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# **Determination of Plutonium in Environmental Samples by Controlled Valence in Anion Exchange**

**Qingjiang Chen, Asker Aarkrog, Sven P. Nielsen, Henning Dahl-  
gaard, H. Nies, Yixuan Yu, K. Mandrup**

**Risø National Laboratory, Roskilde, Denmark  
February 1991**

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DETERMINATION OF PLUTONIUM IN ENVIRONMENTAL SAMPLES BY CONTROLLED  
VALENCE IN ANION EXCHANGE

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Abstract. The method was successfully used for collecting  $^{239,240}\text{Pu}$  from 200 litres seawater by coprecipitation with 16 g  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  under reducing conditions without filtering. The plutonium is leached by concentrated  $\text{HNO}_3 + \text{HCl}$  from the coprecipitate and the solid particles. The precipitate is heated at  $400^\circ\text{C}$  and digested in aqua regia.  $\text{Na}_2\text{SO}_3$  and  $\text{NaNO}_2$  have been applied to obtain  $\text{Pu}^{4+}$  valence in 0.5-1 N  $\text{HNO}_3$  for different samples. Plutonium and thorium are coabsorbed on anionic resin from 8 N  $\text{HNO}_3$ . The column is eluted with 8 N  $\text{HNO}_3$  containing fresh  $\text{NaNO}_2$  to keep  $\text{Pu}^{4+}$  valence for uranium decontamination. The system of the column is changed from 8 N  $\text{HNO}_3$  to concentrated  $\text{HCl}$  with 50 ml conc.  $\text{HCl}$  containing a few milligram  $\text{NaNO}_2$ . Further decontamination of thorium was achieved by elution with concentrated  $\text{HCl}$  instead of 9 N  $\text{HCl}$ . The plutonium is successfully stripped by  $\text{H}_2\text{O}$ ,  $\text{NaOH}$ , 2 N  $\text{HNO}_3$  and 0.5 N  $\text{HNO}_3$  containing 0.01 M  $\text{NaNO}_3$ . The chemical yield of plutonium for a 200 litres-seawater sample is 60-80%. The resolution of the electroplated thin source is very good.

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## 1. INTRODUCTION

Previous works<sup>1,2</sup> have demonstrated that an anion exchange separation of plutonium could be used for routine analysis of environmental samples. The procedures based on the absorption of anionic complexes of plutonium from nitric and hydrochloric acid media have been reviewed<sup>1</sup>. The  $\text{Pu}(\text{NO}_3)_6^{-2}$  and  $\text{PuCl}_6^{-2}$  are absorbed on the anionic exchange. However, the plutonium valence ( $\text{Pu}^{3,4,5,6}$ ) is variable. The  $\text{Pu}^{3+}$  is easily oxidized to  $\text{Pu}^{4+}$  with  $\text{NaNO}_2$  and  $\text{H}_2\text{O}_2$  while  $\text{Pu}^{5,6+}$  are reduced to  $\text{Pu}^{4+}$  with  $\text{NaNO}_2$ , but the reaction is slow and incomplete. Especially for large volumes seawater samples with organic material and impurities, we found that it was very difficult to control the plutonium valence with  $\text{NaNO}_2$  and  $\text{H}_2\text{O}_2$ . The chemical yield of plutonium was low too. We further observed a thorium contamination in case of large volume seawater eluted by 9 N HCl. Hence it was important to develop a new method to control the plutonium valence and improve the thorium decontamination for large volume seawater and environmental samples.

## 2. FLOW SHEET OF THE PROCEDURE FOR 200 LITRES SEAWATER

On board the ship:

- 1) Acidify 200 litres seawater to pH about 2 with 200 ml concentrated HCl.
- 2) Add 16 g  $\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$ ,  $^{242}\text{Pu}$  and 200 g  $\text{Na}_2\text{S}_2\text{O}_5$ . Stir by air bubbling for 1 h to reduce all Pu valences to  $\text{Pu}^{3+}$ .
- 3) Basify the 200 litres seawater to pH = 8.5-9 with diluted NaOH (0.5-1 N) to precipitate  $\text{Fe}(\text{OH})_2$ . The diluted NaOH is added with a shower to reduce formation of  $\text{Ca}(\text{OH})_2$  and  $\text{Mg}(\text{OH})_2$ .
- 4) Let stay for 5 h or overnight. Siphon off the supernatant liquid to get about 5 litres of  $\text{Fe}(\text{OH})_2$  slurry.
- 5) Acidify the solution to about 0.1 N HCl with concentrated HCl (10 ml HCl/litre).
- 6) Transfer the sample to laboratory for analysis.

**In the laboratory:**

2.
  - 1) Add  $\text{Na}_2\text{S}_2\text{O}_8$  (2 g/litre) to the sample solution. Let stay for 1 h.
  - 2) Slowly add diluted NaOH with a small shower to pH = 8.5 to prevent formation of  $\text{Mg}(\text{OH})_2$  and  $\text{Ca}(\text{OH})_2$ . Let stay for 30 min.
  - 3) Siphon off the supernatant liquid. Filter the precipitate with glass filter paper AG/A. Discard the solution.
  - 4) Dissolve the  $\text{Fe}(\text{OH})_2$  with 100 ml conc. HCl and 100 ml conc.  $\text{HNO}_3$ .
  - 5) Filter the solution through glass filter paper AG/A into a 500 ml beaker. Evaporate to complete dryness.
  
3.
  - 1) Heat at 400°C for 1 h. Let stay for cooling. Add 120 ml aqua regia to dissolve. Cover the beaker with a glass disc, heat for 1 h.
  - 2) Evaporate to dryness. Repeat step 1). Filter the solution. Wash the precipitate with 100 ml 8 N  $\text{HNO}_3$ . Discard the precipitate.
  - 3) Evaporate to about 7 ml. Dilute to 150 ml. The acid is about 0.5-1 N  $\text{HNO}_3$ .
  - 4) Add 3 g  $\text{Na}_2\text{SO}_3$ . Let stay for 20 min. The plutonium is reduced to  $\text{Pu}^{+3}$ .
  - 5) Add 3 g  $\text{NaNO}_2$ . Let stay for 10 min. The  $\text{Pu}^{+3}$  is oxidized to  $\text{Pu}^{+4}$ .
  - 6) Acidify the solution to 8 N  $\text{HNO}_3$  with 165 ml concentrated  $\text{HNO}_3$ .
  
4.
  - 1) Add the solution to a column (10 x 2.1 cm AG 1-X<sub>4</sub>, 100-200 mesh) which is equilibrated with 50 ml 8 N  $\text{HNO}_3$  + 1 g  $\text{K}_2\text{S}_2\text{O}_8$  and 100 ml 8 N  $\text{HNO}_3$  + 0.5 g  $\text{NaNO}_2$  (fresh). The flow rate is about 3 ml/min.
  - 2) Wash the column with 350 ml 8 N  $\text{HNO}_3$  (10c.v) + 1 g  $\text{NaNO}_2$  (fresh).
  - 3) Wash with 50 ml concentrated HCl which is saturated with 100 mg  $\text{NaNO}_2$  (fresh).
  - 4) Wash with 300 ml concentrated HCl.

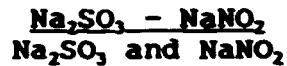
5.
  - 1) Strip with: 30 ml H<sub>2</sub>O, 20 ml 0.3 N NaOH, 30 ml H<sub>2</sub>O, 20 ml 2 N HNO<sub>3</sub>, 200 ml 0.5 N HNO<sub>3</sub> containing 0.01 M NaNO<sub>3</sub>. Evaporate to dryness.
  - 2) Dissolve the precipitate with 10 ml 0.7 N HNO<sub>3</sub>. Add 300 mg Na<sub>2</sub>SO<sub>3</sub>. Stir and let stay for 15 min. Add 300 mg NaNO<sub>2</sub>. Let stay for 10 min. Add 12 ml conc. HNO<sub>3</sub>.
  - 3) Make a column (7 x 0.8 cm) Ag 1-X, 100-200 mesh. Eluate the column with 20 ml 8 N HNO<sub>3</sub> containing 3 mg/ml NaNO<sub>2</sub> (fresh).
  - 4) The solution is passed through the column. The flow rate is about 1 ml/min.
  - 5) Wash the column with 20 ml 8 N HNO<sub>3</sub> containing 3 mg/ml NaNO<sub>2</sub>.
  - 6) Strip with: 4 ml H<sub>2</sub>O, 4 ml 0.3 N NaOH, 4 ml H<sub>2</sub>O, 4 ml 2 N HNO<sub>3</sub>, 20 ml 0.5 N HNO<sub>3</sub> containing 0.3 M NaNO<sub>3</sub>.
  - 7) Add 0.3 ml conc. H<sub>2</sub>SO<sub>4</sub>. Evaporate to dryness.
  
6.
  - 1) Dissolve the precipitate with 0.5 N H<sub>2</sub>SO<sub>4</sub>. Wash the beaker with 9 ml 0.5 N H<sub>2</sub>SO<sub>4</sub>. Combine these solutions into the electrodeposition cell.
  - 2) Adjust the solution to pH = 2.2 for electrodeposition.
  - 3) The current is 0.6 A/cm<sup>2</sup>. The time is 6 h. Cool the cell with water.
  - 4) Cover the surface of the source with VYNS thin film (10-15 μg/cm<sup>2</sup>).

### 3. RESULTS AND DISCUSSION

Seawater samples as large as 200 litres are collected with Fe(OH)<sub>2</sub> coprecipitate at pH = 8.5-9 in a reducing system. The Fe(OH)<sub>2</sub> is dissolved in conc. HCl and conc. HNO<sub>3</sub>. The plutonium is dissolved and leached from possible plankton and solid particles present in the solution. The diluted NaOH (0.5-1 N) is added with a shower to reduce the formation of Ca(OH)<sub>2</sub> and Mg(OH)<sub>2</sub>. This is of benefit for the plutonium purification. The sample is heated to 400°C for one hour and digested with aqua



regia to destroy the organic material, which may interfere when controlling the valency of plutonium. By the heating, decontamination for polonium is furthermore obtained.



are applied in preparation of  $\text{Pu}^{IV}$ . The plutonium valences ( $\text{Pu}^{IV, V, VI}$ ) are reduced to  $\text{Pu}^{III}$  by  $\text{Na}_2\text{SO}_3$ , and then, the  $\text{Pu}^{III}$  is oxidized to  $\text{Pu}^{IV}$  by  $\text{NaNO}_2$  in 0.5-1 N  $\text{HNO}_3$ . Both reactions are fast and nearly quantitative. A high proportion of  $\text{Pu}^{IV}$  is obtained. Table 1 shows the chemical yield of plutonium using redox-systems of  $\text{NaNO}_2$ - $\text{NaNO}_2$  and  $\text{Na}_2\text{SO}_3$ - $\text{NaNO}_2$  respectively.

**Table 1.** Comparing the chemical yield of plutonium by redox-systems of  $\text{NaNO}_2$ - $\text{NaNO}_2$  and  $\text{Na}_2\text{SO}_3$ - $\text{NaNO}_2$  respectively.

No.	Seawater litres	Reducing agent	Oxidizing agent	Chemical yield $^{242}\text{Pu}$ , %
165	50	$\text{NaNO}_2$	$\text{NaNO}_2$	24.0
197	200	$\text{Na}_2\text{SO}_3$	$\text{NaNO}_2$	88.6
198	200	$\text{Na}_2\text{SO}_3$	$\text{NaNO}_2$	83.6

When  $\text{NaNO}_2$  and  $\text{H}_2\text{O}_2$  are applied in preparation of  $\text{Pu}^{IV}$ , the  $\text{Pu}^{III}$  is rapidly oxidized by  $\text{NaNO}_2$  and  $\text{H}_2\text{O}_2$ ; but the  $\text{Pu}^{V, VI}$  are rather slowly reduced to  $\text{Pu}^{IV}$  by  $\text{NaNO}_2$  and  $\text{H}_2\text{O}_2$ . When the  $\text{H}_2\text{O}_2$  is used to prepare  $\text{Pu}^{IV}$ , the decontamination for uranium is furthermore inefficient. This is shown in Table 2.

**Table 2.** Comparing uranium decontamination in seawater using  $\text{H}_2\text{O}_2$  and  $\text{NaNO}_2$  respectively.

No.	Seawater litres	Agent	$^{238}\text{U}$ (Bq/m <sup>3</sup> )	$^{234}\text{U}$ (Bq/m <sup>3</sup> )
165	40	5 ml 30% $\text{H}_2\text{O}_2$	8.1	9.3
168	50	2 g $\text{NaNO}_2$	0.059	0.63

The anion exchange column is equilibrated with 8 N HNO<sub>3</sub> containing K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, and 8 N HNO<sub>3</sub> containing fresh NaNO<sub>2</sub> to clean for any impurity in the anion ion exchange in order to prevent any interference.

During washing of the column with 8 N HNO<sub>3</sub> for uranium decontamination, the chem. yield of plutonium is often lost by a change of plutonium valency. In order to keep Pu<sup>4+</sup>, the eluate of 8 N HNO<sub>3</sub> containing fresh NaNO<sub>2</sub> is used. When the system is changed from HNO<sub>3</sub> to HCl, the plutonium valence is changed by oxidation of the mixture of HNO<sub>3</sub> + HCl. Therefore, 50 ml conc. HCl containing a few milligram NaNO<sub>2</sub> is used as eluate to prevent the change of the plutonium valence. In Table 3 the chemical yields of plutonium samples are compared when the system is changed to HCl with and without the addition of NaNO<sub>2</sub>.

**Table 3.** Comparing the chemical yield of plutonium by changing the system using 50 ml conc. HCl + few milligram NaNO<sub>2</sub> and 50 ml conc. HCl only.

No.	Volume litres	Agent	Chemical yield <sup>242</sup> Pu, %
197	200	50 ml conc. HCl a few milligram NaNO <sub>2</sub>	88.6
198	200	"	83.6
200	200	50 ml conc. HCl	57.5

### Stripping plutonium

We think there are two problems in the plutonium stripping with low acid concentration, i.e. micro-absorption of plutonium and low chemical yield of plutonium. In this work, the plutonium is

successfully stripped with  $H_2O$ , NaOH, 2 N  $HNO_3$ , and 0.5 N  $HNO_3$ , containing 0.03 M  $NaNO_3$ . When Pu is stripped with NaOH, the plutonium is hydrolyzed to  $Pu(OH)_4$ , leaving the anion exchange resin. Then the  $Pu(OH)_4$  is dissolved in 2 N  $HNO_3$ , and further stripped with 0.5 N  $HNO_3$ , containing 0.03 M  $NaNO_3$ , as a scavenger to prevent the micro plutonium absorption. Table 4 shows the stripping efficiency between 500 ml 0.5 N  $HNO_3$ , + 0.03 M  $NaNO_3$ , (low acid concentration) and  $H_2O$ , NaOH, 2 N  $HNO_3$ , 200 ml 0.5 N  $HNO_3$ , + 0.03 M  $NaNO_3$ .

**Table 4.** The chemical yield of plutonium at the different stripping condition between 300 ml 0.5 N  $HNO_3$ , + 0.03 M  $NaNO_3$ , (low acid concentration) and  $H_2O$ , NaOH, 2 N  $HNO_3$ , 200 ml 0.5 N  $HNO_3$ , + 0.03 M  $NaNO_3$ .

No.	Seawater litres	Stripping condition	Chemical yield $^{242}Pu$ , %
175	50	300 ml 0.5 N $HNO_3$ , + 0.03 M $NaNO_3$	46.9
176	200	300 ml 0.5 N $HNO_3$ , + 0.03 M $NaNO_3$	45.0
203	200	$H_2O$ , NaOH, 2 N $HNO_3$ , 200 ml 0.5 N $HNO_3$ , + 0.03 M $NaNO_3$	79.5

Before electrodeposition the sample is heated at 400°C and dissolved in aqua regia for destroying the organic material to get a thin source and for polonium decontamination.

Table 5 and 6 show a comparison of the results obtained by the previous used method and the present one, and Figs. 1 and 2 show sample spectra from the two tables.

**Table 5.** Plutonium analyses of seawater samples from the North Sea using the old radiochemical procedure. (nd = not detected).

Sample no.	Volume (m <sup>3</sup> )	<sup>242</sup> Pu-yield (%)	<sup>228</sup> Th (μBq)	<sup>239</sup> Pu (mBq m <sup>-3</sup> )	<sup>238</sup> Pu (mBq m <sup>-3</sup> )
870075	0.2	7.6	nd	17.1±19%	nd
870076	0.2	12.6	20±43%	13.0±16%	nd
870077	0.2	9.4	nd	16.4±19%	nd
870078	0.2	7.6	15±33%	7.5±30%	nd
870079	0.2	7.3	76±15%	nd	nd
870080	1.0	41.4	228± 9%	12.5± 7%	0.5±25%
870081	1.8	3.7	nd	12.0±22%	nd
870082	1.8	24.8	nd	15.0± 7%	0.7±16%
870083	1.8	7.2	149±15%	15.3±13%	nd

**Table 6.** Plutonium analyses of seawater samples from the Danish Waters (Hesselø) using the new radiochemical procedure.

Sample no.	Volume (m <sup>3</sup> )	<sup>242</sup> Pu-Yield (%)	<sup>228</sup> Th (μBq)	<sup>239</sup> Pu (mBq m <sup>-3</sup> )	<sup>238</sup> Pu (mBq m <sup>-3</sup> )
890197	0.2	88.6	nd	7.4± 8%	0.7±35%
890198	0.2	83.6	nd	7.2± 8%	1.7±17%
890201	0.2	72.5	nd	9.0± 8%	2.0±17%
890202	0.2	76.1	-	-	-
890203	0.2	81.9	-	-	-
890205	0.2	72.2	-	-	-

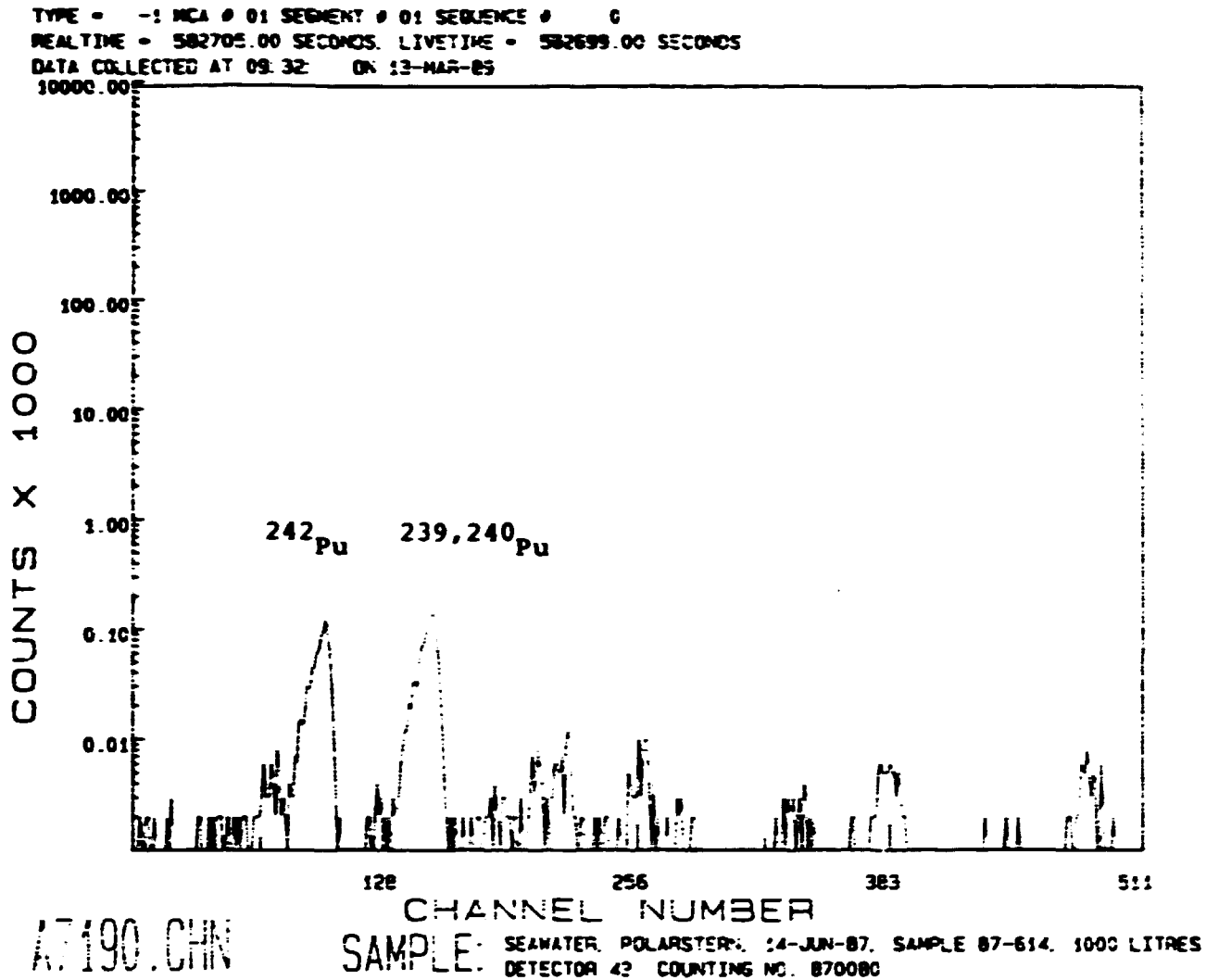
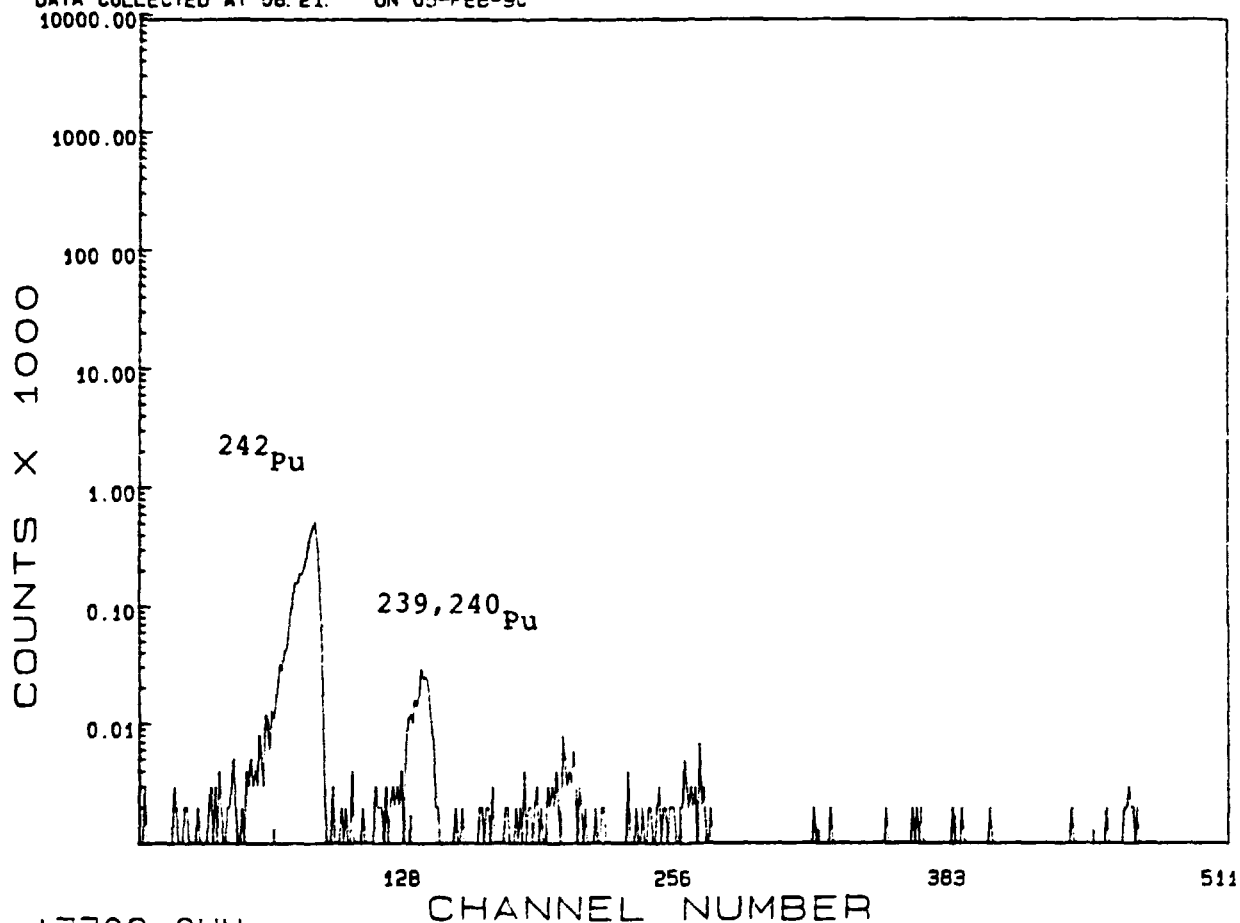


Fig. 1. Sample spectrum (no. 870080) showing thorium contamination ( $^{228}\text{Th}$  and daughters).

TYPE = -1 MCA # 01 SEGMENT # 01 SEQUENCE # 0  
REALTIME = 580186.00 SECONDS. LIVETIME = 580186.00 SECONDS  
DATA COLLECTED AT 08:21: ON 05-FEB-90



A7729.CHN

SAMPLE: SEAWATER, HESSELOE, AUGUST 1989, 200 LITRES  
DETECTOR 33. COUNTING NO. 890198

Fig. 2. Sample spectrum (No. 890198) showing no thorium contamination.

#### 4. CONCLUSION

1.  $\text{Na}_2\text{SO}_3$  and  $\text{NaNO}_2$  are successfully applied to prepare  $\text{Pu}^{4+}$ .
2. The plutonium is stripped from anion ion exchange by  $\text{H}_2\text{O}$ ,  $\text{NaOH}$ , 2 N  $\text{HNO}_3$  and 0.5 N  $\text{HNO}_3$  + 0.01 M  $\text{NaNO}_3$ .
3. With the new procedure we have obtained high decontamination factors for uranium and thorium, high chemical yields (60-80%) for plutonium and high alpha energy resolutions.

## APPENDIX 1

Purification of plutonium from disc

1. Put the disc in a 50 ml beaker. Add about 0.5 ml 8 M HNO<sub>3</sub>. Let stand for 1 hour to dissolve. Wash the disc with conc. HCl several times.
2. Wash the disc with 1 ml HNO<sub>3</sub> until clean. Discard the disc.
3. Add 1 ml 1 M NaNO<sub>3</sub>. Evaporate to dryness. Add 3 ml conc. HNO<sub>3</sub> and 3 ml HCl. Heat to dryness.
4. Dissolve with 10 ml 0.7 N HNO<sub>3</sub>. Heat for a few min.
5. Add 300 mg Na<sub>2</sub>SO<sub>3</sub>. Stir to dissolve. Let stand for 15 min. The plutonium is reduced to Pu<sup>+3</sup> valence. (30 mg/ml Na<sub>2</sub>SO<sub>3</sub>).
6. Add 300 mg NaNO<sub>2</sub> (30 mg/ml). Stir to uniformity. The plutonium is oxidized to Pu<sup>+4</sup>. Let stand for 10 min.
7. Add 12 ml conc. HNO<sub>3</sub> to get about 8 N HNO<sub>3</sub>.
8. Make a column (7x0.8 cm) AG 1-X<sub>4</sub>, 100-200 mesh. Eluate the column with 20 ml 8 N HNO<sub>3</sub> containing 3 mg/ml NaNO<sub>2</sub> (fresh).
9. Add solution to column (0.5 ml/min).
10. Wash the column with 20 ml 8 N HNO<sub>3</sub> containing 3 mg/ml NaNO<sub>2</sub>.
11. Strip with 4 ml H<sub>2</sub>O, 4 ml 0.3 N NaOH, 4 ml H<sub>2</sub>O, 4 ml 2 N HNO<sub>3</sub> and 20 ml 0.5 N HNO<sub>3</sub> + 0.01 M NaNO<sub>3</sub>.
12. Add 0.3 ml conc. H<sub>2</sub>SO<sub>4</sub>. Evaporate to dryness. Add 3 ml conc. HNO<sub>3</sub> and 3 ml conc. HCl. Evaporate to dryness.
13. Dissolve with 5 ml 0.5 N H<sub>2</sub>SO<sub>4</sub>. Wash the beaker three times with 0.5 N H<sub>2</sub>SO<sub>4</sub>. Each time with 3 ml (transfer to electrodeposition cell). Adjust the pH = 2.2 for electrodeposition.
14. The current is 0.6 A/cm<sup>2</sup>. The time is 6 h. Cool the cell with water.
15. Cover the surface of source with VVNS thin film (10-15 μg/cm<sub>2</sub>)



The results of the purification are shown in table 7.

Table 7. After purification, the plutonium chemical yield.

Sample no.	Volume (m <sup>3</sup> )	<sup>242</sup> Pu-Yield (%)	<sup>228</sup> Th (μBq)	<sup>239</sup> Pu (mBq m <sup>-3</sup> )	<sup>238</sup> Pu (mBq m <sup>-3</sup> )
890197	0.2	64.5	nd	7.0±10%	0.88±48%
890198	0.2	65.0	21±37%	7.3±8.9%	1.4±23%
890200	0.2	53.9	19±32%	7.2±9.6%	0.8±38%
8900K1	0.2	58.5	nd	6.4±12.1%	nd
890k2	0.2	66.5	17±43%	8.1±8.8%	0.7±36%

nd = not detected

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2. N.A. Talvitie, Radiochemical Determination of Plutonium in Environmental and Biological Samples by Ion Exchange. Analytical Chemistry. Vol. 43, No. 13 November 1971.

<p>Title and author(s)</p> <p>DETERMINATION OF PLUTONIUM IN ENVIRONMENTAL SAMPLES BY CONTROLLED VALENCE IN ANION EXCHANGE</p> <p>Qingjiang Chen*, Asker Aarkrog, Sven P. Nielsen, Henning Dahlgaard, H.Nies**, Yixuan Yu*, K. Mandrup</p> <p>* Institute of Atomic Energy, Beijing, China</p> <p>** Deutsches Hydrographisches Institut, Hamburg, Germany</p>	<p>Date February 1991</p>
	<p>Department or group</p> <p>Section of Ecology</p>
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<p>Pages 17    Tables 7    Illustrations 2    References 2</p>	<p>ISBN 87-550-1620-0</p>
<p>Abstract (Max. 2000 char.)</p> <p><b>Abstract.</b> The method was successfully used for collecting <math>^{239,240}\text{Pu}</math> from 200 litres seawater by coprecipitation with 16 g <math>\text{FeSO}_4 \cdot 7\text{H}_2\text{O}</math> under reducing conditions without filtering. The plutonium is leached by concentrated <math>\text{HNO}_3 + \text{HCl}</math> from the coprecipitate and the solid particles. The precipitate is heated at <math>400^\circ\text{C}</math> and digested in aqua regia. <math>\text{Na}_2\text{SO}_3</math> and <math>\text{NaNO}_2</math> have been applied to obtain <math>\text{Pu}^{4+}</math> valence in 0.5-1 N <math>\text{HNO}_3</math> for different samples. Plutonium and thorium are coabsorbed on anionic resin from 8 N <math>\text{HNO}_3</math>. The column is eluted with 8 N <math>\text{HNO}_3</math> containing fresh <math>\text{NaNO}_2</math> to keep <math>\text{Pu}^{4+}</math> valence for uranium decontamination. The system of the column is changed from 8 N <math>\text{HNO}_3</math> to concentrated <math>\text{HCl}</math> with 50 ml conc. <math>\text{HCl}</math> containing a few milligram <math>\text{NaNO}_2</math>. Further decontamination of thorium was achieved by elution with concentrated <math>\text{HCl}</math> instead of 9 N <math>\text{HCl}</math>. The plutonium is successfully stripped by <math>\text{H}_2\text{O}</math>, <math>\text{NaOH}</math>, 2 N <math>\text{HNO}_3</math> and 0.5 N <math>\text{HNO}_3</math> containing 0.01 M <math>\text{NaNO}_3</math>. The chemical yield of plutonium for a 200 litres-seawater sample is 60-80%. The resolution of the electroplated thin source is very good.</p>	
<p>Descriptors - INIS</p> <p>ANIONS; CHEMICAL REACTION YIELD; COPRECIPITATION; DECONTAMINATION; HYDROCHLORIC ACID; ION EXCHANGE; IRON SULFATES; LEACHING; NITRIC ACID; PLUTONIUM 239; PLUTONIUM 240; PLUTONIUM IONS; SAMPLING; SEAWATER; SODIUM HYDROXIDES; SODIUM NITRATES; SODIUM SULFATES; THORIUM, URANIUM; VALENCE</p> <p>Available on request from Riso Library, Riso National Laboratory, (Riso Bibliotek, Forskningscenter Riso), P.O. Box 49, DK-4000 Roskilde, Denmark. Telephone +45 42 37 12 12, ext. 2268/2269. Telex: 43116, Telefax: +45 46 75 56 27</p>	

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