Book Chapter

Forensic Analysis of Poisons in Human Serum using Magnetic Alloy Nanoparticles and Mass Spectrometry

Sara A Al-Sayed, Mohamed O Amin* and Entesar Al-Hetlani*

Department of Chemistry, Faculty of Science, Kuwait University, Kuwait

*Corresponding Authors: Mohamed O Amin, Department of Chemistry, Faculty of Science, Kuwait University, P.O. Box 5969, Safat 13060, Kuwait

Entesar Al-Hetlani, Department of Chemistry, Faculty of Science, Kuwait University, P.O. Box 5969, Safat 13060, Kuwait

How to cite this book chapter: Sara A Al-Sayed, Mohamed O Amin, Entesar Al-Hetlani. Forensic Analysis of Poisons in Human Serum using Magnetic Alloy Nanoparticles and Mass Spectrometry. In: Prime Archives in Molecular Sciences: 4th Edition. Hyderabad, India: Vide Leaf. 2023.
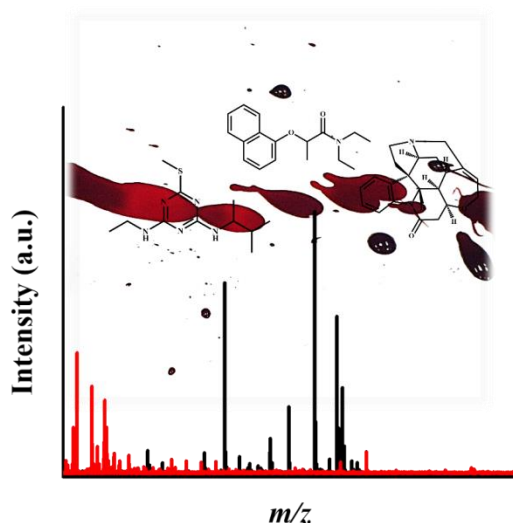
Graphical Abstract

Abstract

In this study, FeNi magnetic alloy nanoparticles (MANPs) were employed for forensic analysis of four poisons—dimethametryn, napropamide, thiodicarb, and strychnine using surface-assisted laser desorption/ionization-mass spectrometry (SALDI-MS). FeNi MANPs were prepared via coprecipitation using two reducing agents, sodium borohydride (NaBH$_4$) and hydrazine monohydrate (N$_2$H$_4$.H$_2$O), to optimize the prepared MANPs and investigate their effect on the performance of SALDI-MS analysis. Thereafter, SALDI-MS analysis was carried out for the detection of three pesticides and a rodenticide. The prepared substrate offered sensitive detection of the targeted analytes with LOD values of 1 ng/mL, 100 pg/mL, 10 ng/mL, and 200 ng/mL for dimethametryn, napropamide, thiodicarb, and strychnine, respectively. The relative standard deviation (RSD) values were in the range of 2.30–13.97% for the pesticides and 15–23.81% for strychnine, demonstrating the good spot-to-spot reproducibility of FeNi substrate. Finally, the MANPs were successfully employed in the analysis of poison-spiked blood serum using a minute quantity of the sample with an LOD of 700 ng/mL dimethametryn and napropamide, 800 ng/mL thiodicarb, and 500 ng/mL strychnine. This study offers great potential on the analysis of several poisons that may be found in human serum, which is significant in self-harming cases.

Keywords

Magnetic Alloy Nanoparticles; Pesticides; Strychnine; SALDI-MS; Forensic Analysis

Introduction

The World Health Organization (WHO) reported that more than 800,000 people die by suicide every year in low- and middle-income countries. Self-poisoning is considered one of the three most commonly used means to end one's life [1]. In particular, intentional ingestion of agricultural pesticides in industrial and developing countries has raised serious alarms owing to their low cost, availability, and fast-acting effect [2,3]. Pesticides account for 4–20% of global suicide rates, causing an

approximate death toll of 110,000–168,000 individuals each year [4]. Pesticide poisoning can be due to occupational, accidental, or intentional exposure; reports show that intentional pesticide poisoning has been responsible for more than 60% of suicide cases in China [5], 71% in Sri Lanka [6], 68% in Trinidad [7], and up to 90% of cases in Malaysia [8]. Strychnine is a rodenticide that is primarily mixed with some drugs such as heroin [9] and cocaine [10] as an adulterant or diluent. Although it is used in quantities that are not life-threatening, no more than 2% [9], a slight increase in these quantities may be lethal [11]. Similar to pesticides, strychnine poisoning may occur due to unintended or intended ingestion, and it has been linked to suicidal or homicidal cases [12].

Blood serum, urine, hair, and saliva are often the biological samples of choice to analyze for pesticide poisoning cases. Blood serum is generally used because it contains the highest concentration of the parent compound rather than the metabolites, and it carries a small risk of contamination [13]. In this respect, several studies have focused on the analysis of pesticides in blood serum; in particular, chromatographic techniques have been utilized to obtain qualitative and quantitative information. Generally, sample extraction and cleanup precede the analysis to eliminate any interferences from the sample matrix. Blood serum is rich in lipids, proteins, sugars, inorganic salts, and pigments, which are likely to interfere with GC-MS analysis [14]. For this reason, several extraction approaches have proposed including, liquid–liquid extraction (LLE), solid-phase extraction (SPE), and QuEChERS-based methods have been employed on blood serum prior to LC-MS and GC-MS analyses [15]; on some occasions, several extraction steps are combined [16]. Although useful, these approaches are recognized as complex, laborious, and consume a large amount of chemicals.

More recently, surface-assisted laser desorption/ionization mass spectrometry (SALDI-MS) has been recognized as a prominent soft ionization technique, which is employed in the analysis of small molecules [17]. It requires minimum sample preparation and produces a clean spectrum with minimum interference from the substrate used. Careful synthesis and tuning of SALDI

substrates are essential to obtain maximum performance; the substrate absorbs the laser energy and transfers this energy to the analyte for desorption and ionization thereby providing minimum fragmentation of the analytes [18]. Several SALDI substrates have been used such as metal oxide nanoparticles [19], nanocomposites [20], carbon-based materials [21], and others. Due to its advantages, SALDI-MS has been employed in the forensic analysis of drugs [19], biological fluids [22], spiked beverages [23], and other substances.

In this study, we report the first use of FeNi magnetic alloy nanoparticles (MANPs) as a new SALDI-MS substrate for forensic analysis of the poisons dimethametryn, napropamide, thiodicarb, and strychnine. FeNi magnetic alloy nanoparticles (MANPs) were synthesized via the coprecipitation method and then were characterized via XPS, BET, UV–Vis spectroscopy, TEM, and VSM. The MANPs showed great SALDI-MS performance and sensitive detection of pesticides and strychnine. The FeNi MANPs were also used in the analysis of the complex sample of human serum spiked with these poisons.

Experiments
Chemicals and Reagents

Iron(II) chloride ($FeCl_2$), nickel(II) chloride ($NiCl_2$), sodium borohydride ($NaBH_4$), hydrazine monohydrate ($N_2H_4.H_2O$), sodium hydroxide (NaOH), dimethametryn, napropamide, thiodicarb, strychnine, acetonitrile, and ethanol were purchased from Sigma Aldrich and used without further purification. Deionized water was obtained from an Elix Milli-Q water deionizer and was used in all the experiments. Blood serum samples were purchased from Bio-reclamation, Inc. (Hicksville, NY, USA).

Synthesis of FeNi Magnetic Alloy Nanoparticles

FeNi magnetic alloy nanoparticles (MANPs) were synthesized via a one pot coprecipitation method using hydrazine monohydrate ($N_2H_4.H_2O$) or sodium borohydride ($NaBH_4$) under a nitrogen atmosphere. Initially, equimolar amounts of $FeCl_2$ and $NiCl_2$, 3 mmol of each salt, were dissolved in 150 mL of distilled water and purged with nitrogen for 45 mins. Then, 1.00 g of

NaOH was dissolved in 25 mL of hydrazine monohydrate and added to the salts mixture dropwise, forming a dark precipitate. The precipitate was allowed to stir and was refluxed at 80°C for 1 hr under a nitrogen atmosphere. The resultant precipitate was then collected with a magnet and washed several times with water and ethanol and finally dried under vacuum at 85 ºC for 24 hrs. Alternatively, FeNi MANPs were prepared according to the method reported in [24], with some modifications. Equimolar amounts of $FeCl_2$ and $NiCl_2$ were dissolved in DI water and purged with nitrogen for 45 mins. Then, 1 g of $NaBH_4$ was added slowly as a powder in excess forming a dark precipitate, which was then stirred and refluxed at 50°C for 1 hr under nitrogen. The black precipitate was collected, washed, and dried as mentioned above.

## Characterization of FeNi Magnetic Alloy Nanoparticles

The surface elemental analysis of the FeNi MANPs was carried out by X-ray photoelectron spectroscopy (XPS); the binding energies were referenced to the C 1s peak at 284.64eV. The Brunauer–Emmett–Teller (BET) method was used to measure the surface area of the prepared material; this method was applied to the adsorption data by measuring the nitrogen sorption isotherms of the sample at −195°C using a model Gemini VII, ASAP 2020 automatic Micromeritics sorptometers (USA). UV–vis spectroscopy was employed to study the optical properties of the obtained material in solid state using Agilent Cary 5000 Scan UV–vis –near-infrared (UV–Vis–NIR) spectrophotometer. The morphology and particle size of the MANPs were determined using transmission electron microscopy (TEM) employing JEOL JEM 1230 (JEOL Ltd., Japan) operated at 120 kV. Measurement of magnetic properties was performed using Lake Shore Model 7410 (USA) vibrating sample magnetometer (VSM) with a moment range between $1x10^{-7}$ emu and 1000 emu at 298K.

Sample Preparation and SALDI-MS Analysis

The pesticide standard solution mixture containing dimethametryn, napropamide, and thiodicarb and a solution of strychnine were prepared in ethanol at a concentration of 1 mg/mL. Then, 2 µL of each analyte standard solution was mixed with 2 µL of the FeNi MANPs solution (1 mg/mL in ethanol)

and deposited on the target plate and allowed to dry at room temperature. The chemical structures for the three pesticides along with strychnine are shown in Figure 1.

SALDI-MS analysis was performed using MALDI Bruker ultrafleXtreme MALDI-TOF/TOF-MS system equipped with a Smartbeam-II. The analysis of the pesticide mixture and strychnine was performed in positive ionization mode, and the spectra were obtained for the analytes using a random walk raster with a frequency of 2000 Hz, ion source voltage of 25.0 kV, and reflector voltage of 26.6 kV, over a mass range of 100–500 Da. The instrument was calibrated prior to the analyses using a ProteoMassTM calibrant (Sigma Aldrich, Chemie GmbH, Schnelldorf, Germany) mixed within the normal range, and the data were processed using Bruker FlexAnalysis (Bruker, Germany).
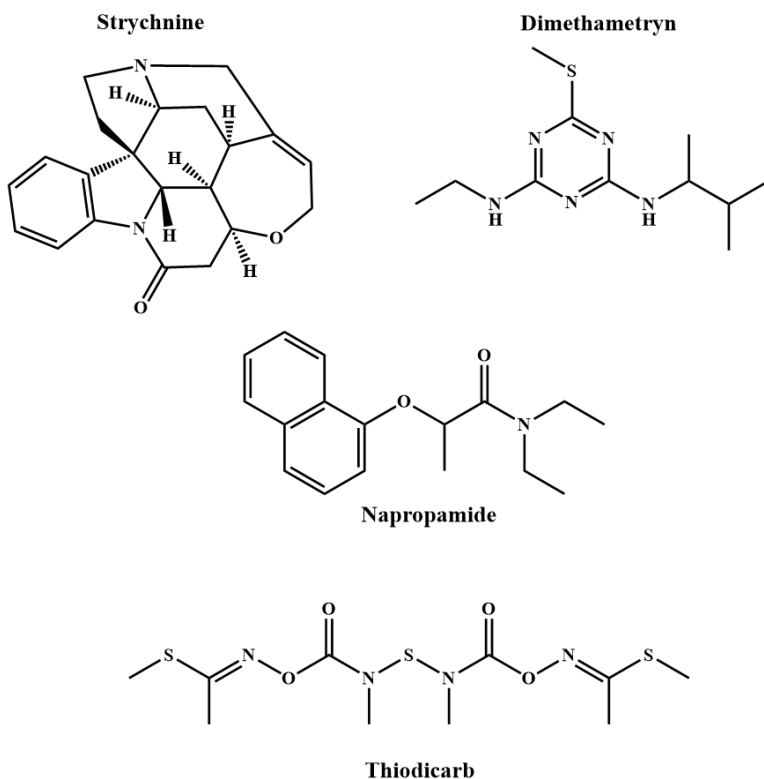
Figure 1: The chemical structure of the studied poisons.

Analysis of Spiked Human Serum

Human serum (200 μL) was spiked with 200 μL of different concentrations of the pesticide mixture or strychnine; then, 200 μL of acetonitrile was added to the mixture. The mixture was then vortexed, centrifuged for 5 min at 15,000 rpm, and the supernatant was collected. After that, 2 μL of the supernatant was mixed with 2 μL of FeNi MANPs, deposited on the target plate, and left to dry at room temperature.

Reproducibility and Limit of Detection (LOD)

The reproducibility of the analyses was determined by obtaining 5–7 spectra for each sample, and the analytes average signal intensities and relative standard deviations (%RSD) were computed. For LOD, a range of concentrations of the analytes (1 mg/mL–1 pg/mL) was analyzed, and the LODs were considered at S/N ratio above 3 for the spectral peak.

Results and Discussion

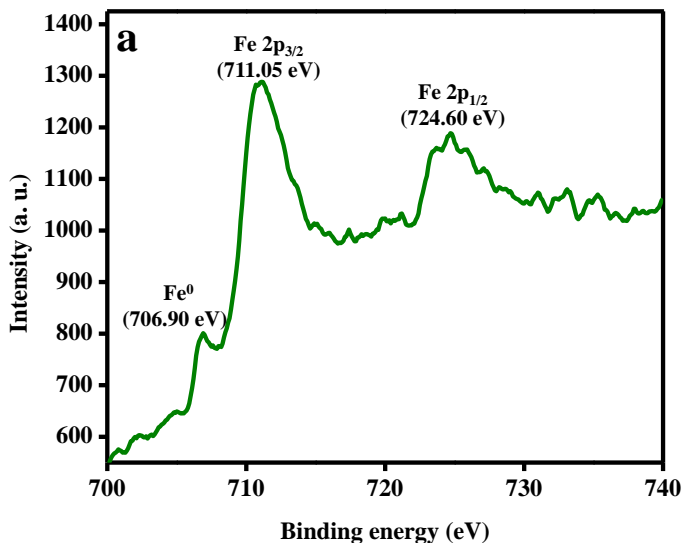## Optimization and Characterization of FeNi Magnetic Alloy Nanoparticles

The surface elemental composition and oxidation states of Ni and Fe in the fabricated FeNi MANPs were investigated via X-ray photoelectron spectroscopy (XPS) as shown in Figures 2a-c. Figure 2a illustrates the XPS spectrum of Fe; the binding energy (BE) at 706.90 eV can be ascribed to Fe^0, and the two peaks at 711.05 and 724.60 eV can be attributed to Fe $2p_{3/2}$ and Fe $2p_{1/2}$ of iron oxide, respectively [20,25]. Furthermore, Figure 2b shows a peak centered at BE of 852.73 eV and 870.00 eV, which can be ascribed to Ni 2p3/2 and Ni 2p1/2 for Ni0, and BEs at 855.70 and 873.50 eV, which are attributed to Ni 2p3/2 and Ni 2p1/2 for Ni2+, respectively [26,27]. Finally, a representative O1s spectrum is shown in Figure 2c showing BE at 531.06 eV, which indicates the presence of oxygen species such as –OH- [28]. These results indicate the successful formation of metallic iron and nickel MANPs, in addition to the hydroxide of both metals on the surface from ambient moisture. Energy dispersive spectroscopy (EDS) measurements were performed on the
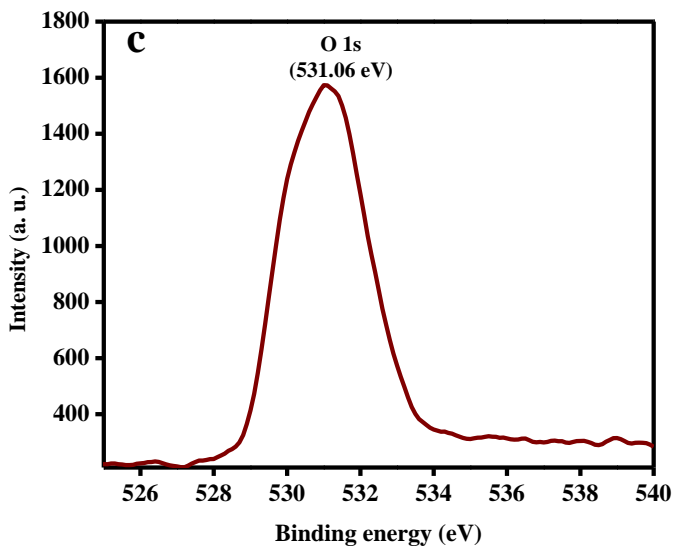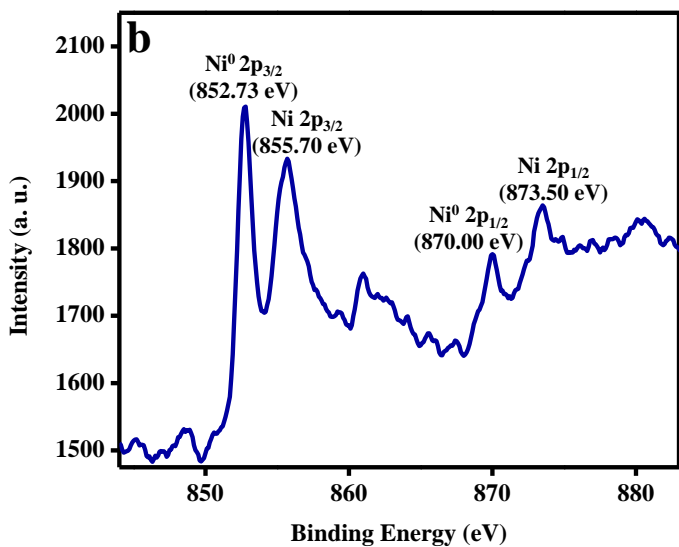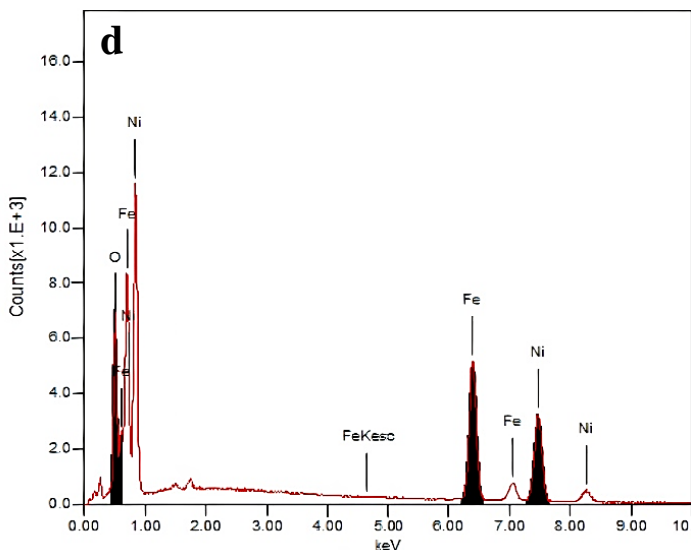
sample, the EDS analysis of FeNi MANPs is demonstrated in the Figure 2d and Table 1. The results confirmed the presence of Fe, Ni and O and the ratio of Fe to Ni in the MANPs was almost 1:1 ratio.

Table 1: Mass (%) and Atom (%) for FeNi using EDS.

| Element	Mass (%)	Atom (%)
Ni	48.13	37.04
Fe	41.44	33.53
O	10.42	29.43

Figure 2: Characterization of FeNi MANPs: (a) Fe 2p, (b) Ni 2p, and (c) O 1s XPS spectra and (d) EDS spectrum of FeNi MANPs.

The efficiency of absorbing the laser irradiation by the substrate and the ability to transfer this energy to the analyte are crucial elements in SALDI analysis [29]. Therefore, nanoparticles with good absorbance in the UV region offer an enhanced SALDI performance and increase the efficiency for analyte detection [30,31]. The UV–vis spectra of FeNi MANPs prepared using both reducing agents are shown in Figure 3a; the spectra revealed a strong absorbance over the visible and UV regions, which is in agreement with the UV–vis absorbance spectrum published by Slaton et al. [25]. The results obtained demonstrate the relatively higher absorbance of FeNi MANPs prepared by NaBH4 as opposed to N2H4.H2O. Other factors such as the size and porosity of the substrates can also contribute to the desorption/ionization efficacy and SALDI detection [32]. For this purpose, the surface area, pore size, and pore volume for FeNi MANPs were determined utilizing N2 adsorption–desorption. Figure 3b depicts the adsorption isotherm, which indicated that the material prepared exhibited IVa isotherm and an H3 hysteresis loop demonstrating the mesoporous nature of the MANPs (the inset shows an enlargement for the hysteresis

gap) [33]. The surface area measured was 6.47m²/g, whereas the pore volume was 0.012cm³/g, and the pore size was 7.68 nm. The morphology and average particle size of the synthesized MANPs were obtained using TEM, as illustrated in Figures 3c. The prepared MANPs possessed a spherical shape and formed aggregations with an average particle size around 42.46 nm, as shown in the inset in Figure 3c. Since small-sized particles offer better desorption/ionization, our findings indicated that the prepared MANPs were good candidates for SALDI analysis [34]. Finally, the magnetic properties of the MANPs were studied by VSM at 298 K as shown in Figure 3d, the magnetic hysteresis loop of the FeNi MANPs proved the ferromagnetic nature of the MANPs (non-zero coercivity value) [25]. The saturation magnetization (M_s) was reached at 84.024 emu/g, and the coercivity (H_c) was found to be 197.88G.
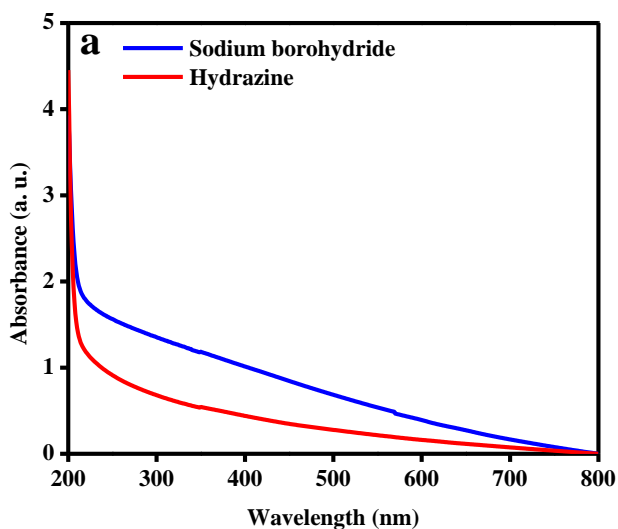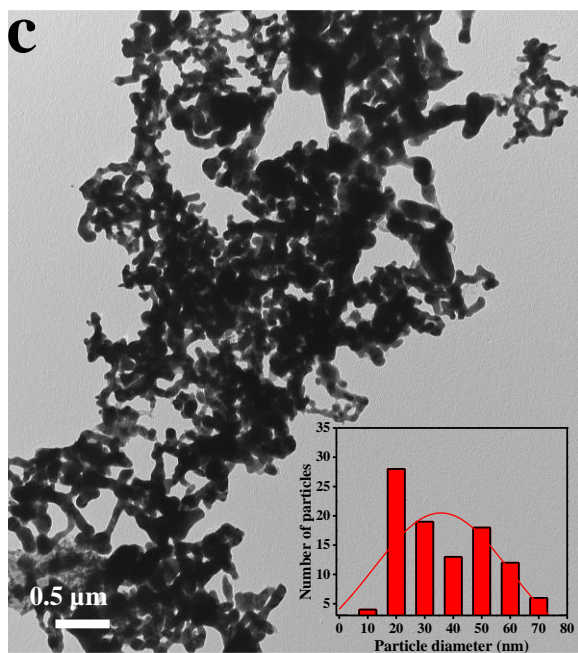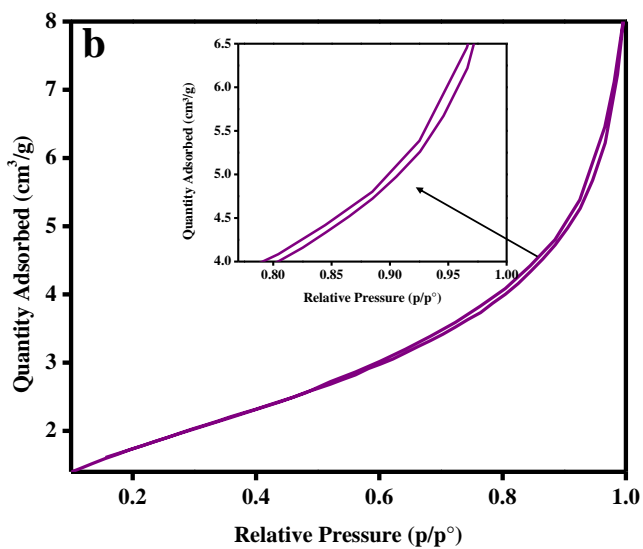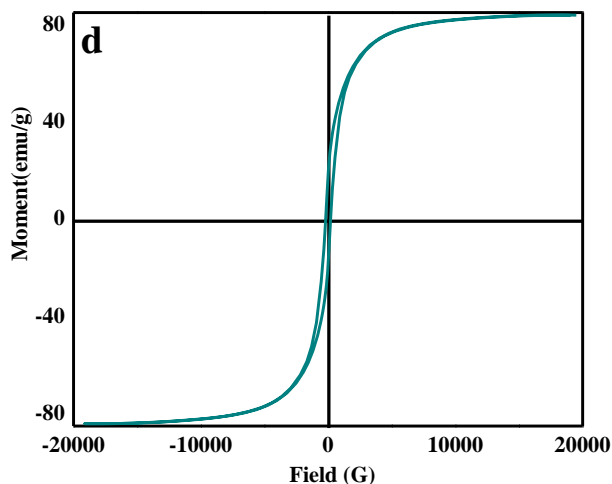
Figure 3: Characterization of FeNi MANPs. **(a)** UV–vis spectrum; **(b)** BET isotherm (inset shows an enlargement of the hysteresis gap); **(c)** TEM image for the prepared MANPs, and the inset shows particle size distribution; and **(d)** magnetic hysteresis loop of the FeNi MANPs at 298 K.

Effect of Reducing Agent on SALDI-MS Analysis

In this work, hydrazine monohydrate ($N_2H_4.H_2O$) and sodium borohydrate ($NaBH_4$) were used as reducing agents for the preparation of FeNi MANPs. Therefore, their effect on the performance of SALDI-MS was investigated using the selected poisons by measuring their signal intensities, as shown in Figure 4. The results obtained for dimethametryn, napropamide, thiodicarb, and strychnine indicated that FeNi MANPs prepared using $NaBH_4$ produced a greater signal intensity when compared to the ones prepared by $N_2H_4.H_2O$ for all targeted analytes. These results are consistent with the UV–vis absorbance (Figure 3a), where $NaBH_4$ showed a stronger absorbance as opposed to $N_2H_4.H_2O$ using the equivalent amounts of both materials. This can be explained by thermally driven ionization mechanism, which involves the adsorption of the analyte on the surface of the substrate, then absorption of laser irradiation by the substrate, and subsequent transfer of the absorbed energy to the analyte [35]. Consequently, a strong UV absorbance is believed to be one of the main contributors to the enhanced ionization and detection process [36]. As our results showed that FeNi MANPs

prepared using $NaBH_4$ offered a higher absorption in both the UV and visible range, it was employed for further study.
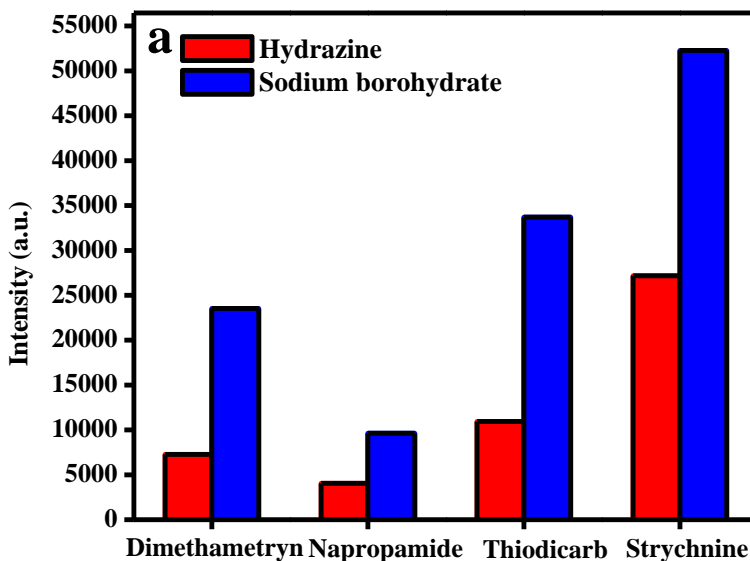
Figure 4: The effect of reducing agents $N_2H_4.H_2O$ and $NaBH_4$ on the performance of FeNi MANPs as SALDI-MS substrates for the detection of different poisons: dimethametryn, napropamide, thiodicarb, and strychnine.

Analysis of Poisons using FeNi MANPs

The analysis of the pesticides and strychnine solutions was performed using SALDI-MS and FeNi MANPs as a substrate; spectra obtained for the three pesticides mixture and strychnine are shown in Figure 5a-b. The ions obtained, their corresponding *m/z*, average intensity, %RSD, and LOD values are displayed in Table 2**.** Figure 5a depicts the peaks corresponding to the predominant sodiated forms of dimethametryn $[Dim+Na]^+$, napropamide $[Nap+Na]^+$, and thiodicarb $[Thi+Na]^+$ as indicated in the spectra. Additionally, for napropamide, the radical cation $[Nap]^{.+}$ protonated $[Nap+H]^+$, and potassiated $[Nap+K]^+$ forms, along with the protonated form of dimethametryn $[Dim+H]^+$ and the potassiated adduct for thiodicarb $[Thi+K]^+$ were detected. On the other hand, in Figure 5b strychnine was obtained in radical ion $[Sty]^+$, protonated $[Sty+H]^+$, sodiated $[Sty+Na]^+$, and potassiated $[Sty+K]^+$ forms. The RSD values were 2.30 and 6.16

for [Dim+H]+ and [Dim+Na]+, respectively, 9.66, 13.97, 8.21, and 11.07 for [Nap]·+, [Nap+H]+, [Nap+Na]+, and [Nap+K]+, respectively, and 9.27 for [Thi+Na]+; whereas, the RSD values for strychnine were 15.83, 17.70, 19.15, and 23.81 for [Sty]·+, [Sty+H]+, [Sty+Na]+, and [Sty+K]+, respectively. The RSD values demonstrated the good spot-to-spot repeatability of the SALDI substrate. Finally, LOD values for each targeted analyte were determined, and 1ng/mL, 100pg/mL, 10ng/mL, and 200ng/mL were obtained for dimethametryn, napropamide, thiodicarb, and strychnine, respectively.
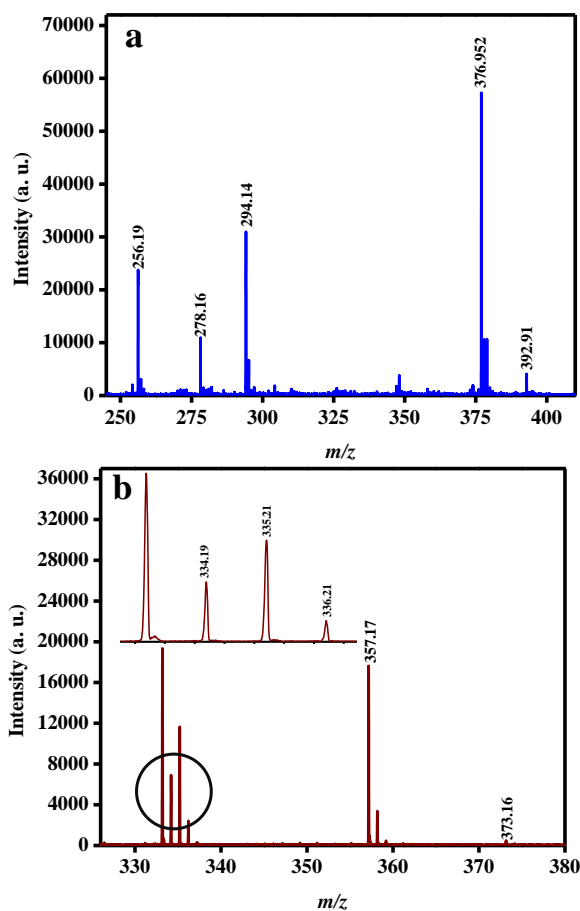
Figure 5: SALDI-MS spectra of **(a)** dimethamtetryn, napropamid, thiodicarb, and **(b)** strychnine using FeNi MANPs as a substrate.
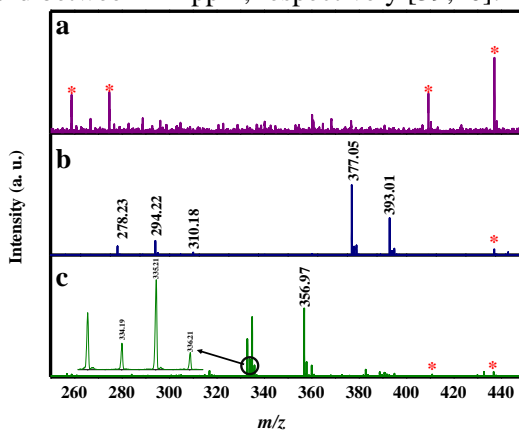
Table 2: Poisons detected, ion formed, *m/z*, average intensity, %RSD, and LOD.

Compound name	Ion formed	*m/z*	Average Intensity	%RSD	LOD
Dimethametryn	[Dim+H]+	256.19	23077.00	2.30	1 ng/mL
	[Dim+Na]+	278.18	11366.61	6.16	
Napropamide	[Nap]·+	271.18	735.47	9.66	100 pg/mL
	[Nap+H]+	278.16	660.36	13.97	
	[Nap+Na]+	294.14	28464.64	8.21	
	[Nap+K]+	310.08	1204.82	11.07	
Thiodicarb	[Thi+Na]+	376.95	76877.32	9.27	10 ng/mL
Strychnine	[Sty]·+	334.28	11014.64	15.83	200 ng/mL
	[Sty+H]+	335.29	16570.42	17.70	
	[Sty+Na]+	357.26	34571.31	19.15	
	[Sty+K]+	373.25	1838.68	23.81	

Analysis of Spiked Human Serum Samples

Self-poisoning by pesticides has become a common means of suicide in various countries and a source of great concern. The fatality rates for these cases were reported to be as high as 46% in hospital-based studies. The identification and quantification of pesticides in biological samples is considered a major key evidence in self-poisoning cases [37]. Additionally, in street-drug culture, the use of rodenticides as diluents is becoming more common at an alarming rate. As recently demonstrated in a study by Blakey et al. [38], the presence of some anticoagulant rodenticides has been identified in some seized 3,4-methylenedioxymethamphetamine (MDMA) tablets as low-level adulterants or contaminants; the risk of being poisoned by such mixed drugs increases with continuous consumption. Herein, FeNi MANPs were employed in the analysis of poison-spiked human serum; dimethametryn, napropamide, thiodicarb, and strychnine in human serum and the LOD for these poisons in human blood serum was investigated. Initially, the spectrum for the blank human serum using FeNi MANPs is shown in Figure 6a. Then, pesticide-spiked blood serum spectrum was obtained as demonstrated in Figure 6b; peaks corresponding to the

prevalent sodiated forms of dimethametryn [Dim+Na]+, napropamide [Nap+Na]+, and thiodicarb [Thi+Na]+ and potassiated adducts of napropamide [Nap+K]+ and thiodicarb [Thi+Na]+ were successfully detected. Figure 6c illustrates the spectrum obtained for strychnine in blood serum showing radical [Sty]·+, protonated [Sty+H]+, sodiated [Sty+Na]+, and potassiated forms [Sty+K]+ of the rodenticide. The ions detected, their corresponding *m/z*, their average intensity, %RSD, and LOD values are displayed in Table 3. The LOD values for the poison-spiked human serum were found to be 700 ng/mL for both dimethametryn and napropamide, 800 ng/mL for thiodicarb, and 500 ng/mL for strychnine. The RSD values were 22.45% for [Dim+Na]+, 14.94 and 18.06% for [Nap+Na]+ and [Nap+K]+, respectively, and 23.93 and 17.68% for [Thi+Na]+ and [Thi+K]+, respectively. The RSD values for strychnine were 13.62, 4.65, 2.19, and 9.16% for [Sty]·+, [Sty+H]+, [Sty+Na]+, and [Sty+K]+, respectively. These values show the good repeatability of the FeNi MANPs as a SALDI substrate, even in a complex sample matrix of human serum. It is worth mentioning that the obtained LODs were 1, 10 and 200 ng/mL for dimethametryn, thiodicarb and strychnine, respectively, and 100 pg/mL for napropamide in human serum. The achieved values are below the lethal dose values for all the poisons; the reported values for dimethametryn, napropamide, thiodicarb and strychnine are higher than 3000, 4680, 50 and between 1-2 ppm, respectively [39,40].

Figure 6: The SALDI-MS spectra using FeNi MANPs as substrate. **(a)** Control human serum sample. **(b)** Dimethamtetryn, napropamid, thiodicarb (the red asterisks point to possible presence of human serum compounds in sample), and **(c)** strychnine in human serum.

Table 3: Poisons detected, ion formed, *m/z*, average intensity, %RSD, and LOD in human serum.

Compound name	Ion formed	*m/z*	Average Intensity	%RSD	LOD (ng/mL)
Dimethamtetryn	[Dim+Na]+	278.23	2582.67	22.45	700
Napropamide	[Nap+Na]+	294.22	5649.92	14.94	700
	[Nap+K]+	310.18	1089.33	18.06	
Thiodicarb	[Thi+Na]+	376.05	20357.78	23.93	800
	[Thi +K]+	393.01	7831.50	17.68	
Strychnine	[Sty]·+	334.19	608.68	13.62	500
	[Sty+H]+	335.21	659.65	4.65	
	[Sty+Na]+	356.97	21779.79	2.19	

A few studies have focused on laser desorption ionization (LDI) analysis of human serum using nanoparticles, nanocomposite, inorganic monoliths, and others as summarized in Table 4. For instance, FePtCu-SO$_3$ NPs were applied for the detection of lysozyme in human serum [41], while silicon nanopost arrays were employed for the analysis of small metabolites and lipids in human [42]. Silver NPs were also applied for the analysis of mouse blood serum to detect glucose and anti-cancer drug 5-fluorouracil with good mass accuracy of 0.007 for the drug [43]. Additionally, our group has previously studied the detection of pesticides in human serum samples using copper ferrite NPs [44] and modified silica monolith [23] as SALDI substrates. Compared with the current study, the results obtained in this work are satisfactory; however, the LOD values obtained using FeNi MANPs were slightly higher than results obtained using SALDI-MS with other substrates, which could be due to the limited surface area of the metallic substrate. Thus, future work may involve modification of FeNi MANPs with carbon-based material, noble metals, or a metal organic framework (MOF) to increase the surface area and consequently SADLI analysis.

Table 4: Comparison of the findings of previous investigations and our study by substrate used, analyte, and LOD.

Substrate used	Surface area (m²/g)	Analyte	LOD	Ref
Silicon nanopost arrays	-	Small metabolites and lipids	-	[42]
Silver NPs	-	5-fluorouracil	-	[43]
FePtCu NPs	-	Lysozyme	-	[41]
Au-SiO₂ monolith	368.2	Dimethametryn and thiodicarb	100 ng/mL	[23]
		Napropamide and metalaxyl	1 ng/mL	
CuFe₂O₄ NPs	19.7	Napropamide	10 µg/mL	[44]
		Metalaxyl	10 ng/mL	
		Thiodicarb	100 pg/mL	
FeNi NPs	6.47	Dimethametryn	700 ng/mL	This work
		Napropamide	700 ng/mL	
		Thiodicarb	800 ng/mL	
		Strychnine	500 ng/mL	

Conclusion

FeNi magnetic alloy nanoparticles (MANPs) were synthesized using sodium borohydride (NaBH$_4$) and hydrazine monohydrate (N$_2$H$_4$.H$_2$O) as reducing agents. The prepared MANPs were characterized using a range of analytical techniques to investigate their chemical and morphological properties. The prepared MANPs using sodium borohydride (NaBH$_4$) showed enhanced detection of poisons in comparison to hydrazine monohydrate (N$_2$H$_4$.H$_2$O). The choice of reducing agent influenced the prepared materials, producing MANPs of good absorbance in the visible and UV regions, thus exhibiting great performance as SALDI-MS substrate. Three pesticides and a rodenticide were analyzed utilizing FeNi MANPs as a SALDI-MS substrate. The (LOD) values for dimethametryn, napropamide, thiodicarb, and strychnine were found to be 1 ng/mL, 100 pg/mL, 10 ng/mL, and 200 ng/mL, respectively. The MANPs were also used in the analysis of poison-spiked human serum with LOD values of 700 ng/mL dimethametryn and napropamide, 800 ng/mL thiodicarb, and 500 ng/mL for strychnine. Further chemical modification of the prepared

MANPs needs to be performed to enhance their surface area and SALDI-MS performance.

References

1. Fleischmann A, D De Leo. The World Health Organization's report on suicide: a fundamental step in worldwide suicide prevention. 2014.
2. Gunnell D, M Eddleston. Suicide by intentional ingestion of pesticides: a continuing tragedy in developing countries. International journal of epidemiology. 2003; 32: 902-909.
3. House A, D Owens, L Patchett. Deliberate self harm. Quality in health care: QHC. 1999; 8: 137.
4. Emma J Mew, Prianka Padmanathan, Flemming Konradsen, Michael Eddleston, Shu-Sen Chang, et al. The global burden of fatal self-poisoning with pesticides 2006-15: systematic review. Journal of affective disorders. 2017; 219: 93-104.
5. Michael R Phillips, Gonghuan Yang, Yanping Zhang, Lijun Wang, Huiyu Ji, et al. Risk factors for suicide in China: a national case-control psychological autopsy study. The Lancet. 2002; 360: 1728-1736.
6. Somasundaram D, S Rajadurai. War and suicide in northern Sri Lanka. Acta Psychiatrica Scandinavica. 1995; 91: 1-4.
7. G Hutchinson, H Daisley, D Simeon, V Simmonds, M Shetty, et al. High rates of paraquat-induced suicide in southern Trinidad. Suicide and Life-Threatening Behavior. 1999; 29: 186-191.
8. Maniam T. Suicide and parasuicide in a hill resort in Malaysia. The British Journal of Psychiatry. 1988; 153: 222-225.
9. Eskes D, J Brown. Heroin-caffeine-strychnine mixtures– where and why. Bulletin on narcotics. 1975; 27: 67-69.
10. Shannon M. Clinical toxicity of cocaine adulterants. Annals of emergency medicine. 1988; 17: 1243-1247.
11. Claire Cole, Lisa Jones, Jim McVeigh, Andrew Kicman, Qutub Syed, et al. Adulterants in illicit drugs: a review of empirical evidence. Drug testing and analysis. 2011; 3: 89-96.
12. Otter J, JL D'Orazio. Strychnine toxicity. StatPearls. 2017.
13. Yongho Shin, Jonghwa Lee, Jiho Lee, Junghak Lee, Eunhye

Kim, et al. Validation of a multiresidue analysis method for 379 pesticides in human serum using liquid chromatography–tandem mass spectrometry. Journal of agricultural and food chemistry. 2018; 66: 3550-3560.

14. Ying Sun, Yiming Pang, Jingxu Zhang, Zhiwen Li, Jufen Liu, et al. Application of molecularly imprinted polymers for the analysis of polycyclic aromatic hydrocarbons in lipid matrix-based biological samples. Analytical and bioanalytical chemistry. 2017; 409: 6851-6860.

15. Jian Li, Tian Chen, Yuwei Wang, Zhixiong Shi, Xianqing Zhou, et al. Simple and fast analysis of tetrabromobisphenol A, hexabromocyclododecane isomers, and polybrominated diphenyl ethers in serum using solid-phase extraction or QuEChERS extraction followed by tandem mass spectrometry coupled to HPLC and GC. Journal of separation science. 2017; 40: 709-716.

16. Thomai Mouskeftara, Christina Virgiliou, Achilleas Iakovakis, Nikolaos Raikos, Helen G Gika. Liquid chromatography tandem mass spectrometry for the determination of nine insecticides and fungicides in human postmortem blood and urine. Journal of Chromatography B. 2021; 122824.

17. Abdelhamid HN. Nanoparticle assisted laser desorption/ionization mass spectrometry for small molecule analytes. Microchimica Acta. 2018; 185: 1-16.

18. Lim AY, J Ma, YCF Boey. Development of nanomaterials for SALDI-MS analysis in forensics. Advanced Materials. 2012; 24: 4211-4216.

19. Amin MO, M Madkour, E Al-Hetlani. Metal oxide nanoparticles for latent fingerprint visualization and analysis of small drug molecules using surface-assisted laser desorption/ionization mass spectrometry. Analytical and bioanalytical chemistry. 2018; 410: 4815-4827.

20. Bessy D'Cruz, Metwally Madkour, Mohamed O Amin, Entesar Al-Hetlani. Efficient and recoverable magnetic AC-Fe3O4 nanocomposite for rapid removal of promazine from wastewater. Materials Chemistry and Physics. 2020; 240: 122109.

21. Chih-Wei Liu, Min-Wei Chien, Ching-Yuan Su, Hui-Yi Chen, Lain-Jong Li, et al. Analysis of flavonoids by

graphene-based surface-assisted laser desorption/ionization time-of-flight mass spectrometry. Analyst. 2012; 137: 5809-5816.

22. Amin MO, E Al-Hetlani. Development of efficient SALDI substrate based on Au–TiO2 nanohybrids for environmental and forensic detection of dyes and NSAIDs. Talanta. 2021; 233: 122530.

23. Ismail MM, MO Amin, E Al-Hetlani. Analysis of drugs and pesticides for forensic purposes using noble metal-modified silica monolith as SALDI-MS substrate. Microchemical Journal. 2021; 166: 106201.

24. Bai Yang, Yue Wu, Xiaopan Li, Ronghai Yu. Chemical synthesis of high-stable amorphous FeCo nanoalloys with good magnetic properties. Nanomaterials. 2018; 8: 154.

25. Rahiem Davon Slaton, In-Tae Bae, Patrick S Lutz, Laxmikant Pathade, Mathew M Maye. The transformation of α-Fe nanoparticles into multi-domain FeNi–M 3 O 4 (M= Fe, Ni) heterostructures by galvanic exchange. Journal of Materials Chemistry C. 2015; 3: 6367-6375.

26. Prashant Acharya, Zachary J Nelson, Mourad Benamara, Ryan H Manso, Sergio I Perez Bakovic, et al. Chemical Structure of Fe–Ni Nanoparticles for Efficient Oxygen Evolution Reaction Electrocatalysis. ACS omega. 2019; 4: 17209-17222.

27. Juan Wang, Qi Zhao, Hongshuai Hou, Yifei Wu, Weizhen Yu, et al. Nickel nanoparticles supported on nitrogen-doped honeycomb-like carbon frameworks for effective methanol oxidation. RSC advances. 2017; 7: 14152-14158.

28. Jean-Charles Dupin, Danielle Gonbeau, Philippe Vinatier, Alain Levasseur. Systematic XPS studies of metal oxides, hydroxides and peroxides. Physical Chemistry Chemical Physics. 2000; 2: 1319-1324.

29. Chiang CK, WT Chen, HT Chang. Nanoparticle-based mass spectrometry for the analysis of biomolecules. Chemical Society Reviews. 2011; 40: 1269-1281.

30. Gargey B Yagnik, Rebecca L Hansen, Andrew R Korte, Malinda D Reichert, Javier Vela, et al. Large scale nanoparticle screening for small molecule analysis in laser desorption ionization mass spectrometry. Analytical chemistry. 2016; 88: 8926-8930.

31. Wen-Tsen Chen, Iva Tomalová, Jan Preisler, Huan-Tsung Chang. Analysis of Biomolecules through Surface-Assisted Laser, Desorption/Ionization Mass Spectrometry Employing Nanomaterials. Journal of the Chinese Chemical Society. 2011; 58: 769-778.

32. Yongsheng Xiao, Scott T Retterer, Darrell K Thomas, Jia-Yuan Tao, Lin He. Impacts of surface morphology on ion desorption and ionization in desorption ionization on porous silicon (DIOS) mass spectrometry. The Journal of Physical Chemistry C. 2009; 113: 3076-3083.

33. Matthias Thommes, Katsumi Kaneko, Alexander V Neimark, James P Olivier, Francisco Rodriguez-Reinoso, et al. Physisorption of gases, with special reference to the evaluation of surface area and pore size distribution (IUPAC Technical Report). Pure and applied chemistry. 2015; 87: 1051-1069.

34. Schürenberg M, K Dreisewerd, F Hillenkamp. Laser desorption/ionization mass spectrometry of peptides and proteins with particle suspension matrixes. Analytical Chemistry. 1999; 71: 221-229.

35. Song K, Q Cheng. Desorption and ionization mechanisms and signal enhancement in surface assisted laser desorption ionization mass spectrometry (SALDI-MS). Applied Spectroscopy Reviews. 2020; 55: 220-242.

36. Wei J, JM Buriak, G Siuzdak. Desorption–ionization mass spectrometry on porous silicon. Nature. 1999; 399: 243-246.

37. Adole PS, S Bora, VA Chaudhari. Clinical utility of validated gas chromatography–ion trap mass spectrometry in patients with anticholinesterase pesticides poisoning. Analytical biochemistry. 2021; 621: 114158.

38. Karen Blakey, Victoria Cusack, Camilla Burnett, Steven Carter, Shiona Croft, et al. Identification of the rodenticide coumatetralyl in seized tablets. Forensic Chemistry. 2021; 23: 100305.

39. Gordon Jr AM, DW Richards. Strychnine intoxication. JACEP. 1979; 8: 520-522.

40. Kathleen A Lewis, John Tzilivakis, Douglas J Warner, Andrew Green. An international database for pesticide risk assessments and management. Human and Ecological Risk Assessment: An International Journal, 2016. 22(4): p. 1050-

1064.

41. Hideya Kawasaki, Tarui Akira, Takehiro Watanabe, Kazuyoshi Nozaki, Tetsu Yonezawa, et al. Sulfonate group-modified FePtCu nanoparticles as a selective probe for LDI-MS analysis of oligopeptides from a peptide mixture and human serum proteins. Analytical and bioanalytical chemistry. 2009; 395: 1423-1431.

42. Andrew R Korte, Sylwia A Stopka, Nicholas Morris, Trust Razunguzwa, Akos Vertes. Large-scale metabolite analysis of standards and human serum by laser desorption ionization mass spectrometry from silicon nanopost arrays. Analytical chemistry. 2016; 88: 8989-8996.

43. Joanna Nizioł, Wojciech Rode, Zbigniew Zieliński, Tomasz Ruman. Matrix-free laser desorption–ionization with silver nanoparticle-enhanced steel targets. International Journal of Mass Spectrometry. 2013; 335: 22-32.

44. Entesar Al-Hetlani, Mohamed O Amin, Metwally Madkour, Bessy D'Cruz. Forensic determination of pesticides in human serum using metal ferrites nanoparticles and SALDI-MS. Talanta. 2021; 221: 121556.