



Near-electrode pH change for voltammetric detection of insoluble lead carbonate

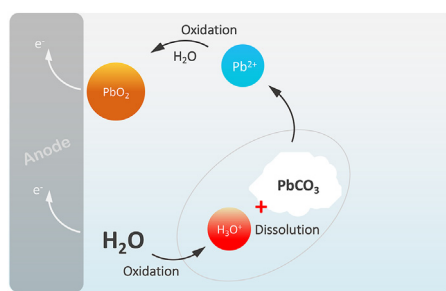
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HIGHLIGHTS

- Near-electrode pH decrease allows for reagentless dissolution of lead carbonate.
- Additions of insoluble lead carbonate to the solution increase the voltammetric response, similarly to soluble lead nitrate.
- Voltammetric quantification of insoluble lead carbonate was achieved without sample preparation.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 15 June 2021

Received in revised form

14 September 2021

Accepted 18 September 2021

Available online 20 September 2021

Keywords:

Reagentless method

Cathodic stripping voltammetry

Electrochemical acidification

Lead detection

Lead particulates

Local pH change

ABSTRACT

Lead contamination of drinking water is a concern to all inhabitants of old cities where lead pipes and soldering are still present. Simple on-site electrochemical detection methods are promising technologies that have gained attention recently. However, conventional electrochemical techniques only quantify soluble forms of lead in water without accounting for insoluble particulates. Herein, a simple voltammetric technique for quantification of insoluble lead species is reported. Lead carbonate (PbCO_3) was used as a model compound to show the possibility of detecting particulate lead species directly in solution without chemical treatment. Specifically, electrochemical generation of protons was used as an alternative method to dissolve PbCO_3 and thus obtain a more realistic assessment of lead contamination. Lead was detected using cathodic stripping square wave voltammetry (CSSWV). After applying a high oxidizing potential to the electrode immersed in a PbCO_3 solution with solid PbCO_3 particulates, a significant increase in current was observed as compared to that of a saturated PbCO_3 solution. The signal was proportional to the amount of added PbCO_3 , even when the solubility limit was exceeded. Thus, the combination of a local pH change with CSSWV provides a simple, rapid, and reagentless method for an in-situ detection of insoluble lead species.

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1. Introduction

Lead is well known for its toxicity. In addition to the deleterious effects common to most heavy metals, it was recently shown that

lead might also cause Alzheimer's disease [1]. Cardiovascular diseases, particularly hypertension, can also be provoked by this metal [2]. Potential sources of lead poisoning include drinking water. In cities built prior to 1987, pipes, fixtures, and welding materials containing lead were employed regularly in drinking water infrastructure. The Flint water crisis is one of the most notable examples of lead pipes having a significant negative impact on human health

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[3,4]. The analytical techniques for lead detection approved by the Environmental Protection Agency (EPA) include inductively coupled plasma mass spectrometry (ICP-MS), inductively coupled plasma atomic emission spectroscopy (ICP-AES), and graphite furnace atomic absorption spectroscopy (GFAAS) [5]. These methods require long sample preparation, the use of corrosive acids, expensive equipment, and trained personnel.

Electrochemical methods are simple, inexpensive, and have high potential for on-site analysis [6,7]. Anodic stripping voltammetry is among the most commonly used electrochemical techniques for the detection of lead, mostly due to its high sensitivity [8–12]. This method is based on the reduction of lead ions (Pb^{2+}) to form metallic lead on the electrode surface (deposition step) and its consecutive oxidation back to Pb^{2+} (stripping step). Several variations of cathodic stripping voltammetry can also be used for lead detection. The first approach, known as adsorptive stripping voltammetry, involves deposition of Pb^{2+} on an electrode surface modified with a reagent that forms a complex with lead, followed by reduction of the deposited product to lead metal (stripping step) [13–15]. The second approach involves direct anodic oxidation of Pb^{2+} ions to form lead (IV) oxide (PbO_2) and the consecutive reduction of the product to Pb^{2+} ions [16,17]. This method avoids the need to modify the electrode surface. Furthermore, the PbO_2 reduction peak appears at a very high potential [17,18], which may eliminate interference from other electroactive components. A similar analysis can be performed using stripping coulometry [19]. However, these techniques can only detect ions or dissolved complexes and do not account for insoluble particles. In most cases, to obtain accurate and representative results, sample preparation is required to transform all lead species into ionic forms.

In addition to Pb^{2+} ions, lead may exist in various nonionic forms (hydroxo complexes, insoluble salts, oxides, complexes with organic ligands, etc.) depending on the matrix composition. For example, in tap water collected from houses with lead pipes or exposed to lead soldering and plumbing fixtures, species such as PbCO_3 , $(\text{PbCO}_3)_2\text{Pb}(\text{OH})_2$, PbO , PbO_2 , and Pb_3O_4 are present [20]. Various ortho- and polyphosphate lead species can also be formed in drinking water [21,22]. Tap water may also contain significant amounts of humic acid [23], which is a strong complexing agent that can easily form soluble complexes with lead and other metal ions [24]. In soil, lead can form insoluble carbonates, sulfates, and

chlorides or bind to fulvic, humic, and amino acids [25]. The distribution of these species, in turn, depends on pH [26], and even time of year [27]. Lead carbonate (PbCO_3 or cerussite) is one of the predominant species in water distribution systems [21]. This compound has a very low solubility in water ($K_s = 7.40 \times 10^{-14}$). However, most carbonates, including PbCO_3 , are very soluble in acids. Thus, when the pH decreases, the solubility of PbCO_3 increases significantly.

Electrochemical pH changes can be used to easily control acidity of a solution without the use of additional aggressive reagents. In the case of natural or drinking water, pH changes mostly result from the neutralization of hydrolyzed salts [28]. Separating the cathode and anode with a non-proton exchange membrane allows for the generation of protons (the actual species formed is hydronium ions, H_3O^+) at the cathode while simultaneously preventing their oxidation at the anode, which aids in achieving a significant pH drop. This approach has been used in sensors to replace classic solution acidification [29]. A similar technique has also been used for weak acid synthesis [30]. Lacombe et al. reported a reagentless sensor for silicate determination that employs hydrogen ion generation to acidify the solution [31].

In an aqueous solution that contains only an indifferent electrolyte, the protons generated at the cathode move towards the anode, where they will be oxidized, with simultaneous movement of the hydroxyl ions generated at the anode towards the cathode, where they will be reduced. In addition, during migration to the corresponding electrodes, these two species can combine to form water molecules. Therefore, during the electrolysis of such solutions, the bulk pH does not change. However, if proton/hydroxyl ion generation occurs much faster than migration, the pH in the vicinity of the electrode surface can shift, especially in an unstirred solution. This near-electrode change in pH has been studied and even visualized by some authors [32–35].

This work demonstrates the potential of combining a local pH change with CSSWV to quantify lead species that were previously impossible to detect using electroanalytical techniques. Due to its very low solubility, PbCO_3 was chosen as a model compound to show the possibility of detecting insoluble lead species in situ. In this approach, a high oxidizing potential is applied to a platinum electrode to induce the simultaneous oxidation of water and Pb^{2+} , producing hydronium ions and PbO_2 , respectively. The hydronium ions chemically react with PbCO_3 in solution to form Pb^{2+} ions which undergo oxidation at the anode and are deposited as PbO_2 . Subsequently, cathodic stripping is performed to realize a quantitative voltammetric analysis of deposited PbO_2 . This method is simple, rapid, and requires no sample preparation.

2. Materials and methods

All reagents were purchased from Sigma-Aldrich. The Ag/AgCl reference electrode was obtained from eDAQ Incorporated, and the platinum working electrode (1.651–1626 mm diameter, 99.95% purity) was obtained from Bioanalytical Systems, Inc. All electrochemical measurements were performed using a PalmSens 3 potentiostat (Bioanalytical Systems, Inc).

Table 1

Areas of PbO_2 stripping peaks collected using $43.7 \mu\text{M}$ $\text{Pb}(\text{NO}_3)_2$ at different deposition potentials.

Deposition potential, V	Peak area, nC
+2.0	24.8 ± 1.0
+1.8	23.8 ± 0.7
+1.675	22.0 ± 0.4
+1.6	22.4 ± 0.1

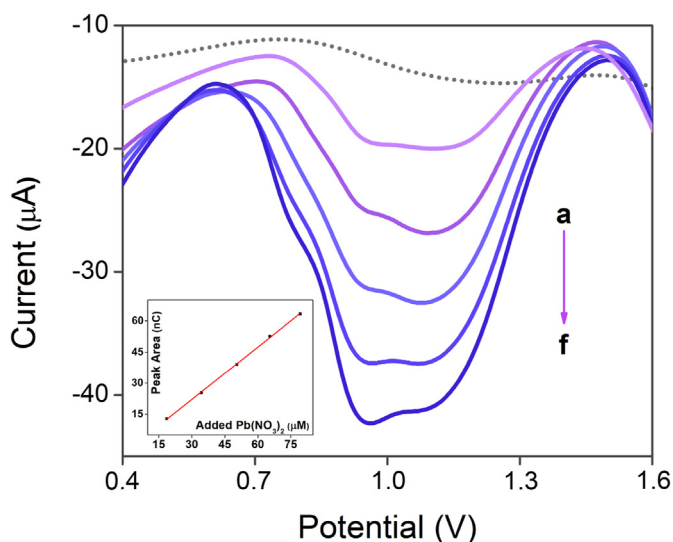
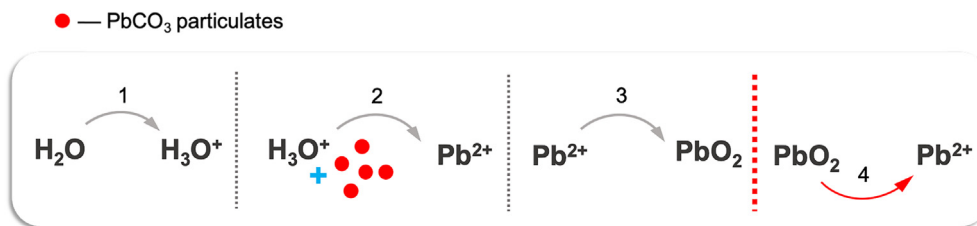


Fig. 1. CSVs for different concentrations of $\text{Pb}(\text{NO}_3)_2$ in STW (in μM): (a) 0, (b) 18.6, (c) 34.4, (d) 50.4, (e) 65.4, and (f) 79.3. Inset: calibration graph for $\text{Pb}(\text{NO}_3)_2$ in STW.



Scheme 1. Schematic of the proposed mechanism for PbCO₃ detection. (1) proton generation, (2) PbCO₃ dissolution, (3) PbO₂ deposition, and (4) PbO₂ stripping.

Simulated tap water (STW) was prepared by adjusting the conductivity of Milli-Q water with KNO₃ to 420 $\mu\text{S cm}^{-1}$, which approximates the conductivity of tap water in the Cincinnati area, OH, USA. The resulting pH was 6.5. This solution was used as a blank throughout the experiments, unless otherwise stated.

A working solution of Pb(NO₃)₂ (10.00 mg L⁻¹) was prepared by diluting a $1000 \pm 2 \text{ mg L}^{-1}$ Pb(NO₃)₂ ICP-MS standard with Milli-Q water. An aqueous suspension of PbCO₃ (1.000 g L⁻¹) was used to prepare PbCO₃ calibration solutions. Each spike was added immediately after sonication. The reported concentrations of PbCO₃ are referred to the number of moles of PbCO₃ (both solid and dissolved) present in 1 L of the mixture. Saturated solutions of PbCO₃ were obtained by centrifugation (45 min at 4000 rpm; F15–8 $\times$ 50cy, Thermo Scientific) of solid PbCO₃ suspended in STW or 0.1 M KNO₃.

Before use, the platinum working electrode was polished with alumina slurry ($d = 0.05 \mu\text{m}$). To remove any residual deposits from the electrode, electrochemical cleaning was performed after each measurement by cycling the electrode between -0.3 and $+1.0 \text{ V}$ (10 cycles at 0.5 V s^{-1}) directly in the tested solution. The counter electrode, electrochemical cell, and stirring bar were soaked in nitric acid to remove all possible contaminants.

Cathodic stripping voltammograms (CSVs) were recorded in the range from $+1.8$ to -0.35 V using the following parameters: deposition potential $+1.675 \text{ V}$; deposition time 20 s; quiet time 20 s; potential step 5 mV; amplitude 50 mV; frequency 60 Hz. All potentials were measured vs. Ag/AgCl. The solution was stirred during the deposition step using Fisher Scientific stirring plate at 100 rpm.

The voltammograms were processed using *PSTrace 5.8* software. The values for peak areas were obtained by integrating the *i*-*V* traces between two specific potentials. For the blank, the integration was performed between 0.76 V and 1.52 V. Same procedure was used for PbO₂ peaks (the potentials varied as the peak gets broader when lead concentration increases).

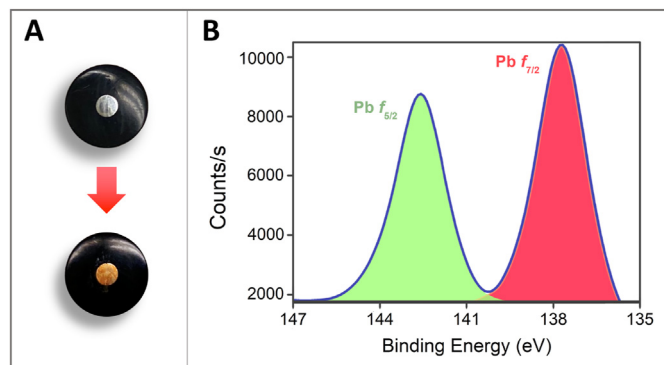


Fig. 2. (A) Color change of platinum electrode surface after deposition of PbO₂ from an oversaturated PbCO₃ solution at $+1.675 \text{ V}$ for 20 min. (B) XPS spectrum of platinum electrode surface after PbO₂ deposition. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

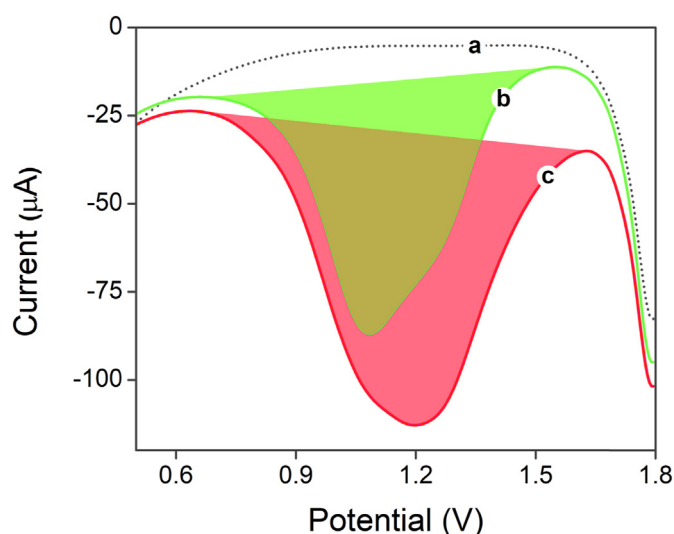


Fig. 3. CSVs recorded after 20 min deposition at $+1.675 \text{ V}$ deposition potential for (a) 0.1 M KNO₃, (b) saturated PbCO₃ in 0.1 M KNO₃, and (c) oversaturated PbCO₃ (with solid PbCO₃ particulates) in 0.1 M KNO₃.

ICP-MS data was collected using an Agilent Technologies 7700 Series ICP-MS system. ²⁰⁹Bi was used as the internal standard. All tested solutions were diluted 1000 times to fit within the calibration range.

X-ray photoelectron spectroscopy (XPS) measurements were

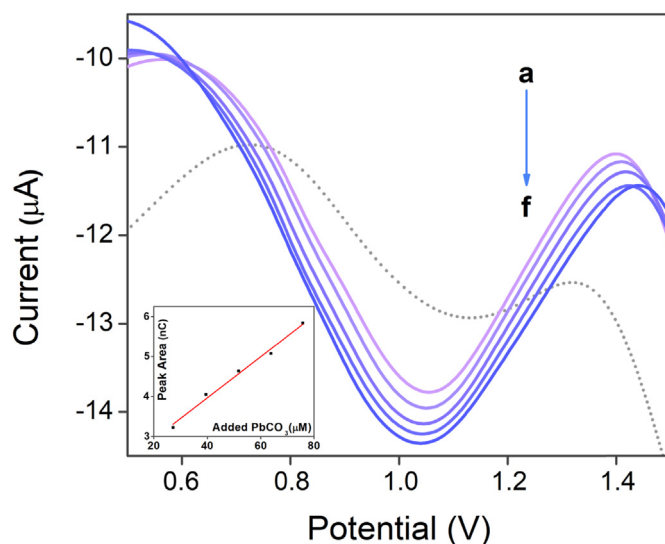


Fig. 4. CSVs for different concentrations of PbCO₃ in STW (in μM): (a) 0, (b) 27.2, (c) 39.5, (d) 51.7, (e) 63.8, and (f) 75.8. Inset: calibration graph for PbCO₃ in STW.

performed on a Thermo Fisher Scientific K-alpha system using an Al monochromatic X-ray source (1486.69 eV) and an electron flood gun for charge neutralization. The column pressure was below 10^{-7} Torr. Survey scans were performed at a pass energy of 160 eV, and high-resolution scans were performed at a pass energy of 20 eV. Peak fittings were analyzed using Avantage software.

3. Results and discussion

3.1. Optimization of CSSWV parameters

The stripping peaks of PbO_2 were observed at +1.1 and +0.9 V (Fig. 1). According to Laitinen et al. [19] and Kinard et al. [16], the secondary peak at +0.9 V is due to the stripping of a PbO_2 monolayer from the platinum surface, whereas the peak near +1.1 V represents the stripping of PbO_2 multilayers, one from another. The areas of both peaks increased when more $\text{Pb}(\text{NO}_3)_2$ was added to the solution. The effects of amplitude, frequency, and deposition potential on the PbO_2 stripping peaks were studied. First, the amplitude of the square wave was optimized. At amplitudes below 0.005 V, the current ranges were very low, and some distortion of the peak shapes was observed at 0.001 V (Figs. S1A and S1B). At higher amplitudes (0.01 and 0.05 V), the peaks were more intense and well-pronounced (Figs. S1C and S1D). Although increasing the amplitude further resulted in higher currents, the peaks become less pronounced (Figs. S1E and S1F). Thus, 0.05 V was chosen as the optimum amplitude. Varying the frequency had almost no effect on the peak shapes, although it significantly affected the current range (Fig. S2). The frequency associated with the most intense peak (60 Hz) was used for all further measurements. The deposition potential must be sufficient for both Pb^{2+} and water oxidation. However, if the potential is too high, oxygen bubbles can form on the electrode and block its electroactive surface. It can be seen from the cyclic voltammogram of STW on a platinum electrode that a sufficient water oxidation current is achieved at potentials higher than +1.4 V (Fig. S3). Fig. S4 shows the CSVs of 43.7 μM $\text{Pb}(\text{NO}_3)_2$ recorded at different deposition potentials. In the range from +1.6 to +2.0 V, only slight differences in peak areas were observed (Table 1). For all further experiments, a deposition potential of +1.675 V was used (as suggested for PbO_2 deposition on a platinum electrode by Zerihun et al. [17]).

3.2. Blank signal

In the CSV of STW, a reduction peak was observed at

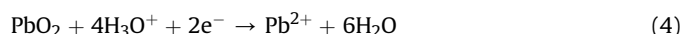
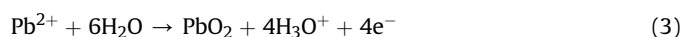
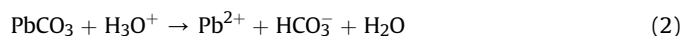
approximately +1.1 V (dashed curve, Fig. 1). This signal appeared even without the deposition step, and the peak area remained nearly constant ($\pm 8\%$) after multiple consecutive scans. It is also observed on the CV of STW (inset of Fig. S3). We assumed that this signal results from the reduction of surface platinum oxide species. A possible redox reaction that involves platinum oxide species and occurs around 1.15–1.40 V was described earlier by Jerkiewicz et al. [36]. A similar faint peak has also been described for PdO_2 reduction [37–39]. For all quantitative measurements, the area of the blank signal was mathematically subtracted from the peak area of any measured signal.

3.3. Quantification of lead ions

For the detection of soluble Pb^{2+} ions, a $\text{Pb}(\text{NO}_3)_2$ solution was used. The calibration range was chosen based on the solubility of PbCO_3 , as it was the species of interest. It was necessary to explore whether a quantitative relationship exists between the signal and the lead concentration in the range that exceeds the solubility limit of PbCO_3 . Using ICP-MS, the solubility of PbCO_3 in STW was determined to be $13.7 \pm 1.1 \mu\text{M}$. Therefore, the calibration graph for $\text{Pb}(\text{NO}_3)_2$ was constructed in the range of 18.6–79.3 μM ($\text{Peak Area} = -(0.64 \pm 0.22) + (0.169 \pm 0.004) \times C_{\text{Pb}(\text{NO}_3)_2}$; $R^2 = 0.9993$).

3.4. Mechanism of PbCO_3 detection

PbCO_3 was chosen as a model compound to show the possibility of using CSSWV for the quantitative analysis of insoluble lead species. The deposition potential of +1.675 V is high enough to induce water oxidation (Equation (1)). As a result, hydronium ions form at the anode. We assume that PbCO_3 particulates chemically interact with hydronium ions (Equation (2)), yielding Pb^{2+} ions that undergo further oxidation (Equation (3)). During the stripping step, deposited PbO_2 is reduced (Equation (4)). A schematic illustration of the proposed mechanism is shown in Scheme 1.



To show that PbO_2 can be formed from PbCO_3 , the platinum electrode was immersed in 5 mM PbCO_3 in STW, and then a

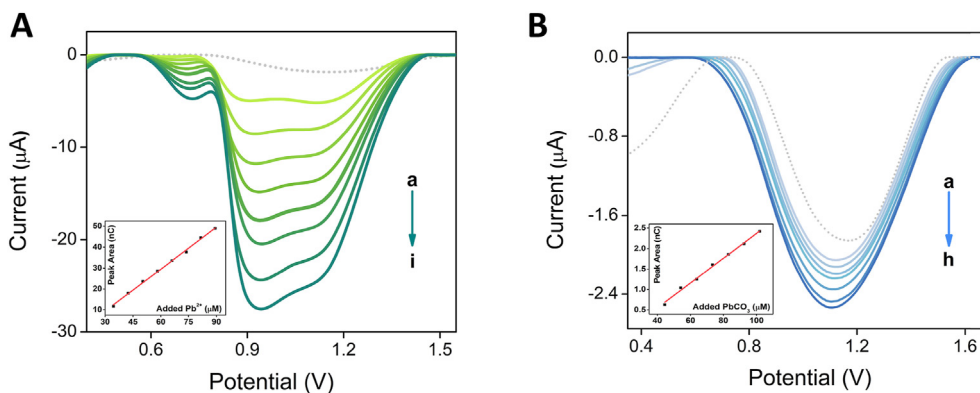


Fig. 5. (A) CSVs for different concentrations of $\text{Pb}(\text{NO}_3)_2$ in tap water (in μM): (a) 0, (b) 34.5, (c) 42.4, (d) 50.3, (e) 58.2, and (f) 66.0, (g) 73.8, (h) 81.6, (i) 89.4. Inset: calibration graph for $\text{Pb}(\text{NO}_3)_2$ in tap water; (B) CSVs for different concentrations of PbCO_3 in tap water (in μM): (a) 0, (b) 44.4, (c) 54.1, (d) 63.8, (e) 73.4, (f) 82.9, (g) 92.5, (h) 102. Inset: calibration graph for PbCO_3 in tap water.

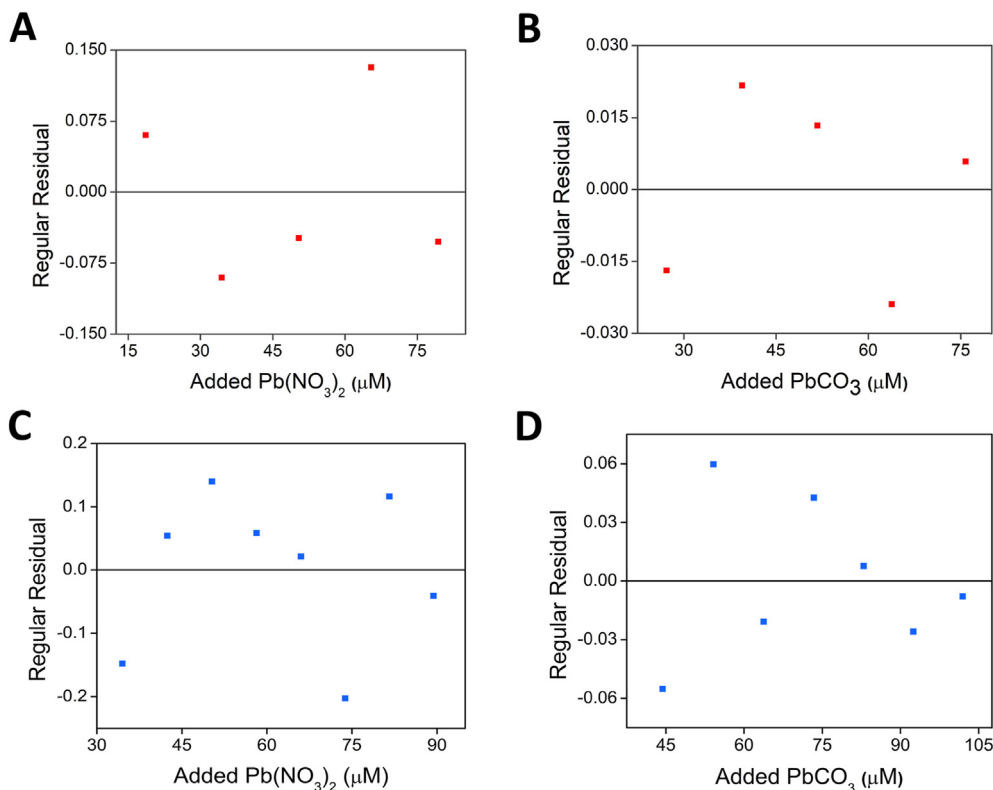


Fig. 6. Regular residual plots for the linear regression of Pb(NO₃)₂ in STW (A), PbCO₃ in STW (B), Pb(NO₃)₂ in tap water (C), and PbCO₃ in tap water (D).

Table 2

Statistical parameters for the calibration graphs.

Calibration graph	V _{xo} , %	CQC, %	LOD _{3s} , μM	LOQ _{10s} , μM
Pb(NO ₃) ₂ in STW	1.3	1.2	0.5	1.8
PbCO ₃ in STW	4	2.2	9	29
Pb(NO ₃) ₂ in tap water	4	5	1.0	3
PbCO ₃ in tap water	0.4	2.2	23	44

V_{xo}: standard deviation of the calibration; CQC: calibration quality coefficient; LOD_{3s}: limit of detection estimated at 3s; LOQ_{10s}: limit of quantification estimated at 10s.

potential of +1.675 V was applied for 20 min. After deposition, a characteristic brown layer of PbO₂ was formed on the electrode (Fig. 2A and S5). An XPS evaluation of this deposit gave a 4f_{7/2} binding energy of 138.0 eV (referenced to the C1s line), which is very close to the value of 137.9 eV for PbO₂ reported by Morgan et al. [40] (Fig. 2B). The XPS survey spectrum and data are shown in Fig. S6 and Table S1, respectively. A similar deposition experiment was performed using 15.0 μM Pb(NO₃)₂, which is higher than the concentration of PbCO₃ in a saturated solution. After applying a potential of +1.675 V for 20 min, no deposited product was observed. This finding indicates that in the case of PbCO₃, solid PbCO₃ dissolves during electrolysis via a chemical reaction, forming significantly more Pb²⁺ ions than were initially present in the solution.

To confirm that protons are involved in the transformation of PbCO₃, CSVs were recorded for saturated and oversaturated (with solid particulates) solutions of PbCO₃ (Fig. 3). As solubility is limited by the solubility constant (at a specific temperature and ionic strength), the initial concentrations of Pb²⁺ in both solutions must be equal. Nevertheless, the peak area obtained in the presence of solid PbCO₃ (195 ± 20 nC) was much larger than that for the

saturated solution (127 ± 2 nC), indicating that more PbO₂ was deposited on the electrode. Thus, it was concluded that solid PbCO₃ undergoes dissolution during the deposition step, producing Pb²⁺ ions. This occurs as a result of local pH decrease on the surface of platinum electrode, in a similar manner to that reported by Bischoff et al. [33], where major local pH changes were visualized at operando using pH indicators. However, due to the limited proton generation times (20 s) employed in our experiments, no pH changes of the bulk solution were observed. When CSVs were recorded in STW, a significant baseline shift was observed for the oversaturated PbCO₃ solution, thus preventing reliable determination of the peak areas. Consequently, the CSVs in Fig. 3 were obtained using 0.1 M KNO₃ as a blank.

3.5. Quantification of PbCO₃

To construct a calibration graph for the quantitative analysis of PbCO₃, different amounts of PbCO₃ (aqueous suspension) were added to STW and CSVs were recorded (Fig. 4). The signal was linearly proportional to the PbCO₃ concentration in the range of 27.2–75.8 μM (Peak Area = (0.38 ± 0.06) + (0.0102 ± 0.0011) × C_{PbCO₃}; R² = 0.9869). At concentrations below the calibration range, the curve deviated from linearity, and at higher concentrations, characteristic “saturation” of the calibration curve was observed (Fig. S7A). In the case of PbCO₃, the deposition rate is limited by the reaction (2). Therefore, at the same concentration, the CSVs recorded for PbCO₃ and Pb(NO₃)₂ have different current values (smaller for PbCO₃). As a result, the calibration graph for PbCO₃ has a smaller slope than that for Pb(NO₃)₂.

Normally, the concentration of lead in drinking water will not exceed the permissible limits of 15 μg L⁻¹ (equivalent to 72 nM of Pb²⁺) required by EPA. PbCO₃ (and other insoluble lead species) in

tap water results from their detachment from lead pipes employed for water transportation. In this case, the concentration of lead ions will significantly increase, as result of PbCO_3 dissociation (solubility of PbCO_3 under tested conditions was $13.7 \mu\text{M}$). Regardless the amount of solid PbCO_3 , concentration of Pb^{2+} produced by PbCO_3 dissociation will remain the same. If dissolved lead species were previously present in solution, their concentration would be negligibly small, when compared to the ions resulting from PbCO_3 dissociation. Thus, the simultaneous presence of both Pb^{2+} and PbCO_3 in tap water should not affect the accuracy of the analysis. In case when significant amount of Pb^{2+} is already present in water and afterwards a PbCO_3 contamination occurs, the accurate quantification will not be possible.

3.6. Quantification of lead ions and PbCO_3 in tap water

The proposed technique was successfully applied for the analysis of a real tap water sample. The tap water sample was used without any previous treatment. The CSV recorded in pure tap water were used as blanks. To construct the calibration graphs for $\text{Pb}(\text{NO}_3)_2$ and PbCO_3 , different amounts of respective species were added in tap water and CSVs were recorded (Fig. 5). For $\text{Pb}(\text{NO}_3)_2$, the signal was linearly proportional to the $\text{Pb}(\text{NO}_3)_2$ concentration in the range of $34.5\text{--}89.4 \mu\text{M}$ ($\text{Peak Area} = -(2.12 \pm 0.24) + (0.134 \pm 0.004) \times C_{\text{Pb}(\text{NO}_3)_2}$; $R^2 = 0.9974$). For PbCO_3 , the signal was linearly proportional to the PbCO_3 concentration in the range of $44.4\text{--}102 \mu\text{M}$ ($\text{Peak Area} = -(0.037 \pm 0.015) + (0.00605 \pm 0.00020) \times C_{\text{PbCO}_3}$; $R^2 = 0.9951$). The deviations from linearity below and above the calibration range are shown in Fig. S7B.

3.7. Statistical analysis of the results

All outliers were identified and removed from the data set using the Grubbs test. The signals were measured in triplicate for each calibration solution. Based on these data, repeatability relative standard deviations (RSD_r) were calculated for $\text{Pb}(\text{NO}_3)_2$ in STW ($\text{RSD}_r = 1\%$ at $50.4 \mu\text{M}$), PbCO_3 in STW ($\text{RSD}_r = 6\%$ at $51.7 \mu\text{M}$), $\text{Pb}(\text{NO}_3)_2$ in tap water ($\text{RSD}_r = 0.4\%$ at $58.2 \mu\text{M}$), and PbCO_3 in tap water ($\text{RSD}_r = 4\%$ at $54.1 \mu\text{M}$). The plots of the regular residuals for all linear regressions have no visible trends but a random spread of data points, thus showing the good linear fits of these curves (Fig. 6).

The quality of each calibration was estimated using the standard deviation of the calibration and the calibration quality coefficient. In each case, these values did not exceed 5%. The limits of detection and limits of quantification were estimated at 3s and 10s, respectively, using the standard deviation of 20 blank signals. All statistical parameters for the calibration graphs are shown in Table 2.

4. Conclusion

Local pH change was successfully applied for near-electrode dissolution of PbCO_3 . Formed lead ions deposited on the electrode surface and contributed to the voltammetric response, thus allowing for the quantification of insoluble PbCO_3 . Three consecutive detections of PbCO_3 in STW and tap water had RSD_r of 6% (for $51.7 \mu\text{M}$) and RSD_r of 4% (at $54.1 \mu\text{M}$) respectively. The calibration graphs were constructed for cathodic stripping square wave voltammetric detection of PbCO_3 under optimum conditions (amplitude 0.05 V , frequency 60 Hz and deposition potential $+1.675 \text{ V}$). The calibration curves possessed good metrological characteristics (both V_{XO} and $\text{CQC} < 5\%$) in the range of $27.2\text{--}75.8 \mu\text{M}$ for STW and $44.4\text{--}102 \mu\text{M}$ for tap water. The proposed approach is simple, reagent-free and allows for an in-situ detection of insoluble PbCO_3 .

CRedit authorship contribution statement

Artur Huseinov: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Writing – original draft, Visualization. **Benjamin L. Weese:** Investigation, Validation. **Brody J. Brewer:** Investigation. **Noe T. Alvarez:** Conceptualization, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work ported in this paper.

Acknowledgements

The authors would like to thank William Heineman for discussion and feedback, and Julio Landero for his assistance with ICP-MS analysis. Finally, authors thank to NSF 2016484 grant under the NSF PFI-RP program.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.aca.2021.339087>.

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