Itoh, T., Tanaka, H., & Itoh, K. (1980). Chelate-forming resins prepared by modification of anion-exchange resins. *Talanta*, *27*(10), 807-810.

[6]　Akaiwa, H., Kawamoto, H., & Ogura, K. (1981). Kinetic studies of ion-exchange of cobalt (II) and nickel (II) on a resin loaded with 5-sulpho-8-quinolinol. *Talanta*, *28*(5), 337-339.

[7]　Lee, K. S., Lee, W., & Lee, D. W. (1978). Selective separation of metal ions by a chelating agent-loaded anion exchanger. *Analytical Chemistry*, *50*(2), 255-258.

[8]　Kilian, K., & Pyrzyñska, K. (2001). Preconcentration of metal ions on porphyrin-modified sorbents as pretreatment step in AAS determination. *Fresenius' journal of analytical chemistry*, *371*(8), 1076-1078.

[9]　Mahmoud, M. E. (1997). Silica gel-immobilized Eriochrome black-T as a potential solid phase extractor for zinc (II) and magnesium (II) from calcium (II). *Talanta*, *45*(2), 309-315.

[10]　Pesavento, M., Biesuz, R., Gallorini, M., & Profumo, A. (1993). Sorption mechanism of trace amounts of divalent metal ions on a chelating resin containing iminodiacetate groups. *Analytical Chemistry*, *65*(18), 2522-2527.

[11]　Pesavento, M., Biesuz, R., & Cortina, J. L. (1994). Sorption of metal ions on a weak acid cation-exchange resin containing carboxylic groups. *Analytica chimica acta*, *298*(2), 225-232.

[12]　Kumagai, H., Inoue, Y., Yokoyama, T., Suzuki, T. M., & Suzuki, T. (1998). Chromatographic selectivity of rare earth elements on iminodiacetate-type chelating resins having spacer arms of different lengths: importance of steric flexibility of functional group in a polymer chelating resin. *Analytical chemistry*, *70*(19), 4070-4073.

[13]　Seneviratne, J., & Cox, J. A. (2000). Sol-gel materials for the solid phase extraction of metals from aqueous solution. *Talanta*, *52*(5), 801-806.

[14]　Greenwood, N. N., & Earnshaw, A. (2012). *Chemistry of the Elements*. Elsevier.

[15]　15. B.Welz, M. Sperling, *Atomic Absorption Spectrometry*, third ed.,Wiley-VCH, Weinheim, New York, 1999.

[16]　Garrido, M. L., Munoz-Olivas, R., & Cámara, C. (1998). Interference removal for cadmium determination in waste water and sewage sludge by flow injection cold vapour generation atomic absorption spectrometry. *Journal of Analytical Atomic Spectrometry*, *13*(10), 1145-1149.

[17]　Butcher, D. J. (2006). Advances in electrothermal atomization atomic absorption spectrometry: Instrumentation, methods, and applications. *Applied Spectroscopy Reviews*, *41*(1), 15-34.

[18]　Zhou, L. Z., Zhou, F. Q., Huang, R. H., Liu, Z. H., & Jiang, F. M. (2008). Study on adsorption performance of trace Hg on an organic–inorganic mesoporous material. *Chin J Anal Lab*, *27*(9), 33-36.

[19]　Golightly, M. B., Golightly, D. W., & Fasser, V. A. (1992). *Inductively coupled plasmas in analytical atomic spectrometry*. Wiley-VCH.

[20]　Korn, M. D. G. A., Jaeger, H. V., Ferreira, A. C., & Spinola Costa, A. C. (2000). Line selection and determination of trace amounts of elements in high-purity iron by inductively coupled plasma atomic emission spectrometry. *Spectroscopy Letters*, *33*(2), 127-145.

[21]　Boevski, I., Daskalova, N., & Havezov, I. (2000). Determination of barium, chromium, cadmium, manganese, lead and zinc in atmospheric particulate matter by inductively coupled plasma atomic emission spectrometry (ICP-AES). *Spectrochimica Acta Part B: Atomic Spectroscopy*, *55*(11), 1643-1657.

[22]　Mizuike, A. (1983). *Enrichment techniques for inorganic trace analysis*. Springer-verlag.

[23]　Umashankar, V., Radhamani, R., Ramadoss, K., & Murty, D. S. R. (2002). Simultaneous separation and preconcentration of trace elements in water samples by coprecipitation on manganese dioxide using D-glucose as reductant for $KMnO_4$. *Talanta*, *57*(6), 1029-1038.

[24]　Matthews, K. M. (1983). Lead Extraction from Natural Waters—A Simple and Rapid Technique. *Analytical letters*, *16*(8), 633-642.

[25]　Peck, G. A., & Smith, J. D. (2000). Determination of 210Po and 210Pb in rainwater using measurement of 210Po and 210Bi. *Analytica chimica acta*, *422*(1), 113-120.

[26]　Towler, P. H., Smith, J. D., & Dixon, D. R. (1996). Magnetic recovery of radium, lead and polonium from seawater samples after preconcentration on a magnetic adsorbent of manganese dioxide coated magnetite. *Analytica chimica acta*, *328*(1), 53-59.

[27]　Yoshikawa, H., YOSHIDA, M., & HARA, I. (1991). En Japonais. *Sangyo Igaku*, *33*(6), 519-526.

[28]　Bispo, M. S., da Boa Morte, E. S., Korn, M. D. G. A., Teixeira, L. S. G., Korn, M., & Costa, A. C. S. (2005). Determination of Pb in river water samples by inductively coupled plasma optical emission spectrometry after ultrasound-assisted co-precipitation with manganese

dioxide. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *60*(5), 653-658.

[29]   Doner, G., & Ege, A. (2005). Determination of copper, cadmium and lead in seawater and mineral water by flame atomic absorption spectrometry after coprecipitation with aluminum hydroxide. *Analytica Chimica Acta*, *547*(1), 14-17.

[30]   Divrikli, Ü., & Elçi, L. (2002). Determination of some trace metals in water and sediment samples by flame atomic absorption spectrometry after coprecipitation with cerium (IV) hydroxide. *Analytica Chimica Acta*, *452*(2), 231-235.

[31]   Soylak, M., Saracoglu, S., Divrikli, U., & Elci, L. (2005). Coprecipitation of heavy metals with erbium hydroxide for their flame atomic absorption spectrometric determinations in environmental samples. *Talanta*, *66*(5), 1098-1102.

[32]   Akagi, T., Fuwa, K., & Haraguchi, H. (1985). Simultaneous multi-element determination of trace metals in sea water by inductively-coupled plasma atomic emission spectrometry after coprecipitation with gallium. *Analytica Chimica Acta*, *177*, 139-151.

[33]   Akagi, T., & Haraguchi, H. (1990). Simultaneous multielement determination of trace metals using 10 mL of seawater by inductively coupled plasma atomic emission spectrometry with gallium coprecipitation and microsampling technique. *Analytical Chemistry*, *62*(1), 81-85.

[34]   Weisel, C. P., Duce, R. A., & Fasching, J. L. (1984). Determination of aluminum, lead, and vanadium in North Atlantic seawater after coprecipitation with ferric hydroxide. *Analytical Chemistry*, *56*(6), 1050-1052.

[35]   Ma, X. G., Kuang, T. C., & Liu, Q. J. (2004). Simultaneous determination of some trace metal impurities in high-purity sodium tungstate using coprecipitation and inductively coupled plasma atomic emission spectrometry. *Rare Metals*, *23*(3), 193-196.

[36]   Elçi, L., & Saraçoğlu, S. (1998). Applying magnesium hydroxide coprecipitation method for trace analysis to dialysis concentrate. *Talanta*, *46*(6), 1305-1310.

[37]   Wu, J., & Boyle, E. A. (1997). Low blank preconcentration technique for the determination of lead, copper, and cadmium in small-volume seawater samples by isotope dilution ICPMS. *Analytical Chemistry*, *69*(13), 2464-2470.

[38]   Saracoglu, S., Soylak, M., & Elci, L. (2003). Separation/preconcentration of trace heavy metals in urine, sediment and dialysis concentrates by coprecipitation with samarium hydroxide for atomic absorption spectrometry. *Talanta*, *59*(2), 287-293.

[39]   Nakamura, T., Oka, H., Ishii, M., & Sato, J. (1994). Direct atomization atomic absorption spectrometric determination of Be, Cr, Fe, Co, Ni, Cu, Cd, and Pb in water with zirconium hydroxide coprecipitation. *Analyst*, *119*(6), 1397-1401.

[40]   Dabeka, R. W. (1989). Graphite-furnace atomic absorption spectrometric determination of lead, cadmium, cobalt and nickel in infant formulas and evaporated milks after nitricperchloric acid digestion and coprecipitation with ammonium pyrrolidine dithiocarbamate. *Science of The Total Environment*, *89*(3), 271-277.

[41]   BANSOD, P., & Rathod, D. (2018). Polyacronitrile Ultra Filtration Membranes Used for Separation of Glycerol from Transesterification Process of Biodiesel production. *Asian Journal of Nanosciences and Materials*, *1*, 157-165.

[42]   Sato, H., & Ueda, J. (2001). Coprecipitation of trace metal ions in water with bismuth (III) diethyldithiocarbamate for an electrothermal atomic absorption spectrometric determination. *Analytical sciences*, *17*(3), 461-463.

[43]   Burba, P., & Willmer, P. G. (1987). Multielement-preconcentration for atomic spectroscopy by sorption of dithiocarbamate-metal complexes (eg, HMDC) on cellulose collectorsMultielement-Voranreicherung für die Atomspektroskopie durch Sorption von Dithiocarbamat-Metallkomplexen an Cellulose-Kollektoren. *Fresenius' Zeitschrift für analytische Chemie*, *329*(5), 539-545.

[44]   Chen, H., Jin, J., & Wang, Y. (1997). Flow injection on-line coprecipitation-preconcentration system using copper (II) diethyldithiocarbamate as carrier for flame atomic absorption spectrometric determination of cadmium, lead and nickel in environmental samples. *Analytica Chimica Acta*, *353*(2-3), 181-188.

[45]   Moghimi, A ,Yousefi Siahkalrodi S. (2018). Extraction and Determination of Pb (II) by Organic Functionalisation of Graphenes Adsorbed on Surfactant Coated C18 in Environmental Sample Journal of Chemical Health Risks 3 (3).Kagaya, S., Saiki, M., Malek, Z., Araki, Y., & Hasegawa, K. (2001). Coprecipitation with lanthanum phosphate as a technique for separation and preconcentration of iron (III) and lead. *Fresenius' journal of analytical chemistry*, *371*(3), 391-393.

[46]   Zhuang, Z., Yang, C., Wang, X., Yang, P., & Huang, B. (1996). Preconcentration of trace elements from natural water with palladium precipitation. *Fresenius' journal of analytical chemistry*, *355*(3-4), 277-280.

[47]   Hopkins, D. M. (1991). An analytical method for hydrogeochemical surveys: inductively

coupled plasma-atomic emission spectrometry after using enrichment coprecipitation with cobalt and ammonium pyrrolidine dithiocarbamate. *Journal of Geochemical Exploration*, *41*(3), 349-361.

[48]   Atanassova, D., Stefanova, V., & Russeva, E. (1998). Co-precipitative pre-concentration with sodium diethyldithiocarbamate and ICP-AES determination of Se, Cu, Pb, Zn, Fe, Co, Ni, Mn, Cr and Cd in water. *Talanta*, *47*(5), 1237-1243.

[49]   Burridge, J. C., & Hewitt, I. J. (1985). Coprecipitation of microgram amounts of lead and tin with aluminium, using 8-hydroxyquinoline, tannic acid and either thionalide or sodium sulphide. *Analyst*, *110*(7), 795-800.

[50]   Morrison, G. H., & Freiser, H. (1957). Solvent extraction in analytical chemistry.

[51]   Karger, B. L., Snyder, L. R., & Horvath, C. (1973). Introduction to separation science.

[52]   Jabbari, H. (2018). Production of methyl ester biofuel from sunflower oil via transesterification reaction. *Asian Journal of Nanosciences and Materials*, *1*, 52-55.

[53]   Townshend, A. (1980). MS Cresser, Solvent extraction in flame spectroscopic analysis: Butterworths, London, 1978, ix+ 200 pp., price£ 15.00.

[54]   Fang, Z. (1993). *Flow injection separation and preconcentration*. VCH.

[55]   Amorim, F. A., & Ferreira, S. L. (2005). Determination of cadmium and lead in table salt by sequential multi-element flame atomic absorption spectrometry. *Talanta*, *65*(4), 960-964.

[56]   Bader, N. (2018). Stir bar sorptive extraction as a sample preparation technique for chromatographic analysis: An overview. *Asian Journal of Nanosciences and Materials*, *1*, 54-60.

[57]   Alkan, M., & Kara, D. (2004). Preconcentration of Heavy Metal Ions from Wastewater by Solvent Extraction Using N, N′-bis (2- Hydroxy- 5- bromo- benzyl)- 1, 2 diaminopropane Prior to Their Determination by Flame Atomic Absorption Spectrometry. *Instrumentation Science & Technology*, *32*(3), 291-301.

[58]   Ndung'u, K., Franks, R. P., Bruland, K. W., & Flegal, A. R. (2003). Organic complexation and total dissolved trace metal analysis in estuarine waters: comparison of solvent-extraction graphite furnace atomic absorption spectrometric and chelating resin flow injection inductively coupled plasma-mass spectrometric analysis. *Analytica Chimica Acta*, *481*(1), 127-138.

[59]   Wang, J., & Hansen, E. H. (2002). FI/SI on-line solvent extraction/back extraction preconcentration coupled to direct injection nebulization inductively coupled plasma mass spectrometry for determination of copper and lead. *Journal of Analytical Atomic Spectrometry*, *17*(10), 1284-1289.

[60]   Kokšal, J., Synek, V., & Janoš, P. (2002). Extraction-spectrometric determination of lead in high-purity aluminium salts. *Talanta*, *58*(2), 325-330.

[61]   Carasek, E., Tonjes, J. W., & Scharf, M. (2002). A liquid-liquid microextraction system for Pb and Cd enrichment and determination by flame atomic absorption spectrometry. *Química Nova*, *25*(5), 748-752.

[62]   Carasek, E., Tonjes, J. W., & Scharf, M. (2002). A new method of microvolume back-extraction procedure for enrichment of Pb and Cd and determination by flame atomic absorption spectrometry. *Talanta*, *56*(1), 185-191.

[63]   Zendelovska, D., Pavlovska, G., Cundeva, K., & Stafilov, T. (2001). Electrothermal atomic absorption spectrometric determination of cobalt, copper, lead and nickel traces in aragonite following flotation and extraction separation. *Talanta*, *54*(1), 139-146.

[64]   Ansari, I. A., Dewani, V. K., & Khuhawar, M. Y. (1999). Evaluation of metal contents in phulleli canal and Hyderabad city sewage by flame atomic absorption spectrophotometer. *JOURNAL-CHEMICAL SOCIETY OF PAKISTAN*, *21*(4), 359-367.

[65]   Batterham, G., Munksgaard, N., & Parry, D. (1997). Determination of trace metals in sea-water by inductively coupled plasma mass spectrometry after off-line dithiocarbamate solvent extraction. *Journal of Analytical Atomic Spectrometry*, *12*(11), 1277-1280.

[66]   Saran, R., Basu Baul, T. S., Srinivas, P., & Khathing, D. T. (1992). Simultaneous determination of trace heavy metals in waters by atomic absorption spectrometry after preconcentration by solvent extraction. *Analytical letters*, *25*(8), 1545-1557.

[67]   Camel, V. (2003). Solid phase extraction of trace elements. *Spectrochimica acta. Part B, Atomic spectroscopy*, *58*(7), 1177-1233.

[68]   Su, X. G., Wang, M. J., Zhang, Y. H., Zhang, J. H., Zhang, H. Q., & Jin, Q. H. (2003). Separation and preconcentration procedures for the determination of lead using spectrometric techniques: A review. *Talanta*, *59*, 989-995.

[69]   de Godoi Pereira, M., & Arruda, M. A. Z. (2004). Preconcentration of Cd (II) and Pb (II) using humic substances and flow systems coupled to flame atomic absorption spectrometry. *Microchimica Acta*, *146*(3-4), 215-222.

[70]   Evans, E. H., Day, J. A., Price, W. J., Smith, C. M., Sutton, K., & Tyson, J. F. (2003). Atomic spectrometry update. Advances in atomic emission, absorption and fluorescence spectrometry and related techniques. *Journal of Analytical Atomic Spectrometry*, *18*(7), 808-833.

[71]   Tuzen, M., Narin, I., Soylak, M., & Elci, L. (2004). XAD- 4/PAN Solid Phase Extraction System for Atomic Absorption Spectrometric Determinations of Some Trace Metals in Environmental Samples. *Analytical letters*, *37*(3), 473-489.

[72]   Tokalioglu, S., Kartal, S., & Elci, L. (2002). Determination of trace metals in waters by FAAS after enrichment as metal-HMDTC complexes using solid phase extraction. *Bulletin of the Korean Chemical Society*, *23*(5), 693-698.

[73]   Kim, Y. S., In, G., Han, C. W., & Choi, J. M. (2005). Studies on synthesis and application of XAD-4-salen chelate resin for separation and determination of trace elements by solid phase extraction. *Microchemical journal*, *80*(2), 151-157.

[74]   Ceccarini, A., Cecchini, I., & Fuoco, R. (2005). Determination of trace elements in seawater samples by on-line column extraction/graphite furnace atomic absorption spectrometry. *Microchemical Journal*, *79*(1-2), 21-24.

[75]   Fernandes, A. P., de Moraes, M., & Neto, J. A. G. (2003). Flow injection AAS determination of Cd, Cu, and Pb at trace levels in wine using solid phase extraction. *ATOMIC SPECTROSCOPY-NORWALK CONNECTICUT-*, *24*(5), 179-184.

[76]   Castillo, M., Pina-Luis, G., Díaz-García, M. E., & Rivero, I. A. (2005). Solid-phase organic synthesis of sensing sorbent materials for copper and lead recovery. *Journal of the Mexican Chemical Society*, *49*(2), 174-179.

[77]   Ferreira, S. L. C., Dos Santos, W. N. L., Bezerra, M. D. A., Lemos, V. A., & Bosque-Sendra, J. M. (2003). Use of factorial design and Doehlert matrix for multivariate optimisation of an on-line preconcentration system for lead determination by flame atomic absorption spectrometry. *Analytical and bioanalytical chemistry*, *375*(3), 443-449.

[78]   Lemos, V. A., & Ferreira, S. L. (2001). On-line preconcentration system for lead determination in seafood samples by flame atomic absorption spectrometry using polyurethane foam loaded with 2-(2-benzothiazolylazo)-2-p-cresol. *Analytica Chimica Acta*, *441*(2), 281-289.

[79]   Lemos, Valfredo A., Miguel de la Guardia, and Sérgio LC Ferreira. "An on-line system for preconcentration and determination of lead in wine samples by FAAS." *Talanta* 58.3 (2002): 475-480.

[80]   Ensafi, A. A., Khayamian, T., & Karbasi, M. H. (2003). On-line preconcentration system for lead (II) determination in waste water by atomic absorption spectrometry using active carbon loaded with pyrogallol red. *Analytical sciences*, *19*(6), 953-956.

[81]   Elçi, L., Arslan, Z., & Tyson, J. F. (2000). Flow injection solid phase extraction with Chromosorb 102: determination of lead in soil and waters by flame atomic absorption spectrometry. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *55*(7), 1109-1116.

[82]   Seki, T., Takigawa, H., Hirano, Y., ISHIBASHI, Y., & OGUMA, K. (2000). On-line preconcentration and determination of lead in iron and steel by flow injection-flame atomic absorption spectrometry. *Analytical sciences*, *16*(5), 513-516.

[83]   Pyrzyńska, K., & Cheregi, M. (2000). Lead determination with on-line enrichment system. *Water Research*, *34*(17), 4215-4219.

[84]   Sant'Ana, O. D., Jesuino, L. S., Cassella, R. J., Carvalho, M. S., & Santelli, R. E. (2004). Determination of lead by electrothermal atomic absorption spectrometry employing a novel sampling strategy of polyurethane foam impregnated with thiazolylazo-p-cresol (TAC). *Journal of the Brazilian Chemical Society*, *15*(1), 96-102.

[85]   Isah, S. (2018). Advanced Materials for Energy Storage Devices. *Asian Journal of Nanosciences and Materials*, *1*, 87-100.

[86]   Ferreira, S. L., Lemos, V. A., Santelli, R. E., Ganzarolli, E., & Curtius, A. J. (2001). An automated on-line flow system for the pre-concentration and determination of lead by flame atomic absorption spectrometry. *Microchemical journal*, *68*(1), 41-46.

[87]   del Carmen Yebra, M., Rodríguez, L., Puig, L., & Moreno-Cid, A. (2002). Application of a field flow preconcentration system with a minicolumn packed with Amberlite XAD-4/1-(2-pyridylazo)-2-naphthol and a flow injection-flame atomic absorption spectrometric system for lead determination in sea water. *Microchimica Acta*, *140*(3-4), 219-225.

[88]   Costa, A. C. S., Lopes, L., Korn, M. D. G. A., & Portela, J. G. (2002). Separation and Pre-concentration of Cadmium, Copper, Lead, Nickel and Zinc by Solid-Liquid Extraction of their Cocrystallized Naphthalene Dithizone Chelate in Saline Matrices. *Journal of the Brazilian Chemical Society*, *13*(5), 674-678.

[89]   Dadfarnia, S., Shabani, A. H., & Shirie, H. D. (2002). Determination of lead in different samples by atomic absorption spectrometry after

preconcentration with dithizone immobilized on surfactant-coated alumina. *Bulletin-Korean Chemical Society*, *23*(4), 545-548.

[90]   Wuilloud, R. G., Acevedo, H. A., Vazquez, F. A., & Martinez, L. D. (2002). Determination of lead in drinking water by ICP-AES with ultrasonic nebulization and flow-injection on-line preconcentration using an amberlite XAD-16 resin. *Analytical letters*, *35*(10), 1649-1665.

[91]   Tewari, P. K., & Singh, A. K. (2002). Preconcentration of lead with Amberlite XAD-2 and Amberlite XAD-7 based chelating resins for its determination by flame atomic absorption spectrometry. *Talanta*, *56*(4), 735-744.

[92]   Kumar, M., Rathore, D. P. S., & Singh, A. K. (2001). Quinalizarin anchored on Amberlite XAD-2. A new matrix for solid-phase extraction of metal ions for flame atomic absorption spectrometric determination. *Fresenius' journal of analytical chemistry*, *370*(4), 377-382.

[93]   Goswami, A., & Singh, A. K. (2002). 1, 8-Dihydroxyanthraquinone anchored on silica gel: synthesis and application as solid phase extractant for lead (II), zinc (II) and cadmium (II) prior to their determination by flame atomic absorption spectrometry. *Talanta*, *58*(4), 669-678.

[94]   Ekinci, C., & Köklü, Ü. (2000). Determination of vanadium, manganese, silver and lead by graphite furnace atomic absorption spectrometry after preconcentration on silica-gel modified with 3-aminopropyltriethoxysilane. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *55*(9), 1491-1495.

[95]   Zougagh, M., De Torres, A. G., Alonso, E. V., & Pavón, J. C. (2004). Automatic on line preconcentration and determination of lead in water by ICP-AES using a TS-microcolumn. *Talanta*, *62*(3), 503-510.

[96]   Takemori, S., Yamada, K., Itoh, O., Nanbu, N., & Akama, Y. (2004). Solid-phase extraction of lead and copper by chelating cellulose functionalized with thioglycollic acid. *Bunseki Kagaku*, *53*(8), 841-845.

[97]   Soylak, M., Narin, I., de Almeida Bezerra, M., & Ferreira, S. L. C. (2005). Factorial design in the optimization of preconcentration procedure for lead determination by FAAS. *Talanta*, *65*(4), 895-899.

[98]   Bispo, M. S., Korn, M. D. G. A., da Boa Morte, E. S., & Teixeira, L. S. G. (2002). Determination of lead in seawater by inductively coupled plasma optical emission spectrometry after separation and pre-concentration with cocrystallized naphthalene alizarin. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *57*(12), 2175-2180.

[99]   Matsumiya, H., Iki, N., Miyano, S., & Hiraide, M. (2004). Preconcentration of copper, cadmium, and lead with a thiacalix [4] arenetetrasulfonate-loaded Sephadex A-25 anion-exchanger for graphite-furnace atomic-absorption spectrometry. *Analytical and bioanalytical chemistry*, *379*(5-6), 867-871.

[100]   Shahpar, M., & Esmaeilpoor, S. (2018). The study of range-scaling transformation of nanoparticle compounds on thin films of gold-centered monolayer protected nanoparticles by molecular modeling. *Asian Journal of Nanosciences and Materials*, *1*, 1-8.

[101]   GANJALI, M. R., BABAEI, L. H., Badiei, A., ZIARANI, G. M., & TARLANI, A. (2004). Novel method for the fast preconcentration and monitoring of a ppt level of lead and copper with a modified hexagonal mesoporous silica compound and inductively coupled plasma atomic emission spectrometry. *Analytical sciences*, *20*(4), 725-729.

[102]   Krishna, P. G., Rao, K. S., Biju, V. M., Rao, T. P., & Naidu, G. R. K. (2004). Simultaneous preconcentration of Cu, Cd and Pb from soil samples by solid phase extraction and their determination by flame AAS. *Chemia analityczna*, *49*(3), 383-393.

[103]   Soylak, M. (2004). Solid phase extraction of Cu (II), Pb (II), Fe (III), Co (II), and Cr (III) on chelex- 100 column prior to their flame atomic absorption spectrometric determinations. *Analytical Letters*, *37*(6), 1203-1217.

[104]   Venkatesh, G., Singh, A. K., & Venkataramani, B. (2004). Silica gel loaded with o-dihydroxybenzene: design, metal sorption equilibrium studies and application to metal enrichment prior to determination by flame atomic absorption spectrometry. *Microchimica Acta*, *144*(4), 233-241.

[105]   Tuzen, M., & Soylak, M. (2004). Column system using diaion HP-2MG for determination of some metal ions by flame atomic absorption spectrometry. *Analytica chimica acta*, *504*(2), 325-334.

[106]   Maltez, H. F., Melo, L. F. C., de Queiroz, S. C. D. N., Jardim, I. C. S. F., Curtius, A. J., & Carasek, E. (2004). A comparative study of homemade C 18 and commercial C 18 sorbents for preconcentration of lead by minicolumn solid phase extraction. *Microchimica Acta*, *144*(1-3), 17-21.

[107]   Matoso, E., Kubota, L. T., & Cadore, S. (2003). Use of silica gel chemically modified with zirconium phosphate for preconcentration and determination of lead and copper by flame atomic absorption spectrometry. *Talanta*, *60*(6), 1105-1111.

[108] Demirel, E., Ozcan, M., Akman, S., & Tokman, N. (2003). Atomic absorption spectrometric determination of lead and cadmium in waste water samples after enrichment and separation using purolite C-100 E resin filled in a syringe-mountable filter. *Journal of trace and microprobe techniques*, *21*(1), 161-169.

[109] Uzun Karatepe, A., Soylak, M., & Elci, L. (2003). Separation/preconcentration of copper, lead, and iron in natural water samples on chromosorb-105 resin prior to flame atomic absorption spectrometric determinations. *Analytical letters*, *36*(4), 797-812.

[110] Cai, Y., Jiang, G., Liu, J., & Liang, X. (2002). Solid phase extraction of trace amounts of lead derivatized with 8-hydroxyquinoline using a GC stationary phase mini-column packed with chromosorb 105. ATOMIC SPECTROSCOPY-NORWALK CONNECTICUT-, 23(2), 52-58.

[111] Ganjali, M. R., Basiripour, F., & SALAVATI, N. M. (2002). @ DETERMINATION OF TRACE AMOUNTS OF COPPER AND LEAD IN WATER, ENVIRONMENTAL AND BIOLOGICAL SAMPLES BY ATOMIC ABSORPTION SPECTROMETRY AFTER THEIR SEPARATION AND PRECONCENTRATION BY USING MODIFIED OCTADECYL SILICA MEMBRANE DISKS.

[112] Filik, H. (2002). Metal ion preconcentration with amberlite XAD-2 functionalized with 5-palmitoyl-8-hydroxyquinoline and its analytical applications. *Analytical letters*, *35*(5), 881-894.

[113] Saracoglu, S., Soylak, M., & Elci, L. (2001). Determination of trace impurities in cadmium compounds by flame atomic absorption spectrometry after solid phase extraction. *Canadian journal of analytical sciences and spectroscopy*, *46*(4), 123-129.

[114] Yebra, M. C., Carro, N., Moreno- Cid, A., & Puig, L. (2001). Minicolumn field sampling and flow- injection- atomic absorption spectrometric determination of lead in seawater. *Field Analytical Chemistry & Technology*, *5*(5), 239-243.

[115] Narin, I., Soylak, M., Elci, L., & Dogan, M. (2001). Separation and enrichment of chromium, copper, nickel and lead in surface seawater samples on a column filled with Amberlite XAD-2000. *Analytical Letters*, *34*(11), 1935-1947.

[116] Da Silva, J. B. B., Quináia, S. P., & Rollemberg, M. C. E. (2001). On-line preconcentration with different solid adsorbents for lead determination. *Fresenius' journal of analytical chemistry*, *369*(7-8), 657-660.

[117] Hashemi, O. R., Kargar, M. R., Raoufi, F., Moghimi, A., Aghabozorg, H., & Ganjali, M. R. (2001). Separation and preconcentration of trace amounts of lead on octadecyl silica membrane disks modified with a new S-containing Schiff's base and its determination by flame atomic absorption spectrometry. *Microchemical journal*, *69*(1), 1-6.

[118] Yebra-Biurrun, M. C., Enriquez-Dominguez, M. F., Garcia-Garrido, A., & Moreno-Cid, A. (2000). Trace level determination of lead by flame AAS using on-line separation and preconcentration. *ATOMIC SPECTROSCOPY-NORWALK CONNECTICUT-*, *21*(6), 225-228.

[119] Zhang, X. Y. (2000). Flow-injection quantification of trace lead in water by on-line preconcentration-flame atomic absorption spectrometry. *CHINESE JOURNAL OF ANALYTICAL CHEMISTRY*, *28*(12), 1493-1496.

[120] Korn, M. D. G. A., Bispo, M. S., Korn, M., Costa, A. B. D., Mattos, J. C. P. D., Paniz, J. N. G., & Flores, É. M. D. M. (2005). Solid sampling analysis by flame atomic absorption spectrometry for lead determination in seawater samples after pre-concentration using cocrystallized alizarin red-naphthalene. *Journal of the Brazilian Chemical Society*, *16*(6A), 1241-1247.

[121] Salih, B. (2000). Speciation of inorganic and organolead compounds by gas chromatography-atomic absorption spectrometry and the determination of lead species after pre-concentration onto diphenylthiocarbazone-anchored polymeric microbeads. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *55*(7), 1117-1127.

[122] Castillo, E., Cortina, J. L., Beltrán, J. L., Prat, M. D., & Granados, M. (2001). Simultaneous determination of Cd (II), Cu (II) and Pb (II) in surface waters by solid phase extraction and flow injection analysis with spectrophotometric detection. *Analyst*, *126*(7), 1149-1153.

[123] Keil, O., Dahmen, J., & Volmer, D. A. (1999). Automated matrix separation and preconcentration for the trace level determination of metal impurities in ultrapure inorganic salts by high-resolution ICP-MS. *Fresenius' journal of analytical chemistry*, *364*(8), 694-699.

[124] Hu, Q., Yang, G., Yin, J., & Yao, Y. (2002). Determination of trace lead, cadmium and mercury by on-line column enrichment followed by RP-HPLC as metal-tetra-(4-bromophenyl)-porphyrin chelates. *Talanta*, *57*(4), 751-756.

[125] Olsen, S., Pessenda, L. C., Růžička, J., & Hansen, E. H. (1983). Combination of flow injection analysis with flame atomic-absorption spectrophotometry: determination of trace amounts

of heavy metals in polluted seawater. *Analyst*, *108*(1289), 905-917.

[126] Fang, Z., Růžička, J., & Hansen, E. H. (1984). An efficient flow-injection system with on-line ion-exchange preconcentration for the determination of trace amounts of heavy metals by atomic absorption spectrometry. *Analytica chimica acta*, *164*, 23-39.

[127] Soignet, S. L., Maslak, P., Wang, Z. G., Jhanwar, S., Calleja, E., Dardashti, L. J., ... & Pandolfi, P. P. (1998). Complete remission after treatment of acute promyelocytic leukemia with arsenic trioxide. *New England Journal of Medicine*, *339*(19), 1341-1348.

[128] Morsi, M. A., & Nageeb, A. S. (2018). Thermodynamic data (Voltammetrically) Estimated for the Interaction of Nano Cadmium Chloride (Ncc) with Isatin Using Glassy Carbon Electrode. *Asian Journal of Nanosciences and Materials*, *1*(4. pp. 172-293), 282-293.

[129] Ruzicka, J., & Arndal, A. (1989). Sorbent extraction in flow injection analysis and its application to enhancement of atomic spectrometry. *Analytica Chimica Acta*, *216*, 243-255.

[130] Liu, Z. S., & Huang, S. D. (1993). Automatic on-line preconcentration system for graphite furnace atomic absorption spectrometry for the determination of trace metals in sea water. *Analytica chimica acta*, *281*(1), 185-190.

[131] Moghimi, A., Ghiasi, R., Abedin, A., & Ghammamy, S. (2009). Solid phase extraction of Cd (II) using mesoporous organosilicas and determination by FAAS. *African Journal of Pure and Applied Chemistry*, *3*(3), 051-059.

[132] BASAVAIAH, K., Tadesse, A., RamaDevi, D., & Hagos, M. (2018). Facile green synthesis of fluorescent carbon quantum dots from citrus lemon juice for live cell imaging. *Asian Journal of Nanosciences and Materials*, *1*, 32-42.

[133] Moghimi, A. (2013). Separation of lead (II) paraffin-embedded tissues from liver loggerhead turtles specimens by organic-solution-processable functionalized-nano graphene prior to determination by flame atomic absorption spectrometry (FAAS). *African Journal of Pure and Applied Chemistry*, *7*(2), 79-90.

[134] Moghimi, A., & Ghiasi, R. (2008). Solid Phase Extraction of Copper (II) from Aqueous Solutions by Adsorption of its 2-propylpiperidine-1-carbodithioate Complex on Alumina Column. *Journal of the Korean Chemical Society*, *52*(4), 362-368.

[135] Moghimi, Ali. "Adsorption and preconcentration of lead (II) by solid-phase extraction prior to determination by flame atomic absorption spectrophotometry." *Australian Journal of Basic and Applied Sciences* 6.3 (2012): 320-330.

[136] MEIHUA, J. T. (2015). SYNTHESIS, CHARACTERIZATION AND CYTOTOXICITY EVALUATION OF CARBOXYLATED CARBON NANOTUBES FUNCTIONALIZED WITH SILIBININ, BETULINIC ACID AND LEVODOPA FOR DRUG DELIVERY.

[137] Tajodini, N., & Moghimi, A. (2010). Simultaneous preconcentration of Cadmium (II) and Lead (II) in water samples using resin amberlite XAD-2 functionalized with nitroso R salt and determination with atomic absorption spectrometry. *Asian Journal of Chemistry*, *22*(5), 3349-3361.

[138] Moghimi, A., & Poursharifi, M. J. (2009). Preconcentration and simultaneous determination of lead (II) and copper (II) by 1-(2-pyridylazo)-2-naphthol adsorbed on surfactant coated alumina by electro thermal atomic absorption spectrometry. *Asian Journal of Chemistry*, *21*(2), 849.

[139] Tohidifar, H., Moghimi, A., Ayvazzadeh, O., & Eskandari, S. (2013). Determination of Lead (II) in Milk by Flame Atomic Absorption Spectrometry after Solid Phase Extraction. *Asian Journal of Chemistry*, *25*(11).

[140] Moghimi, A., & Siahkalrodi, S. Y. (2013). Extraction and Determination of Pb (II) by Organic Functionalisation of Graphenes Adsorbed on Surfactant Coated C18 in Environmental Sample. *Journal of Chemical Health Risks*, *3*(3).

[141] Moghimi, A. (2016). Review of preconcentration and solid phase extraction for the determination of trace Lead. *Int. J. Bio-Inorg. Hybrid Nanomater.*, *5*(1), 5-18.

[142] Moghimi, A. (2016). Review of preconcentration and solid phase extraction for the determination of trace Lead. *Int. J. Bio-Inorg. Hybrid Nanomater.*, *5*(1), 5-18.

[143] Poursharifi, M. J., & Moghimi, A. (2009). Solid Phase Extraction of Trace Amounts Cu, Fe and Pb as 5-(6-Methoxy-2-benzothiazoleazo)-8-aminoquinoline Complexes on Naphthalene Adsorbent and Flame Atomic Absorption Determination. *Asian Journal of Chemistry*, *21*(4), 2549.

[144] Moghimi, A., & Poursharifi, M. J. (2009). Preconcentration and simultaneous determination of lead (II) and copper (II) by N, N′-disalicylideneethylenediamine by electro thermal atomic absorption spectrometry. *Asian Journal of Chemistry*, *21*(3), 1657-1666.

[145] Moghimi, A. (2014). Separation and extraction of Co (II) using magnetic chitosan nanoparticles

grafted with β-cyclodextrin and determination by FAAS. *Russian Journal of Physical Chemistry A*, *88*(12), 2157-2164.

[146] Moghimi, A., & Yari, M. (2014). Preconcentration of trace Ni (II) using C18 disks nano graphene with amino propyltriethoxysilane (APTES). *Merit Research Journal of Environmental Science and Toxicology (MRJEST)*, *2*(5), 110-119.

[147] Moghimi, A., & Akbarieh, S. P. (2014). Evaluation of Solid-phase Extraction Sorbent with Octadecane-functionalized Nano Graphene (OD-G) for the Preconcentration of Chromium Species in Water. *International Journal of Scientific Research in Knowledge*, *2*(1), 8.

[148] Moghimi, A. (2013). Detection of trace amounts of Pb (II) by schiff base-chitosan-grafted multiwalled carbon nanotubes. *Russian Journal of Physical Chemistry A*, *87*(7), 1203-1209.

[149] Moghimi, A. (2016). Review of preconcentration and solid phase extraction for the determination of trace Lead. *Int. J. Bio-Inorg. Hybrid Nanomater.*, *5*(1), 5-18.

[150] Javad Poursharifi, M., & Moghimi, A. (2012). Cloud-Point Method of Extraction Co (II) and Determination by FAAS. *Oriental Journal of Chemistry*, *28*(1), 379.

[151] Moghimi, A., Ghiasi, R., & Behrouzinia, S. (2011). Extraction Pb (II) by (Z)-Furan-2-carbaldehyde Thiosemicarbazone adsorbed on surfactant coated alumina before determination by FAAS. *International Journal of Fundamental Physical Sciences*, *1*(4), 78-82.

[152] Amos, P., Louis, H., Adesina Adegoke, K., Eno, E. A., Udochukwu, A. O., & Odey Magub, T. (2018). Understanding the Mechanism of Electrochemical Reduction of CO2 Using Cu/Cu-Based Electrodes: A Review. *Asian Journal of Nanosciences and Materials*, 183-224.

[153] Marzban, S., & Khorrami, S. A. (2013). International Journal of Bio-Inorganic Hybrid Nanomaterials. *Int. J. Bio-Inorg. Hybd. Nanomat*, *2*(4), 491-494.

[154] Yan, X. P., & Adams, F. (1997). Flow injection on-line sorption separation and preconcentration with a knotted reactor for electrothermal atomic absorption spectrometric determination of lead in biological and environmental samples. *Journal of Analytical Atomic Spectrometry*, *12*(4), 459-464.

[155] Sperling, M., Yan, X. P., & Welz, B. (1996). Investigation of on-line coupling electrothermal atomic absorption spectrometry with flow injection sorption preconcentration using a knotted reactor for totally automatic determination of lead in water samples. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *51*(14), 1891-1908.

[156] Ivanova, E., Van Mol, W., & Adams, F. (1998). Electrothermal atomic absorption spectrometric determination of cadmium and lead in blood using flow injection on-line sorption preconcentration in a knotted reactor1. *Spectrochimica Acta Part B: Atomic Spectroscopy*, *53*(6-8), 1041-1048.

[157] Salonia, J. A., Wuilloud, R. G., Gáquez, J. A., Olsina, R. A., & Martinez, L. D. (1999). Determination of lead in tap water by ICP-AES with flow-injection on-line adsorption preconcentration using a knotted reactor and ultrasonic nebulization. *Journal of Analytical Atomic Spectrometry*, *14*(8), 1239-1243.

[158] Wang, J., & Hansen, E. H. (2002). Coupling sequential injection on-line preconcentration using a PTFE beads packed column to direct injection nebulization inductively coupled plasma mass spectrometry. *Journal of Analytical Atomic Spectrometry*, *17*(10), 1278-1283.

[159] Ke, S. H., Huang, L. S., Huang, J. S., & Lin, K. C. (2001). Flow-injection inductively coupled plasma mass spectrometer incorporated with an ultrasonic nebulizer-membrane dryer: Application to trace lead detection in aqueous solution and seawater. *Applied Spectroscopy*, *55*(5), 604-610.

[160] Lou, T., Chen, Z., Wang, Y., & Chen, L. (2011). Blue-to-red colorimetric sensing strategy for Hg2+ and Ag+ via redox-regulated surface chemistry of gold nanoparticles. *ACS applied materials & interfaces*, *3*(5), 1568-1573.

[161] Abbas, M. N., & Mostafa, G. A. E. (2003). New triiodomercurate-modified carbon paste electrode for the potentiometric determination of mercury. *Analytica Chimica Acta*, *478*(2), 329-335.

[162] Qu, W., Zhai, Y., Meng, S., Fan, Y., & Zhao, Q. (2008). Selective solid phase extraction and preconcentration of trace mercury (II) with poly-allylthiourea packed columns. *Microchimica Acta*, *163*(3-4), 277-282.

[163] Zhai, Y., He, Q., Yang, X., & Han, Q. (2010). Solid phase extraction and preconcentration of trace mercury (II) from aqueous solution using magnetic nanoparticles doped with 1, 5-diphenylcarbazide. *Microchimica Acta*, *169*(3-4), 353-360.

[164] Zhang, L., Chang, X., Hu, Z., Zhang, L., Shi, J., & Gao, R. (2010). Selective solid phase extraction and preconcentration of mercury (II) from environmental and biological samples using nanometer silica functionalized by 2, 6-pyridine dicarboxylic acid. *Microchimica Acta*, *168*(1-2), 79-85.

[165] Neuenkamp, L., Metsoja, J. A., Zobel, M., & Hölzel, N. (2013). Impact of management on

biodiversity-biomass relations in Estonian flooded meadows. *Plant ecology*, *214*(6), 845-856.

[166]   Khajesarvi, A., & Akbari, G. (2018). Study of molybdenum effect on synthesis behavior of nanocrystalline NiAl intermetallic during mechanical alloying. *Asian Journal of Nanosciences and Materials*, *1*, 143-156.

[167]   Rabiee, N., Safarkhani, M., & Rabiee, M. (2018). Ultra-sensitive electrochemical on-line determination of Clarithromycin based on Poly (L-Aspartic Acid)/Graphite Oxide/Pristine Graphene/Glassy Carbon Electrode. *Asian Journal of Nanosciences and Materials*, *1*, 61-70.

[168]   Halimi, M., Nasrabadi, M., Soleamani, N., & Rouhani, N. (2018). Green synthesis of nanosilver particles from extract of Dracocephalum Lindbergii. *Asian Journal of Nanoscience and Materials*, *1*(1), 19-24.

[169]   Moghimi, A. (2007). Solid Phase Extraction of Trace Copper (II) Using Octadecyl Silica Membrane Disks Modified with N, N′Disalicylideneethylenediamine. *Chinese Journal of Chemistry*, *25*(12), 1842-1848.

[170]   Moghimi, A. (2007). Preconcentration and Determination of Copper (II) Using Octadecyl Silica Membrane Disks Modified by 1, 5-Diphenylcarhazide and Flame Atomic Absorption Spectrometry. *Chinese Journal of Chemistry*, *25*(11), 1663-1668.

[171]   Moghimi, A. (2007). Selective Pre-concentration and Solid Phase Extraction of Mercury (II) from Natural Water by Silica Gel-loaded (E)- N- (1- Thien- 2′- ylethylidene)- 1, 2- phenylenediamine Phase. *Chinese Journal of Chemistry*, *25*(10), 1536-1541.

[172]   Ali, M. (2007). Preconcentration and determination of trace amounts of heavy metals in water samples using membrane disk and flame atomic absorption spectrometry. *Chinese Journal of Chemistry*, *25*(5), 640-644.

[173]   Poursharifi, M. J., & Moghimi, A. (2011). Determination of ultratrace amounts of bismuth in water samples by electrothermal atomic absorption spectrometry (ET-AAS) after cloud point extraction. *Asian Journal of Chemistry*, *23*(4), 1424.

[174]   Poursharifi, M. J., & Moghimi, A. (2011). Determination of ultratrace amounts of bismuth in water samples by electrothermal atomic absorption spectrometry (ET-AAS) after cloud point extraction. *Asian Journal of Chemistry*, *23*(4), 1424.

[175]   Moghimi, A., & Poursharifi, M. J. (2011). Preconcentration and determination of ultratrace of Cd (II) in water samples using dispersive liquid-liquid microextraction with N-benzoyl-N-phenylhydroxylamine. *Asian Journal of Chemistry*, *23*(4), 1429.

[176]   Moghimi, A., & Poursharifi, M. J. (2011). Cloud point extraction, simultaneous and preconcentration spectrophotometric determination of nickel and cobalt in water samples. *Asian Journal of Chemistry*, *23*(4), 1435.