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Speciation and determination of mercury by various analytical techniques

Abstract: Mercury is one of the most important metals to environmental researchers due to its toxicity. In recent years, many authors determined the concentration of mercury and its different forms in the environment, such as soil, water, atmosphere and biota, with various analytical techniques, such as atomic absorption spectrometry, spectrophotometry, voltammetry, inductively coupled plasma mass spectrometry, inductively coupled plasma atomic emission spectrometry, spectrofluorometry and chromatography. The objective of this paper is to summarize the recent understanding of the available techniques for the analysis and speciation of mercury in environmental and biological samples reported worldwide during 2010–2011. We tabulated all the analytical parameters of about 129 research papers published in reputable international journals during 2010–2011 about mercury determination and speciation studies.

Keywords: analytical methods; environmental and biological samples; mercury; methylmercury.

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Introduction

In our modern periodic table of elements, mercury, also known as quicksilver, is the only metal that exists in the liquid state under normal temperature and pressure conditions. Mercury is mostly obtained from its sulfide ore, i.e., cinnabar. It is used in thermometers, fluorescent lamps, some electrical switches and as electrodes. Mercury exists in three forms, i.e., elemental mercury and inorganic and organic forms. Elemental mercury is mostly used in thermometers and some electric switches. Inorganic mercury [Hg(II)] is more soluble in water and more reactive. Organic forms of mercury include compounds like methylmercury, dimethylmercury and phenylmercury. Among organic forms of mercury, methylmercury is the most commonly existing in the environment. The sources of mercury are classified into two types: natural and anthropogenic sources. Natural sources of mercury include volcanoes and forest fires. Regarding anthropogenic sources, incineration of municipal and medical wastes and emissions from coal-using power plants contribute a major role to high levels of mercury in the environment. The major sources of mercury in aquatic environments include atmospheric deposition, erosion, urban discharges, agricultural materials, mining and combustion and industrial discharges (Wang et al. 2004). Metallic and inorganic mercury compounds enter into the atmosphere from mining ore deposits, burning of coal and waste from the manufacturing plants. It can enter into the water or soil from natural deposits, disposal of wastes and volcanic activity. Microorganisms like bacteria can form methylmercury in water and soil. Mostly, the methylmercury builds up in the tissues of fish; larger and older fishes may have high levels of methylmercury (ATSDR 1999). Mercury emissions from various sources in the environment are converted into methylmercury, which are bioaccumulated in the food chain. The topmost predators in the food chain have higher concentrations of methylmercury than the animals in the lower part of the food chain.

There are several ways by which humans are exposed to mercury including eating fish with methylmercury and breathing mercury vapors in air from the burnings of mercury-containing fuels and incinerators. The most tragic incident in history regarding mercury poisoning was observed in 1956 at Minamata Bay in Japan. The disease, named Minamata disease, induced symptoms such as numbness in the hands and feet, damage to hearing and speech, and even leads to death (http://en.wikipedia.org/wiki/Minamata_disease). Because of the toxicity of mercury, European countries like Norway, Sweden and Denmark banned its use in recent years [http://en.wikipedia.org/wiki/Mercury_(element)].

At the United Nations Organization meeting of world environmental ministers held in Kenya during February 2009, more than 140 countries worldwide agreed to reduce global mercury emissions by 2013 (http://www.mpe-magazine.com/legal-brief/global-

mercury-treaty-gets-go-ahead). Production of switches and relays containing mercury was banned in China from the year 2010 (Cheng and Hu 2012). Many international agencies made standards for the presence of mercury in different sources to avoid its adverse effects on human health. The high toxicity of mercury attracted many researchers to investigate its concentration in various environmental matrices. Park et al. (2010) reported the determination of mercury and methylmercury in freshwater fish in South Korea. The determination of mercury in mushrooms was reported by Jarzynska and Falandysz (2011). The oral bioaccessibility and health risk of mercury and other metals in urban street dusts of Nanjing, a mega city in China, was investigated by Hu et al. (2011). Much importance was given in recent years to the determination and speciation of mercury by researchers worldwide. This compelled us to review the recent trends in mercury determination.

Speciation and determination studies of mercury based on various analytical methods

Several authors reviewed the reported concentration of mercury and/or methylmercury in various environmental matrices with different analytical techniques. They are discussed briefly here.

Leermakers et al. (2005) discussed the sample preparation methods of mercury. They also reviewed the speciation and detection of mercury in environmental samples by using various analytical techniques. Li et al. (2009) reviewed mercury pollution in Asian countries. They found that the most mercury pollution arose from chemical industries, mercury mining and gold mining in Asian countries. Sanchez-Rodas et al. (2010) reviewed the speciation studies of arsenic, selenium, antimony and mercury by using atomic fluorescence spectrometry (AFS). This review mainly focused on instrumental couplings of chromatographic and nonchromatographic separations with AFS detection. They concluded that the advantages of AFS over inductively coupled plasma (ICP) techniques are low acquisition and ease of operation. Dadfarnia and Shabani (2010) reviewed the developments in liquid-phase microextraction for determination of trace-level concentrations of metals including mercury. In this review, the authors described various microextraction techniques such as single-drop microextraction, hollow-fiber liquid-phase microextraction, dispersive liquid-liquid microextraction and solidified floating organic drop microextraction for the determination of metals. Leopold et al. (2010) reviewed the determination and speciation of mercury, but it was limited only to natural waters including rivers, lakes, rain and groundwater. Pandey et al. (2011) reviewed measurement techniques for various forms of mercury (gaseous elemental mercury, reactive gaseous mercury and particle-bound mercury) in ambient air. Studies on speciation and analysis of mercury in environmental and biological samples by microwave-assisted extraction were reviewed by Reyes et al. (2011). This review predicts the drawbacks of microwave-assisted extraction for mercury such as inability of simultaneous extraction of multiple samples, losing of volatile organomercury compounds and the samples to be extracted at atmospheric pressure and at/or below the boiling point of the solvents used for extraction. A recent study in China (Cheng and Hu 2012) reviewed the presence of mercury in municipal solid waste (MSW). According to this study, mercury in MSW is not receiving the required attention in China. This study recommends that source reduction is the best option to regulate mercury pollution in the environment.

Among all the analytical instruments, a survey of the literature clearly reveals that the majority of the researchers preferred various spectroscopic methods such as atomic absorption spectrometry (AAS), inductively coupled plasma atomic emission spectrometry (ICP-AES), inductively coupled plasma mass spectrometry (ICP-MS), spectrophotometry and spectrofluorometry. Further, among all the spectroscopic methods, most researchers worldwide were commonly using the cold vapor-AAS (CV-AAS) and CV-AFS methods for mercury determination. A review (Clevenger et al. 1997) about trace determination of mercury in the 1990s also observed the same trend.

In the CV-AAS technique, first the samples were digested and oxidized to convert the different forms of mercury into their ions. These mercury ions were then reduced to the elemental state with 10% $SnCl_2 \cdot 2H_2O$ in 1 M HCl and aerated from a solution in a closed system. The mercury vapor passes through a cell in which the absorbance is measured to determine the concentration of mercury. In the CV-AFS technique, very low levels of mercury can be detected by applying accurate and proper sample collection. In this method, oxidation and reduction into elemental form in the sample container takes place, and then the sample is collected on a gold trap. Mercury vapors that are produced in the desorption process are passed through a cell in which absorbance is measured by a fluorescence detector (Microbac Laboratory Services 2011). The analytical parameters measured by researchers in the determination of mercury reported worldwide by using spectroscopic instruments are presented in Table 1.

The electrochemical instruments used by the researchers for the determination of mercury in various samples

Table 1 Analytical parameters of reviewed research papers about the determination of mercury by spectrometric instruments.

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
1	Hg	Automated atmospheric elemental Hg analyzer	Dielectric barrier discharge atomic emission	0.12 ng l^{-1}	Up to 6.6 ng l^{-1}	Atmosphere	–	Gold on tungsten coiled filament	Puanngam et al. 2010
2	Hg vapor	AFS	*In situ* automatic measurements	–	–	Ambient air	–	–	Brown et al. 2010
3	Total Hg	CV-AAS	Wet digestion	0.52 ng g^{-1}	–	Fish tissue	–	–	Voegborlo and Adimado 2010
4	Hg	CV-AAS	Acid digestion	–	–	Canned tuna fish	–	–	Rahimi et al. 2010
5	Total Hg	AFS	Flow injection analysis	0.2 pg of Hg	0.08–100 ng l^{-1}	Sea and river waters	–	Nanostructured active gold	Zierhut et al. 2010
6	Gaseous Hg	Automated Hg vapor analyzer	Adsorption on gold absorbents	4 (total Hg), 0.2 (MeHg) ng g^{-1}	–	Atmosphere	–	–	Fu et al. 2010b
7	Hg(II)	–	Fluorescent detection	–	Up to 8 μM	Aqueous solutions	–	6-Carboxyfluorescein	Zhang et al. 2010b
8	Total Hg	ET-AAS	Single drop microextraction	10 ng l^{-1}	–	Sea water, fish tissue, hair and wine	–	Tetradecyl(trihexyl) phosphonium chloride	Martinis and Wuilloud 2010
9	Total Hg	Direct Hg analyzer	Total digestion	–	–	Soil samples	–	–	Gil et al. 2010
10	Hg	CV-AAS	Preconcentration	3 ng l^{-1}	10–250 ng l^{-1}	Water and wastewater samples	Cu(II), Pb(II), Fe(III), Ni(II), and Mn(II) do not interfere	Silver wool solid sorbent	Mousavi et al. 2010
11	Hg	AFS	–	–	–	Bottled mineral water	–	–	Birke et al. 2010
12	Hg	CV-AFS	CPE	5 pg ml^{-1}	0.05–5.0 pg ml^{-1}	Water samples	Cd(II), Pb(II), Ni(II), Mn(II), Co(II) do not interfere up to 500 ng ml^{-1}	Triton X-114	Yuan et al. 2010
13	Hg	GF AAS	Preconcentration	0.08 μg l^{-1}	–	Gasoline diluted in ethanol	–	Gold column	Torres et al. 2010
14	Hg(II)	CV-AFS	Electrochemical	1.3 pg ml^{-1}	–	Human hair	No significant interference of ions as high as 0.2 μg ml^{-1} for Fe^{3+}, Mn^{2+} and Cu^{2+}; 0.1 μg ml^{-1} for Co^{2+}, Cr^{3+}, Ni^{2+}, Se^{+4}, Pb^{2+} and 0.05 μg ml^{-1} for Mo^{6+}, Sn^{4+}, Cd^{2+} containing 2 ng ml^{-1} Hg^{2+}	Polyaniline modified graphite	Jiang et al. 2010

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
15	Total Hg	CV-AAS	High-pressure oxygen microwave-assisted wet decomposition	0.12 μg l^{-1}	0–20 μg l^{-1}	Reference materials	Interference of unused H_2O_2 and HNO_3	–	Matusiewicz and Stanisz 2010
16	Hg	AFS	Photochemical cold vapor generation	0.08 ng ml^{-1}	1 mg l^{-1}	White vinegar	Sugar interferes in the analysis of vinegar; because of this, they analyzed only white vinegar, which does not have sugar	–	Liu 2010a
17	Hg(II)	Mercury sensor	Adsorption	0.64 μg ml^{-1}	1–30.0 μg ml^{-1}	Industrial wastewater	1000-fold excess of Fe^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cr^{3+} and 500-fold of As^{3+}, Sb^{3+}, Se^{4+} and Pb^{2+} had no interference in the analysis of 15.0 μg ml^{-1} of Hg^{2+}	Carbon nanotubes	Safavi et al. 2010
18	Hg	ET-AAS	Solid sampling	120 pg	–	Soil, sediments and plants	–	Electrodeposited Pd and Ir/Au	Cervenka et al. 2010
19	Hg speciation	HPLC-CV-AFS	–	0.05 (MeHg), 0.07 (Et Hg), 0.1 (Hg^{2+}) μg l^{-1}	–	CRM[a] and biological samples	–	L-Cysteine	Wang et al. 2010c
20	Hg	ET-AAS	Microextraction	70 ng l^{-1}	0.2–3.0 μg l^{-1}	Bottled and tap waters	Calcium interfere exceeding 50 mg l^{-1}	–	Garcia et al. 2010
21	Hg	AAS	–	3 ng m^{-3}	–	Ambient air	–	$KMnO_4/H_2SO_4$	Pehnec et al. 2010
22	Hg(II)	AFS	Cold vapor generation	1.4 ng l^{-1}	–	Traditional Chinese medicines	Interference of Fe^{3+}, Co^{2+}, Ni^{2+}, and Cu^{2+} (20 mg l^{-1}) is avoided by using HCOOH. 0.5 mg l^{-1} Bi^{3+}, Cd^{2+}, Ge^{4+}, Pb^{2+}, Se^{4+}, Sn^{2+}, Zn^{2+} and As^{3+} had no significant influence on the measurement of 1 μg l^{-1} Hg^{2+}	Pt/Ti cathode	Zhang et al. 2010c
23	Hg	CV-AAS	–	0.38 ng ml^{-1}	2.5–25 ng ml^{-1}	Fish samples	–	Low-density polyethylene	Ramezani et al. 2010
24	Inorganic Hg and total Hg	CV-AAS	–	0.35 ng ml^{-1} (Hg^{2+}), 0.54 ng ml^{-1} (MeHg)	5–100 ng ml^{-1} (MeHg), 2–100 ng ml^{-1} (Hg^{2+})	CRM	–	$NaBH_4$	Zhu et al. 2010

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
25	Total Hg, MeHg	CV-AFS	Gold amalgamation trapping	0.02 ng l^{-1} (MeHg)	–	Sediments and biota samples	–	–	Williams et al. 2010
26	Hg speciation	GC-AFS (MeHg), AAS (total Hg)	–	1.5 ng g^{-1} (total Hg)	5–40 ng l^{-1}	Human hair	–	–	Gao et al. 2010
27	Hg speciation	AFS	Extraction	1 (Hg^{2+}), 40 (PhHg), 68 (MeHg), 99 (Me_2Hg) ng l^{-1}	Up to 100 μg l^{-1}	Antarctic samples	Tolerance limit for Al^{3+}, Zn^{2+}, Cu^{2+}, Fe^{3+} is 10 μg ml^{-1} and for Ca^{2+} is 2000 μg l^{-1}	$SnCl_2$, UV radiation, $K_2S_2O_8$, $NaBH_4$	Pacheco et al. 2010
28	Hg(II)	–	Fluorescent intensity	2.59×10^{-9} M	$0.4–8\times10^{-7}$ M	Water samples	No effects found in the presence of 5.0×10^{-4} M Zn^{2+}, Mg^{2+}, Mn^{2+}; 1.0×10^{-4} M, Ni^{2+}, Co^{2+}, Al^{3+} or Fe^{3+}; and 2.0×10^{-5} M, Ag^{+}, Cu^{2+}, Pb^{2+}, or Cd^{2+}; in the determination of 6.0×10^{-7} M of Hg^{2+}	Silica nanoparticles	Liu et al. 2010
29	Hg(II)	Confocal laser scanning microscopy	Fluorescence imaging	–	–	*Arabidopsis thaliana* (plant)	–	Rhodamine B thiolactone	Zhang et al. 2011b
30	Total Hg, MeHg	CV-AFS	Dual-stage gold amalgamation	0.2 ng l^{-1} (Hg), 0.032 ng l^{-1} (MeHg)	–	Reservoir waters	–	–	Yao et al. 2011
31	Gaseous Hg/ speciation	Zeeman AAS	–	2 ng m^{-3}	–	Atmosphere	–	–	Kocman et al. 2011
32	Hg(II)	CV-AAS	Solid-phase extraction	0.16 μg l^{-1}		Natural water and plant samples	50 μg l^{-1} of Cu^{2+}, Zn^{2+} or Cd^{2+} did not interfere with the determination of 2.0 μg l^{-1} of Hg^{2+}	Magnetic nanoparticles	Zhai et al. 2010
33	Hg(II)	ICP-AES	Solid-phase extraction	0.10 ng ml^{-1}	–	Certified materials and water samples	50 μg l^{-1} of Fe^{3+}, Cr^{3+}, Cd^{2+}, Zn^{2+}, Ni^{2+}, Cu^{2+}, Pb^{2+} and Mn^{2+} ions did not interfere, but 20 μg l^{-1} of Co^{2+} interfered in the determination of 1 μg l^{-1} of Hg^{2+}	2-(2-Oxoethyl) hydrazine carbothioamide	Chai et al. 2010
34	GEM	Zeeman AAS	Online (without preconcentration)	0.3 ng m^{-3}	–	Atmosphere	–	–	Ci et al. 2011a
35	Hg(0)	CV-AAS	SPME	90 pg ml^{-1}	Up to 80 ng ml^{-1}	Mussel tissue and lobster hepatopancreas	–	Pd-based substrates	Romero et al. 2011

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
36	Hg speciation	AAS	Sequential extraction	0.1 μg kg^{-1} for total Hg[b]	–	Soil samples	–	–	Coufalik et al. 2011
37	Total Hg	CV-AAS	Cloud point extraction	0.117 μg kg^{-1}	Up to 10 μg l^{-1}	Broiler chicken tissues	–	–	Shah et al. 2010
38	Inorganic Hg	CV AFS	–	0.27 ng l^{-1}	0.05–5 μg l^{-1}	River water	Cu(II) severely interfered even at 20 mg l^{-1}	Phosphate-buffered solution	Zhang et al. 2011a
39	MeHg and total Hg	CV AFS	Two-stage gold amalgamation	0.2 ng l^{-1} for total Hg	–	Reservoir water samples	–	–	Feng et al. 2011
40	Hg speciation	CV AAS	Acid digestion	0.01 ng l^{-1}	–	Sea water	–	–	Matsuyama et al. 2011
41	Hg and MeHg	CV AAS	Digestion	0.1 for total Hg, 0.2 ng g^{-1} for MeHg	–	Fish and human hair	–	–	Miklavcic et al. 2011
42	Elemental Hg	EXAFS	Slow cooling/ crystallization	–	–	Mine wastes	–	–	Jew et al. 2011
43	Hg speciation	AFS	Online pre-concentration	0.004 μg l^{-1} for Hg(II)	0.02–8 μg l^{-1}	Water and CRMs	Interference of Cr(III) is eliminated with 0.1% (m/v) of EDTA as a masking agent	Diethyldithiocarbamate	Gao et al. 2011
44	Hg(II), MeHg, EtHg	Multisyringe chromatography coupled with CV-AFS	Multi-isocratic elution	0.11 Hg(II), 0.03 MeHg, 0.09 EtHg μg ml^{-1}	2–16 Hg(II), 0.5–8 MeHg, 1–8 EtHg μg l^{-1}	Dogfish muscle, pediatric vaccines	–	RP C18 monolithic column	Guzman-Mar et al. 2011
45	Hg(II)	Fiber-optic spectrometer	Optical fiber chemical sensing	5.0×10^{-7} M	1.0×10^{-6}–2.5×10^{-4} M	River water samples	Selected heavy metals do not significantly interfere in 1:10 Hg:heavy metal	Tripodal chromoionophore-PVC film	Nuriman et al. 2011
46	Hg total	FAAS	Acid digestion	–	–	Fish samples	–	–	Yamashita et al. 2011
47	Hg(II)	Near-IR spectroscopy	Preconcentration	–	4.228–50.38 mg l^{-1}	River waters	K^+, Na^+, Ca^{2+}, Mg^{2+} ions do not interfere	Thiol-functionalized Mg phyllosilicate clay	Li et al. 2011b
48	Hg speciation	CV AAS	Adsorption	0.06 μg l^{-1}	–	Wastewater samples	5 mg l^{-1} of Mn^{2+}, Cr^{3+}, Fe^{3+}, Cu^{2+}, Ni^{2+}, Zn^{2+} and Pb^{2+} do not interfere	*Lemna minor* powder	Xing et al. 2011
49	Organic Hg	BSA@R6G/MPA-Au NP sensor	Fluorescence sensor	3.0 nM for total organic Hg, 20 nM for PhHg	100 nM–2.5 μM	River, sea, tap waters and fish samples	Cd^{2+}, Ag^+, Pb^{2+}, Pt^{2+}, Hg^{2+} interference is avoided by using Te nanowires as masking agent	Gold nanoparticles	Chang et al. 2011
50	Hg total	CV AAS	–	0.005 μg g^{-1}	–	Mushrooms	–	–	Brzostowski et al. 2011

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
51	Hg speciation	IC-CV AFS	Photo-induced chemical vapor generation	0.1 (Hg) and 0.08 ng ml^{-1} (MeHg)	5–500 ng ml^{-1} (Hg, MeHg)	CRM (dogfish muscle)	–	Cysteine	Liu 2010b
52	Total Hg	CV-AAS	Acid digestion	–	–	Fish muscles	–	–	Fatemeh et al. 2011
53	Hg(II)	CV AAS	SPE	1.06 ng l^{-1}	0.02–1.90 μg l^{-1}	Mineral and sea water samples	5 mg l^{-1} of Pb^{2+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, Co^{2+}, Ag^{+}, Cd^{2+} do not interfere in the determination of 0.5 μg l^{-1} of Hg^{2+}	Octadecyl silica membrane disks modified by EPT	Rofouei et al. 2011
54	GEM	ZAAS	–	6.0 pg l^{-1}	–	Air-sea exchange in the Yellow Sea	–	–	Ci et al. 2011b
55	Hg(II)	Chemiluminescence	Biosensor	3.0×10^{-10} M	1.0×10^{-6}–1.0×10^{-9} M	Tap waters	–	DNA labeled with ruthenium complex	Li 2011
56	DGM, GEM	CV AFS	Gold amalgamation	3.0 pg l^{-1}	–	Coastal sea water	–	Gold trap and carbon trap	Ci et al. 2011c
57	Hg(II)	Fluorescence	–	10 nM	25.0–500 nM	Soil and water samples	Li^{+}, Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Ag^{+}, Au^{3+} do not interfere up to 265-fold to Hg^{2+} concentration	Polythymine/ benzothiazoium-4-quinolinium dimer derivative	Lin et al. 2011
58	Hg and MeHg	CV AFS	Gold amalgamation	0.023 ng l^{-1}	–	Water, sediment, fish	–	–	Williams et al. 2011
59	Hg	CCPM-AES	Cold vapor	0.05 ng ml^{-1} or 0.08 μg g^{-1}	0.2–25 ng ml^{-1}	Plastics, biodegradable materials	–	–	Frentiu et al. 2011
60	Hg total	CV AAS and ICP-AES	–	–	–	Mushrooms	–	–	Jarzynska and Falandysz 2011
61	Hg	Spectrophotometer	Adsorption	–	–	Water samples	–	Activated carbon	Silva et al. 2010
62	Hg(II)	Spectrophotometer	Colorimetric determination	–	0.39–8.89 μM	Water samples	Interference of Pb^{2+} eliminated with 2,6-pyridine dicarboxylic acid as masking agent	Gold nanoparticles	Wang et al. 2010a

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
63	Hg(II)	Spectrophotometer	Colorimetric sensing	–	200–800 nM	Drinking and sea water	Selective for Hg^{2+} and Ag^{+} in the presence of Li^{+}, Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Cd^{2+}, Al^{3+}, Pb^{2+}	Gold nanoparticles	Lin et al. 2010
64	Hg(II)	Spectrophotometer	Formation of nanoparticles	2 ppb	10–1000 nM	Aqueous solutions	Ba^{2+}, Mg^{2+}, Cd^{2+}, Co^{2+}, Cu^{2+}, Pb^{2+}, Fe^{3+} and Al^{3+} ions do not interfere even 100-fold excess than Hg^{2+}	$HAuCl_4/NH_2OH$	Fan et al. 2010
65	Hg(II)	Fluorescent probe	Chemosensor	–	0–12 ppb	Aqueous solutions	–	Rhodamine-based sensor	Song et al. 2010
66	Hg(II)	Spectrophotometer	Optical sensor	2.0×10^{-10} M	9.0×10^{-10}–2.5×10^{-7} M	Water samples	Tolerance limit for Cu^{2+} is 10-, Cd^{2+} is 7-, Pb^{2+} is 26-, Ag^{+} is 3-, Zn^{2+} is 32-fold than Hg^{2+}	1,3-Di(2-ethylhexyl) phosphate	Gholivand et al. 2010
67	Hg(II)	Spectrophotometer	Complexation	0.026 μg ml^{-1}	0.2–2.0 μg ml^{-1}	Wastewater and fertilizer samples	Selective from the interference of Co^{2+}, Ni^{2+}, Cd^{2+}, Au^{3+}, up to 100-fold excess than Hg^{2+}	6-Hydroxy-3-(2-oxoindolin-3-ylideneamino)-2-thioxo-2*H*-1,3-thiazin-4(3*H*)-one	Hamza et al. 2010
68	Hg	Spectrophotometer	Microextraction	0.2 μg l^{-1}	2–50 μg l^{-1}	Spiked water samples	Mn^{2+}, Zn^{2+}, Fe^{2+}, Pb^{2+}, Cd^{2+}, Co^{2+} did not interfere up to 200-fold excess than Hg^{2+}	–	Yang et al. 2010
69	Hg	Spectrofluorometer	Fluorescent detection	2.9×10^{-7} M	2.5–50 μM	Water samples	Simultaneous determination of Cu^{2+}, Zn^{2+} and Hg^{2+} is proposed	(4-[(*E*)-2-(4′-methyl-2,2′-bipyrinin-4-l)vinyl] phenol)	Pinheiro et al. 2010
70	Hg(II)	Spectrophotometer	Optical sensor	1.11×10^{-9} M	1.52×10^{-9}–1.70×10^{-2} M	Cyanidic garbage and resinic black mud	Minor interference of Co^{2+} over 100-fold excess than Hg^{2+}	Indicator dye	Yari and Abdoli 2010
71	Hg(II)	Synchronous fluorescence spectroscope	Fluorescence probe	4.5×10^{-9} M	0.15×10^{-7}–125×10^{-7} M	Water samples	Cu^{2+} interferes even at 10-fold excess than Hg^{2+}	CdS nanoparticles	Liang et al. 2010
72	Hg(II)	Spectrofluorometer	Fluorescence detection	0.25 nM	10–1500 nM	Aqueous solutions	Interference of heavy metals particularly Cu^{2+} eliminated with acetylacetonate as a masking agent	CdS nanoparticles	Chen et al. 2010b

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
73	Hg(II)	Spectrophotometer	Chelation/optical sensor	1×10^{-6} M	1.0×10^{-2}–1.0×10^{-5} M	Amalgam alloy and spiked water samples	Co^{2+}, Ba^{2+}, Na^{+}, Mg^{2+}, Al^{3+}, K^{+}, Cu^{2+}, Sr^{2+}, Zn^{2+}, Pb^{2+}, Ag^{+}, Cd^{2+}, Mn^{2+}, Ca^{2+}, Fe^{3+}, Cr^{3+}, Ni^{2+} and Tl^{+} at concentrations up to 100 times of Hg^{2+}	2-[(2-Sulfanylphenyl) ethanimidoyl] phenol on agarose membrane	Alizadeh et al. 2011a
74	Hg(II)	Spectrophotometer	Chelation	0.0939 μg ml^{-1}	0.814–8.1456 μg ml^{-1}	Spiked water samples	Tolerance limit for Pd^{2+} (0.13), Co^{2+} (0.51), Cu^{2+} (0.45) and Ni^{2+} (0.61 μg ml^{-1}) at Hg^{2+} (4.1 μg ml^{-1})	Anthrone phenylhydrazone	Veeranna et al. 2011
75	Hg(II)	Fluorophotometer	Optical sensor	6.3×10^{-8} M	1.0×10^{-7}–1.0×10^{-5} M	Tap and lake water	No significant interference of Cr^{3+}, Zn^{2+}, Cd^{2+}, Cu^{2+}: 5.0×10^{-5} M at Hg^{2+} (1.0×10^{-5} M)	1-Amino-8-napthol-3,6-disulfonic acid sodium	Sun et al. 2011
76	Hg(II)	Fluorescence spectrometer/ UV-visible spectrophotometer	Chemosensor	–	0.5–10 μM	Aqueous solutions	Pb^{2+}, Cd^{2+}, Cr^{3+}, Zn^{2+}, Cu^{2+}, Fe^{2+}, Co^{3+}, Ni^{2+} ions do not interfere	Rhodamine-derived Schiff base	Quang et al. 2011
77	Hg(II)	Fluorescence spectrophotometer	Fluorescence probe	1.55×10^{-9} M	$2.0–14.0\times10^{-9}$ M	–	Quenching effect of Fe^{2+} is eliminated by using sodium citrate as a masking agent	Quantum dots	Li et al. 2011c
78	Hg(II)	Spectrophotometer	Derivative mode	–	1.003–12.03 μg ml^{-1}	Synthetic alloys	Interference of Al^{3+} eliminated with thiourea as a masking agent. Other ions do not interfere significantly	Diacetyl monoxime isonicotinoyl hydrazone	Chandra Sekhar Reddy 2011
79	Hg	Spectrophotometer	Extraction	–	2.0–9.0 μg ml^{-1}	Ayurvedic medicine	–	Toluene-dithizone	Jain et al. 2011
80	Hg(II)	Spectrofluorometer	Fluorescent probe	4×10^{-9} M	4–600 nM	Urine samples	Cu^{2+} can interfere over 2 μM and Fe^{3+} interference eliminated by pretreatment with H_2O_2	Terbium chelate	Tan et al. 2011
81	Hg speciation	HPLC-ICP-MS	Dispersive liquid-liquid microextraction	1.3 (Hg^{2+}), 7.2 ($MeHg^{+}$), 5.4 ng l^{-1} ($EtHg^{+}$)	0.005–2 (Hg^{2+}), 0.01–2 (MeHg, EtHg) ng ml^{-1}	Cosmetic liquid samples	Tolerance limit of Fe^{3+}, Zn^{2+}, Pb^{2+}, Bi^{3+}, Au^{3+}, Ti^{2+} is 20 μg l^{-1} in 1.0 ng ml^{-1} of Hg species	APDC	Jia et al. 2011b
82	Hg speciation	HPLC-ICP-MS	Dispersive liquid-liquid microextraction	0.0076 (Hg^{2+}), 0.0014 ng ml^{-1} ($MeHg^{+}$)	0.01–2.0 (MeHg), 0.005–2.0 (Hg^{2+}) ng ml^{-1}	Sea water (reference material)	Tolerance limit of Fe^{3+}, Zn^{2+}, Ni^{2+}, Co^{2+}, Mn^{3+} is 50 ng ml^{-1} in 0.5 ng ml^{-1} of Hg species	Sodium diethyl dithiocarbamate	Jia et al. 2011a

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
83	Hg total	ICP-OES	Vapor generation	0.090 μg l^{-1}	Up to 500 μg l^{-1}	Mineral and certified waters	Au^{3+} interferes at 10 mg l^{-1} (Hg concentration is 50 μg l^{-1})	–	Wu et al. 2011
84	Hg speciation	LC-CV-ICPMS	Extraction	–	5.0 μg l^{-1} (Hg, MeHg)	Mushrooms	–	–	Pilz et al. 2011
85	Hg total	ICP-OES	Wet and microwave digestion	0.03 mg l^{-1}	–	Mushroom samples	–	–	Kula et al. 2011
86	MeHg(I) and Hg(II)	ICPMS	Extraction	–	0–100 μg l^{-1} (MeHg, Hg)	Fish tissues and sediments	–	5% 2-mercapto ethanol	Jagtap et al. 2011
87	Total Hg	FI-ICP-MS	Extraction	–	–	Swordfish and zebra fish	–	2-Mercaptoethanol	Lopez et al. 2010
88	Hg	ICP-OES	Ultrasonic bath	–	–	Compact fluorescent lamp	–	–	Santos et al. 2010b
89	Hg	CV-ICP OES	Photochemical cold vapor generation	0.3 μg l^{-1}	0.5–10 μg l^{-1}	Thimerosal in humans and veterinarian vaccines	–	–	Santos et al. 2010a
90	Hg	CV-ICP MS	Microwave digestion	–	–	Coal samples	–	–	Antes et al. 2010
91	Hg speciation	HPLC-ICPMS	Solid-phase extraction	3 ng l^{-1}	–	Water samples	–	Dithizone	Yin et al. 2010
92	Hg(II)	FI-ICP-OES	Extraction	0.04 ng ml^{-1}	0.2–100 ng ml^{-1}	Aqueous samples	20-fold of Cu^{2+} and 5-fold of Ag^{+}, Au^{3+}, Pd^{2+} does not interfere	Sodium dodecyl sulfate	Faraji et al. 2010
93	Hg	CV-ICP OES	Cloud point extraction	2.2 ng g^{-1}	–	Honey	–	–	Depoi et al. 2010
94	MeHg, inorganic Hg	LC-ICP MS	Extraction	0.25 μg l^{-1} (inorganic Hg), 0.1 μg l^{-1} (MeHg)	0–20 μg l^{-1} (all Hg species)	Blood samples	–	Mercaptoethanol, L-cysteine	Rodrigues et al. 2010
95	Hg speciation	FI-Chemical vapor generation-ICPMS	Chemical vapor generation	2.52 pg (inorg Hg), 3.24 pg (MeHg)	0.1–10 ng ml^{-1} (all Hg species)	Water samples	Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{3+}, Zn^{2+}, Cu^{2+}, Pb^{2+}, Cr^{3+} do not interfere up to 1–200 μg ml^{-1} each (Hg species at 1 ng ml^{-1})	Polyaniline column	Krishna et al. 2010
96	MeHg, EtHg	LC-ICP-MS	Solid-phase microextraction	0.06 μg l^{-1} (MeHg, EtHg)	1–50 μg l^{-1} (MeHg, EtHg)	Urine samples	–	–	Tsoi et al. 2010
97	Hg	HPLC-ICP-MS	Simultaneous analysis of Hg, Se	0.3–2.46 ng	Up to 180 μg l^{-1}	Human urine and serum	–	–	Moreno et al. 2010

(**Table 1** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
98	Hg total	ICP-MS	Microwave digestion	0.010 mg kg^{-1} [b]	0–20 μg l^{-1}	Foodstuffs	–	–	Millour et al. 2011
99	Hg(II)	ICP-AES	Solid-phase extraction	0.09 ng ml^{-1}	–	Balsam pear leaves, river water samples	1000-fold of Co^{2+}, Cr^{3+}, Mn^{2+}, 400-fold of Cd^{2+}, Cu^{2+}, Ni^{2+}, Zn^{2+}, Pb^{2+} caused little interference with the determination of Hg^{2+} (20 μg l^{-1})	2,6-Pyridine dicarboxylic acid	Zhang et al. 2010a
100	Hg(II)	ICP-AES	Adsorption	0.09 ng ml^{-1}	–	Water samples	50 μg ml^{-1} of Ni^{2+}, Cd^{2+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Cu^{2+} and Fe^{3+} does not interfere in the determination of Hg^{2+}	4-Amino antipyrine ontobentonite	Wang et al. 2011
101	Hg speciation	LC-ICP-MS	Extraction	0.25 (IHg), 0.20 (EtHg), 0.1 ng g^{-1} (MeHg)	–	Brazilian seafood samples	–	Mercaptoethanol	Batista et al. 2011
102	Hg speciation	GC coupled with ICP-MS	Microwave-assisted sample preparation	–	–	Blood samples	–	Tetramethylammonium hydroxide	Rodrigues et al. 2011

[a]CRM, certified reference material.

[b]Limit of quantification.

SPE, solid-phase extraction; EPT, 1,3-bis(2-ethoxyphenyl)triazene; DGM, dissolved gaseous mercury; CCPM-AES, capacitively coupled plasma microtorch atomic emission spectrometry.

Table 2 Analytical parameters of reviewed research papers about the determination of mercury using potentiometry and voltammetry.

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
1	Hg and MeHg	Capillary electrophoresis	Complexation	0.005±0.002 μg l^{-1} for Hg(II) and 0.4±0.05 μg l^{-1} for MeHg	0.01–10.0 (Hg^{2+}) and 0.5–50.0 ($MeHg^{+}$) μg l^{-1}	Coal samples	–	Cysteine	Martin et al. 2010
2	Inorganic Hg(II)	Anodic stripping voltammeter	Electrochemical	56 ppb (2.1×10^{-7})	1.0×10^{-8}–1.0×10^{-5} M	–	–	Poly(2,2′-dithiodianiline)	Somerset et al. 2010
3	Hg(II)	Anodic stripping voltammeter	Electrochemical detection	2.0×10^{-10} M	5.0×10^{-10}–1.5×10^{-7} M	Water samples	1.0×10^{-5} M of Fe^{3+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Zn^{2+}, Cr^{3+}, Cd^{2+}, Ti^{4+}, Ag^{+}, Pb^{2+}, Al^{3+}, Cu^{2+} does not interfere in determination of 5.0×10^{-8} M of Hg^{2+}, but Ag^{+} interferes in 2-fold excess than Hg^{2+}	*p-tert*-Butylthiacalix[4] arene	Wang et al. 2010b
4	Hg(II)	Cyclic voltammeter	Fabrication	3 ppb	10–1000 ppb	–	–	Au-Ag-Au electrode system	Chen et al. 2010a
5	Hg(II)	Stripping voltammeter	Electrochemical detection	6 ppt	0.1–60 ppb	River water	20 ppb Fe^{3+}, Co^{2+}, Zn^{2+}, Cd^{2+}, Cu^{2+} does not interfere in the determination of 1 ppb of Hg^{2+}	Gold nanoparticles	Gong et al. 2010
6	Hg(II)	Potentiometer	–	2.5×10^{-9} M (0.5 ppb)	5.0×10^{-9}–1.0×10^{-4} M	Dental amalgam and water samples	1.0×10^{-3} M of Cd^{2+}, Zn^{2+}, Pb^{2+}, Cu^{2+}, Co^{2+}, Mn^{2+}, Ni^{2+} does not interfere in the determination of 1.0×10^{-9}–1.0×10^{-4} M of Hg^{2+}	Carbon nanotubes and carbon paste electrode	Khani et al. 2010
7	Hg(II)	Voltammeter	Electrochemical detection	60 pM	0.2–1 nM	Aqueous solutions	Up to 200-fold of Zn^{2+}, Ni^{2+}, Pb^{2+}, Cd^{2+}, Mn^{2+}, Cu^{2+} does not interfere in the determination of Hg^{2+}	Polythymine oligonucleotide	Wu et al. 2010
8	Hg(II)	Square wave stripping voltammeter	Electrochemical determination	3 nM	10–140 nM	Water samples	100-fold Cd^{2+}, Pb^{2+},50-fold Zn^{2+}, 25-fold Cu^{2+}, 10-fold Ag^{+}, Fe^{2+}, and Mn^{2+} caused within ±5% changes of voltammetric signal of 0.15 μM of Hg^{2+}	Chitosan-multiwalled carbon nanotubes	Deng et al. 2010
9	Hg(II)	Square wave anodic voltammeter	Electrochemical determination	0.08 μg l^{-1}	2–16 μg l^{-1}	Tap water	5 μg l^{-1} of Cu^{2+} and Pb^{2+} interfere in the determination of 0.5 μg l^{-1} of Hg^{2+}	Screen-printed electrodes	Mandil et al. 2010

(**Table 2** Continued)

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
10	Hg(II)	Stripping Voltammeter	Electrochemical determination	0.02 nM	0.05–10 nM	Tap water samples	Ag^{+} shows little interference in 50-fold excess than Hg^{2+}	2-Mercaptobenzothiazole	Fu et al. 2010a
11	Hg(II)	Potentiometer	Cation exchanger	5×10^{-10} mol l^{-1}	10^{-10}–10^{-1} M	Tap and wastewater	Cu^{2+}, Zn^{2+}, Ni^{2+}, Sr^{2+}, Mn^{2+} ions have low selectivity coefficients and do not interfere in the determination of Hg^{2+}	Polyaniline-zirconium titanium phosphate	Khan and Paquiza 2011
12	Hg(II)	Differential pulse voltammeter	Electrochemical sensor	5.2×10^{-10} M	2.5×10^{-9}–5.0×10^{-7} M	Tap, river and lake waters	Up to 100-fold of Cu^{2+} and Cd^{2+} does not interfere in the determination of Hg^{2+}	Ion-imprinted polymer	Alizadeh et al. 2011b
13	Hg(II)	Voltammetry	Electrochemical detection	2.3×10^{-9} M	10 nM–20 μM	Tap and wastewater	No interference of Cd^{2+}, Zn^{2+}, Fe^{2+}, Co^{2+}, Mg^{2+} in 10-fold excess than Hg^{2+}	Carbon nanocomposite electrode	Safavi and Farjami 2011
14	Hg(II)	Stripping voltammeter	Ion imprinting strategy	0.1 nM	1.0–160.0 nM	Aqueous samples	50-fold of Pb^{2+}, 100-fold of Cd^{2+}, Zn^{2+}, Cu^{2+} interferes very slightly	Poly(2-mercaptobenzothiazole)	Fu et al. 2011
15	Hg(II)	Stripping voltammeter	Electrochemical detection	3.8×10^{-5} M	–	River water	–	SPCEs and CPEs	Somerset et al. 2011
16	Hg(II)	Square wave anodic stripping voltammeter	Electrochemical sensor	1.1 ng ml^{-1}	–	Ambient water samples	–	Screen-printed gold electrodes	Bernalte et al. 2011
17	Hg(II)	Capillary electrophoresis	Liquid-liquid micro extraction	0.62 μg l^{-1}	1–1000 μg l^{-1}	Tap and sea waters	2 mg l^{-1} of Pb^{2+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Co^{2+}, Cd^{2+} and 1 mg l^{-1} of Cu^{2+} do not cause significant interference in Hg^{2+} recovery	1-(2-Pyridylazo)-2-naphthol	Li et al. 2011a
18	Hg(II)	Linear anodic stripping voltammeter	Electrochemical detection	2.4×10^{-9} M	6.7×10^{-9}–8.3×10^{-8} M	Natural and industrial wastewater samples	100-fold excess of Fe^{3+}, Cu^{2+}, Zn^{2+}, Mn^{2+}, Pb^{2+}, Ni^{2+} does not interfere in the determination of Hg^{2+}	Carbon nanotube paste electrode modified with cross-linked chitosan	Janegitz et al. 2011
19	Hg, MeHg, PhHg	High-performance capillary electrophoresis with UV detector	Capillary microextraction coupled to capillary electrophoresis	0.012 μg ml^{-1} (MeHg), 0.007 μg ml^{-1} (PhHg), 0.003 μg ml^{-1} (Hg^{2+})	10–250 (Hg, MeHg), 10–200 (PhHg) ng ml^{-1}	Certified GBW 10029 fish sample	Fe(III), Mn(II), Al(III), Cu(II), and Zn(II) interfere	3-Mercaptopropyl trimethoxysilane	Bai and Fan 2010

Table 3 Analytical parameters of reviewed research papers about the determination of mercury by GC and HPLC.

S. no.	Analyte	Analytical instrument used for the detection	Method	Limit of detection (LOD)	Linearity range	Analyzed samples	Interference study	Supporting media	References
1	MeHg and total Hg	GC coupled with ICP-MS	Specific isotope dilution	1.4 μg kg^{-1} for Hg and 1.2 μg kg^{-1} for MeHg[a]	–	Seafood samples	–	–	Clemens et al. 2011
2	Hg(II)	GC-FID	Microextraction	0.02 μg ml^{-1}	0.05–5.0 μg ml^{-1}	Natural waters	Pb^{2+} shows recovery of only 77% at 100-fold excess than Hg^{2+} (1 μg ml^{-1}). Cu^{2+}, Cd^{2+}, Zn^{2+}, Ca^{2+}, Ni^{2+}, Mg^{2+} do not interfere at 100-fold excess than Hg^{2+}	Phenylboronic acid	Yazdi et al. 2010
3	Hg, MeHg	GC-MS	Extraction	0.1 ng g^{-1} (MeHg)	–	Freshwater fish and sediments	–	Dithizone	Park et al. 2010
4	Inorganic Hg, MeHg	GC-MS	Isotope dilution analysis	10 ng g^{-1} (inorganic Hg and MeHg)	–	CRMs	–	–	Castillo et al. 2010
5	Hg(II)	HPLC-fluorescent detector	Fluorescence detection	50–100 ppb	–	–	No interference of Pb^{2+}, Cd^{2+}, Cu^{2+}, Mg^{2+}, N^{i2+}, Mn^{2+}, Co^{2+}, Zn^{2+} ions in 1000:1 ratio to Hg^{2+}	Poly(aryleneethynylene)	Compagnone et al. 2010
6	MeHg	GC-ECD	Extraction	0.5 μg kg^{-1}	–	Marine and freshwater fish	–	Dithizone in toluene	Voegborlo et al. 2011
7	Hg speciation	HPLC	Dispersive liquid-liquid microextraction	0.32 (Hg^{2+}), 0.96 ($MeHg^{+}$), 1.91 μg l^{-1} ($PhHg^{+}$)	3–100 (Hg^{2+}), 5–100 ($MeHg^{+}$), 8–100 μg l^{-1} ($PhHg^{+}$)	Tap, river and lake waters	EDTA was used in the mobile phase to avoid the interferences of Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Al^{3+} ions	Dithizone	Gao and Ma 2011

were the anodic stripping voltammeter and potentiometer. The analytical parameters measured by the researchers in the determination of mercury by using electrochemical instruments are presented in Table 2. On the basis of the literature survey, only approximately 5% of the research papers described the determination and speciation of mercury with the use of chromatographic instruments, such as gas chromatography (GC) and high-performance liquid chromatography (HPLC). The analytical parameters measured by researchers in the determination of mercury reported worldwide by using chromatographic instruments are presented in Table 3.

The present study reveals that approximately 81% of research papers described the determination of mercury by spectroscopic instruments followed by electrochemical instruments (approximately 14%) and chromatographic instruments (only 5%).

Regarding the analysis of samples, most of the researchers determined the concentration of mercury in different water samples or aqueous solutions. The determination of mercury in various water contents is gaining more importance particularly in drinking water because it affects the human health directly. The United States Environmental Protection Agency (USEPA) also reviewed and approved some methods for the determination of mercury in drinking water. These are methods 200.8, 245.1, 245.2 and 245.7. Among these methods, method 200.8 describes the determination of mercury in drinking water by using ICP-MS, which has a detection limit of 0.0002 mg l^{-1}. Method 245.1 describes mercury determination in drinking water by using CV-AAS, and method 245.2 with automated CV technique (ACVT). Methods 245.1 and 245.2 have no method detection limits, but method 245.7 describes mercury determination by using CV-AFS, which has a very low method detection limit (0.0000018 mg l^{-1}) among all the methods mentioned above (USEPA 2009).

In the determination of mercury, there are so many challenges to overcome. If solid samples are considered for mercury analysis, there is the problem of heterogenic distribution of mercury. The high volatile nature of mercury and its compounds causes the loss of some content during sampling. It is very important to minimize the contamination of mercury from other sources during sampling and from laboratory reagents (Crock 2005). The most challenging issue in the determination and speciation of mercury is choosing the analytical technique because of the need for a highly sensitive and selective technique due to the very low concentrations of mercury in samples. As a result, many researchers are still using CV-AAS and CV-AFS because of the low cost and high sensitivity of these methods (Jokai Szatura 2007). Researchers must be aware of the quality of the data produced in the determination of mercury. The quality of the data can be enhanced by analyzing the related standard reference materials (SRMs) containing mercury.

Accurate determination of mercury concentration in various samples in the environment depends on many factors such as avoiding contamination during sampling and in the laboratory during analysis, choosing a highly selective and sensitive analytical technique and using SRMs for accuracy of the data.

Conclusion

A few historical tragic incidents of mercury poisoning, like the Minamata tragedy, make the determination and speciation of mercury an important task to environmental researchers worldwide. This study clearly predicts the importance of the determination and speciation of mercury in various environmental and biological samples due to the toxic nature of mercury and its different forms. Most of the researchers are aware of mercury contamination in drinking water. Apart from the drinking water, mercury can also enter the food chain through fish. For this reason, many researchers are interested in the determination of mercury concentration in fishes. Some international agencies like the USEPA and the World Health Organization also established standards for the concentration of mercury in water and fishes. Based on the literature survey, very few researchers measured the concentration of mercury in ambient air. It is very important to measure the ambient concentration of mercury because coal burning in thermal power stations is one of the major sources of mercury in the environment. A large number of papers were published about the determination of mercury in recent years. Most of the researchers performed total mercury studies instead of speciation studies. However, it is very important to determine methylmercury levels due to its toxicity. Regarding the analytical methods, most of the researchers used CV-AAS and CV-AFS for mercury determination. The determination and speciation studies of mercury in various environmental samples worldwide give useful information about mercury concentration that is needed for the implementation of the regulatory policies to decrease the mercury content in the environment. Another important factor is source prediction; by knowing the sources of mercury in the environment, it is easy to regulate its concentration in the environment.

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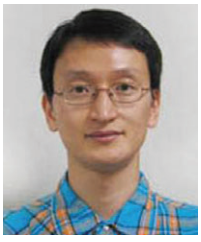

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