Deposition Efficiency of Polonium-210 on Various Metals

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Abstract – Polonium-210 is widely studied due to its potential significance on radiological health and usefulness as a natural tracer of environmental processes. The technique for a determination of \( ^{210} \)Po involves spontaneous deposition onto polished metal surfaces in weak acid solutions. This research studied on the effects of HCl concentration, plating time and plating temperature on the \( ^{210} \)Po deposition efficiency of different metals. The average percentage of \( ^{210} \)Po deposition efficiency on silver, nickel and copper were 84, 72 and 63, respectively. The conditions of 5 hours plating time, at 80\( ^0 \)C and 0.3 M HCl obtained the optimum deposition efficiency of the three studied metals. However, the deposition efficiency indicated Ag > Ni > Cu. The obtained deposition conditions were validated to determine the \( ^{210} \)Po activity in seafood. Nickel metal with 5 hours plating time and at 80\( ^0 \)C was performed in the analysis because the metal is more economical than silver.

Keyword: polonium-210, plating metal, spontaneous deposition, deposition efficiency, seafood
1. Introduction

Polonium-210 ($^{210}$Po) is a naturally occurring $\alpha$-emitter with a half life of 138.4 days. $^{210}$Po exists in the environment as a decay product of uranium-238 series. It has featured particularly prominently in studies of marine sedimentation processes, food chains, atmospheric circulation and aerosol behavior [1-6].

The method of $^{210}$Po analysis divides into 2 steps which the first step is purification using radiochemical separation, liquid-liquid chromatography, solid phase extraction or ion exchange resin. The final step is source preparation in order to measure the $^{210}$Po concentration activity in the alpha spectrometer which spontaneous or auto deposition is employed. The analysis of $^{210}$Po in environmental samples depends on the radiochemical procedure and plating technique used [2, 4-6].

Of the natural radioactivity of human foodstuffs, $^{210}$Po is the major contributor, with 8% of the natural internal radiation dose to man. The maximum permissible human body burden for ingested $^{210}$Po is only 1.1-10.3 Becquerel (Bq). With regard to internal exposure to humans, $^{210}$Po is one of the most radiotoxic nuclides due to its $\alpha$-emitter and concentration in the soft tissue, such as muscle, liver, kidney, spleen and bone marrow.

The studies of $^{210}$Po in marine organism have attracted the attention of researchers because of their relatively high concentrations in comparisons with those in terrestrial organisms. Marine organisms have the capacity of bioaccumulation more radionuclides from water and $^{210}$Po is found to be accumulated in seafood with high potential It has been reported that $^{210}$Po is particularly concentrated in the digestive glands of mollusks and crustaceans.[2,4].

In the present study, a spontaneous deposition technique was determined for the deposition efficiency of $^{210}$Po on three metals i.e., silver, nickel and copper at different deposition conditions. The achieved conditions were validated by applying for the analysis of $^{210}$Po in seafood (squid) samples.

2. Research methodology

2.1. Investigation of various metals deposition efficiency

In the literature was found that the Po spontaneous deposition is more efficient from HCl solutions than from HNO$_3$ or H$_2$SO$_4$ [3, 4]. Therefore, in this study a hydrochloric solution was applied.

The effects of molarity of HCL solution, plating temperature and plating time on the Po plating yield were evaluated independently by varying one of the parameters while keeping the other two as constant.

Silver, nickel and copper with 95% pure of effective area of 1.8x1.8 cm$^2$ have been used in experiments. The metal plates were polished on one side and the other side was coated with rubber adhesive. On the corner of metal plate was punched a 0.1 mm diameter hole. The solution of 0.3, 0.5 and 1 M HCl and the temperature of 25 (room temperature), 80 and 90°C were carried out while the deposition times investigated were 1, 3, 5, 7, 16, and 18 hours.

Since $^{209}$Po is mostly used in laboratory as analytical tracer, in this study we have preferred a $^{209}$Po. The $^{209}$Po (Eckert & Ziegler Isotope Products) with known activity was spiked into 100 ml of 0.3, 0.5 and 1 M HCL, respectively. Ascorbic acid 0.5 g was added to eliminate the interference by reducing Fe (+3) to Fe (+2) [2, 3].

$^{210}$Po was spontaneously deposited in HCL at set temperature and plating time with a mechanical stirring throughout the experiment. The plating metal was immersed in the solution using a glass hook. After completion of the deposition, the metal was removed, rinsed with distilled water and dried at room temperature. $^{210}$Po was measured by $\alpha$-spectrometer equipped with semiconductor surface barrier silicon detectors (ORTEC, Model Octete PLUS).

2.2 Application of the technique on analysis of $^{210}$Po in seafood

The seafood under this investigation were exported products during 2010 Fukushima event. Three samples of each company were taken out on validating the conditions. Head and body of squids were analyzed separately. A batch of experiments was undertaken, with three each on squid samples and identical deposition conditions. Five gram of freeze dried seafood (squid) sample was spiked with $^{209}$Po as a yield tracer. The sample was digested in concentrated HNO$_3$, HClO$_4$ and HCl subsequently. Each portion of acids was evaporated to dryness at temperature of about 80°C. The dry residue was dissolved in 100 ml of 0.3 M HCL and after addition of ~ 0.5-1 g ascorbic acid or until yellowish solution turn into clear; Po was spontaneously plated from the solution at the gained conditions which plating steps followed as mention in 2.1. The sample was measured for 2-4 days.

The accuracy and precision of the radiochemical method were evaluated using IAEA reference materials.

3. Results and Discussion

3.1. Investigation of various metals deposition efficiency

The effects of plating time, plating temperature and HCl concentration on the Po deposition efficiency of different metals were shown in Fig 1-3.

The molarity of HCl solution and the deposition temperature were investigated in a deposition time of 1, 3, 5, 7, 16, and 18 hours However, results showed in Fig 1 and 2 are held with plating time of 5 hrs because no dramatic effect observed on metal surfaces.
The curve illustrated in Fig.1 shows that the deposition efficiency appears to be affected by the molarity of HCl solution. The plating yield trend to be downward at the molarity of HCl increased. Silver, nickel and copper showed the highest deposition efficiency of 90, 83 and 76% and the lowest of 80, 75 and 67%, respectively. Hence, the 0.3 M HCl was used in the further studied conditions.

As shown in Fig 3, the Po deposition efficiency increased exponentially with increasing plating time. The silver metal was deposited for 18 hours, exhibiting very little surface etching and consequently possessing a better alpha resolution. On nickel, an average deposition efficiency of 72% was reached in 5 hours. Longer deposition times than 5 hours, the sample solution had a significant pale green color arising from dissolved Ni²⁺ ions. Deposition efficiency dramatically dropped to 56%. In addition, the surface of nickel has been altered as a result of the oxidation of nickel metal to Ni²⁺ [3]. Hence, the suggested deposition time of 18 hours on nickel seemed unnecessary. With Copper, the deposition efficiency after 5 hours, at room temperature was lower, average 63%.

3.2 Application of the technique on analysis of $^{210}$Po in seafood

The condition of Ni metal, 5 hours plating time and 80°C was employed. Although Ni metal is more prone to interferences as some $^{210}$Bi and/or $^{210}$Pb may also be deposited, the use of this metal likely to reduce costs. The reproducibility was determined from three squid samples which were divided into edible part of head and body. Triplicate on each squid samples and identical depositions were performed. The average overall statistical uncertainty from the measurement was 5%, at the 95% confidence level. The uncertainty depends on the activity concentration of the sample, and statistical uncertainty is lower at higher activity concentrations. Uncertainty can be slightly reduced by increasing the count rate. In this study, a count rate of at least 1000 counts was required because it was considered to provide sufficient accuracy.

It was reported that $^{210}$Po in the tap waters of Vienna were measured to be a mean value of 2.18 ± 1.06 mBq.Kg⁻¹ [7] while in the mussel of the Atlantic coast of Portugal were 759 ± 277 Bq.Kg⁻¹ (dry weight) [8]. For very low-level sample, the silver metal was suggested to be performed since a higher deposition yield resulted in lower detection limit. Therefore, the use of metals other...
than silver seems to be little benefit. In addition, in the previous work [3, 6] observed the heating losses at more than 300°C of polonium deposited on nickel were markedly higher than silver. It indicated a high thermal stability of the silver metal. Therefore, detectors are less contaminated with polonium by using silver during the measurement under vacuum due to its shorter measurement time.

In conclusion, the best choice of spontaneous deposition is silver metal, 0.3 M HCl concentration, at room temperature and overnight plating time (16-18 hours). However, the condition of nickel metal, 0.3 M HCl concentration, at 80°C and 5 hours plating time is an alternation for rather high 210Po samples such as polluted water from mining activities, tobacco leaves, and seafood.

4. Conclusions

Five sets of each parameter tests were performed to determine the effects of the concentration of acid used, plating temperature and time on the 210Po deposition efficiency. The auto-deposition of 210Po was performed in a constantly stirred using a magnetic stirrer.

The optimum conditions, 0.3M HCl, at 80°C and 5 hours of plating time offered the maximum deposition efficiency of the three studied metals. The deposition efficiency of Po towards these metals is in the following order: silver > nickel > copper.

The advantage of silver was the best deposition yield which necessary for low detection limits in low-level analyses and of nickel was the low cost. However, Ni metal is more prone to interferences as some 210Bi and/or 210Pb may also be deposited. Hence, nickel can be employed in the sample only with high content of 210Po i.e., mine water drainage, tobacco leaves and seafood.

The deposition conditions have been successfully applied to squid samples, obtaining reproducible results.

It should be noted that it is important to reduce the relative uncertainty for each Po measurement by getting good count rates. In this study, the count rate of at least 1000 counts was considered. The accuracy of the analysis method is determined by the alpha counting error and its propagation through calculations.

References


