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Corresponding Author : H. Kusuno (kusuno@um.u-tokyo.ac.jp)

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An approach for measuring the $^{129}\text{I}/^{127}\text{I}$ ratio in fish samples

Abstract

The $^{129}\text{I}/^{127}\text{I}$ ratio in marine fish samples was measured employing accelerator mass spectrometry. The measurement was successful because of the low experimental background of ^{129}I . Pyrohydrolysis was applied to extract iodine from fish samples. The experimental background of pyrohydrolysis was checked carefully and evaluated as 10^4 – 10^5 atoms ^{129}I /combustion. The methodology employed in the present study thus required only 0.05–0.2 g of dried fish samples.

The methodology was then applied to obtain the $^{129}\text{I}/^{127}\text{I}$ ratio of marine fish samples collected from the Western Pacific Ocean as $(0.63\text{--}1.2) \times 10^{-10}$. These values were similar to the ratio for the surface seawater collected at the same station, 0.4×10^{-10} . The $^{129}\text{I}/^{127}\text{I}$ ratio of IAEA-414, which was a mix of fish from the Irish Sea and the North Sea, was also measured and determined as 1.82×10^{-7} . Consequently, fish from the Western Pacific Ocean and the North Sea were distinguished by their $^{129}\text{I}/^{127}\text{I}$ ratios. The $^{129}\text{I}/^{127}\text{I}$ ratio is thus a direct indicator of the area of habitat of fish.

1. Introduction

In recent decades, most Iodine-129 (^{129}I) in the Earth's surface environment has been of anthropogenic origin; that is, the result of human nuclear activity. This anthropogenic ^{129}I , released into the sea directly or indirectly (transported by the atmosphere), has dramatically increased the concentration of ^{129}I in surface seawater. In particular, the concentration has risen to 10^{10} atoms/L in the Irish Sea and the North Sea owing to the direct discharge of ^{129}I from nearby nuclear reprocessing plants, Sellafield and La Hague [1, 2], while in the far field such as the Pacific and Indian Oceans, the rise had been rather mild, up to 10^6 – 10^7 atoms/L [3–5]. In the Pacific Ocean, ^{129}I and several anthropogenic nuclides are known to transfer from the atmosphere and slowly diffuse into deeper layers such that there is a steep gradient of the concentration [see, e.g., 5]; that is, the ^{129}I concentration is high at the surface and suddenly decreases with depth. This depth profile is reflected by the iodine isotopic ratio ($^{129}\text{I}/^{127}\text{I}$) profile since the concentration of stable iodine (^{127}I) is almost uniform in seawater (400–500 nmol/L [6]).

Iodine is known to be a biophile. It is an essential element in the thyroid metabolism of all vertebrates in that it is a major component of thyroid hormones, thyroxine (T4), and triiodothyronine (T3) [7]. In fish, the thyroid metabolism plays an important role in, for example, growth, smoltification, osmoregulation, and larval metamorphosis [7]. It is assumed that fish accumulate iodine from their food, and the $^{129}\text{I}/^{127}\text{I}$ ratio in fish would be expected to reflect that in the habitat of the fish as the ratios would be linked by the food chain; that is, the

$^{129}\text{I}/^{127}\text{I}$ ratio in fish should agree with that in seawater. As the $^{129}\text{I}/^{127}\text{I}$ ratio of seawater varies by region and depth owing to the input of anthropogenic ^{129}I , the ratio in fish should be a good indicator of the location of habitat of the fish.

However, few studies have applied the $^{129}\text{I}/^{127}\text{I}$ ratio to marine biology because the abundance of ^{129}I is so low that it is hardly detected using ordinary analytical techniques. Although the technique of accelerator mass spectrometry (AMS) has been developed and has demonstrated excellent sensitivity in detecting a $^{129}\text{I}/^{127}\text{I}$ ratio as low as 10^{-14} , it typically requires 1 mg of iodine.

Considering the typical iodine concentration in a marine fish sample (500–5000 $\mu\text{g}/\text{kg}$, dry basis [8]), 500–5000 g of dry fish sample is needed to obtain 1 mg of iodine, which is not practical. In this study the “carrier method” was adopted to overcome this difficulty. This method has been successfully employed for a minimal amount of solid and liquid samples [4, 9, 10]. The iodine carrier increases the total iodine amount so that it can be treated easily. However, the isotopic ratio $^{129}\text{I}/^{127}\text{I}$ is highly diluted by the carrier. To maintain a detectable ^{129}I signal even after adding the carrier, the isotopic ratio of the carrier should be as low as possible. Woodward iodine (from Woodward Iodine Corporation, OK, USA), estimated to have a $^{129}\text{I}/^{127}\text{I}$ ratio of 1.5×10^{-14} [11], was used as a carrier for samples with a $^{129}\text{I}/^{127}\text{I}$ ratio lower than 10^{-13} in this study.

The pyrohydrolysis method, which has been successfully employed for soil samples [12], was applied to extract iodine from fish samples. Applying this method, the sample was

combusted in a quartz tube at 1000 °C. Since most of the iodine in a sample is volatilized at this temperature [12], the “memory effect” in the sequential sample treatments does not pose a problem if the concentration of ^{129}I is on the same order. However, care should be taken in the treatment of an extremely high ^{129}I concentration. The present study evaluated the memory effect in the sequential combustion and determined an effective way of avoiding the memory effect.

In this study, the $^{129}\text{I}/^{127}\text{I}$ ratio in actual fish samples collected in the Western Pacific Ocean was measured and compared with that of seawater at the same location. In addition, the $^{129}\text{I}/^{127}\text{I}$ ratio in fish from the Western Pacific Ocean and that in IAEA-414 (a mix of fish from the North Sea and Irish Sea) were compared in a preliminary experiment.

2. Sample and Methods

2.1. Sample

Two sets of mixed fish and seawater samples were collected at the Sta. SBD in the Western Pacific Ocean (subtropical zone, 25°00'N, 160°00'E) during research cruise KH-14-2 (May 20 to June 11, 2014). The fish samples were collected using an ORI net (i.e., a cone-sharped net developed by the Ocean Research Institute for sampling plankton) at depths of 0–170 m and seawater samples were collected using Niskin bottles at depths of 0–5768 m. One set of mixed fish included mainly *Myctophidae*. The second set contained an unknown species (that looked like *Salangidae*); this sample was named “Larva”.

The $^{129}\text{I}/^{127}\text{I}$ ratio in IAEA-414 was measured for comparison with that in fish samples obtained from the Sta. SBD. In addition, the ^{129}I concentration in the IAEA-414 sample was measured for comparison with reported results [13, 14].

2.2. Treatment of fish samples

The pretreatment of fish samples used in this study was a modification of that used in [12]. A fish sample was dried in a freeze dryer. After crushing and homogenization, 0.05–0.3 g of dried fish sample was covered by vanadium (V) oxide (V_2O_5) on a ceramic combustion boat. The boat with sample was combusted at 1000 °C in a quartz tube by a tubular furnace with flowing oxygen gas and water vapor (pyrohydrolysis). The exit side of the quartz tube was capped by quartz wool with a Pt wire. The quartz tube and quartz wool were combusted at 1000 °C beforehand. The quartz tube was inserted into the tubular furnace from the edge gently. Here, it is important to insert the tube carefully so that the sample does not catch fire. Otherwise, the generation of smoke would interrupt the gas flow. It took 60 min for the combustion of one sample. Volatilized iodine was trapped in the alkaline solution. This alkaline solution includes 2% tetramethylammonium hydroxide (TAMAPURE-AA-1000) and 0.1% sodium sulfate (Na_2SO_3 , Wako Chemical Special Grade Chemicals). A 1-mL aliquot of the alkaline solution was taken for the measurement of ^{127}I by inductively coupled plasma mass spectrometry (Agilent 7500a).

0.6 – 1.5 mg of iodine carrier, as an iodide form, was added to the remaining solution

with sodium sulfate solution, as a reducing agent, so that all iodine was of the form I^- . Woodward iodine ($^{129}\text{I}/^{127}\text{I} = 1.5 \times 10^{-14}$ [11]) or Ionplus (iodide solution provided by Thermo Fisher Scientific, $^{129}\text{I}/^{127}\text{I} = \text{around } 1.7 \times 10^{-13}$ [12]) was used for the carrier depending on the ^{129}I concentration in the sample. Sodium nitrite (NaNO_2) was then added to oxidize ionic iodide to molecular iodine I_2 and carbon tetrachloride (CCl_4) was added. Molecular iodine was extracted as the CCl_4 phase. After rejection of the aqueous phase, iodine was back-extracted into the aqueous phase by reducing I_2 to I^- with the addition of sodium sulfite (Na_2SO_3). The aqueous phase was collected and concentrated in a beaker by heating with a hotplate. The iodine was precipitated as silver iodide with silver nitrate (AgNO_3). Dried silver nitrate was mixed with Nb powder and pressed into a cathode for AMS. The $^{129}\text{I}/^{127}\text{I}$ ratio was measured at the Micro Analysis Laboratory, Tandem accelerator, The University of Tokyo. The $^{129}\text{I}/^{127}\text{I}$ ratio was normalized by the standard reference materials Z94-0597 and Z94-0596 provided by PRIME Lab. The nominal ratio of Z94-0597 is 8.378×10^{-12} and that of Z94-0596 is 6.540×10^{-11} [15, M. Caffee, private communication].

2.3. Evaluation of the background and cross contamination of chemical treatment

To evaluate the memory effect in the pyrohydrolysis process, several blank tests were conducted. First, chemical blanks (CB) without the pyrohydrolysis process were tested. The same procedures after pyrohydrolysis (i.e., solvent extraction/back extraction and precipitation) were performed on the 0.6 mg of Woodward iodine carrier with the same

solution as the trap solution for the pyrohydrolysis. The AMS results for CB showed $^{129}\text{I}/^{127}\text{I}$ ratios of the order of 10^{-14} , which was the same order as for the Woodward carrier itself. This ^{129}I content was $(1.5 \pm 0.5) \times 10^{-14} - (4.8 \pm 1.1) \times 10^{-14}$.

Several series of blanks were tested. The BLK0 was made by combustion, as in normal pyrohydrolysis, with the new quartz tube and new quartz wool but without samples. A new quartz tube used for BLK0 was washed with detergent and deionized water. Carrier was then added to the trap solution, extracted by solvent extraction/back extraction and collected as AgI precipitation. BLK1 was made in the same way as BLK0 but after the IAEA-414 (0.2 g) sample was combusted in the same quartz tube and wool. BLK2 differed from BLK1 only in that quartz wool was removed before treatment. The BLK3 was also made after IAEA-414 combustion, but the quartz tube/wool was baked for 30 min before the blank processing. The BLK4 was treated with a quartz tube that was washed with detergent in an ultrasonic bath after IAEA-414 combustion.

The memory effect of IAEA-414 combustion in a quartz tube was simply evaluated by comparing the BLK0 and BLK1. The memory reduction by baking was evaluated by comparing the BLK2 and BLK3.

2.4. Chemical treatment of seawater samples

Since the iodine concentration in seawater is typically 400–500 nM, the carrier method is useful for ^{129}I analysis. In this study, 0.5–2.0 L of seawater was treated. Iodine carrier

(0.6–1.3 mg, Woodward iodine for deep seawater and Ionplus for near-surface seawater) was added to the seawater sample after filtering with a 0.45- μ m membrane filter. HCl and ascorbic acid were then added to obtain a uniform chemical form of iodine (I^-). Iodine was purified by solvent extraction and back-extraction. This procedure was then the same as described in section 2.2.

3. Results and discussion

3.1. Background and cross contamination of pyrohydrolysis

Table 1 and Fig. 1 present the ^{129}I content (atoms/combustion) in each trap solution. ^{129}I content in the BLK0 was $(1.0 \pm 0.4) \times 10^5 - (1.5 \pm 0.3) \times 10^5$ atoms/combustion (mean value: $(1.3 \pm 0.3) \times 10^5$) (Table 1). However, after 0.2 g of IAEA-414 (^{129}I content: ca. 8×10^8 atoms) was combusted, $(4.1 \pm 0.2) \times 10^6$ atoms of ^{129}I were observed in BLK1, which corresponds to 0.5% of the previous sample (0.2 g IAEA-414). This ^{129}I memory was reduced to $(8.9 \pm 0.9) \times 10^5$ atoms of ^{129}I (ca. 0.1% of 0.2 g IAEA-414) in BLK2, for which the quartz wool was removed after IAEA-414 combustion. From the comparison between BLK1 and BLK2, it was considered that most of the ^{129}I memory was trapped in the quartz wool. It was found that, to reduce this memory, the quartz tube and quartz wool should have been combusted for an additional 30 min (BLK3, mean value of ^{129}I content: $(8.6 \pm 0.2) \times 10^5$). With additional combustion, the memory was found to be as low as 0.1% of the previous sample. The BLK4 was treated with a quartz tube that was washed in an ultrasonic bath with

detergent after IAEA-414 combustion. The BLK4, which showed $(5.8 \pm 0.1) \times 10^4$ of mean value of ^{129}I content, had ^{129}I content as low as that of the BLK0.

In summary, ca. 0.5% of the ^{129}I amount of the previous sample remained in the quartz tube, especially in the quartz wool. Additional heating for 30 min reduced the memory to 0.1%. By washing the quartz tube and refreshing the quartz wool, the memory was almost completely eliminated.

3.2. Determination of the $^{129}\text{I}/^{127}\text{I}$ ratio and ^{129}I activity of IAEA-414

The $^{129}\text{I}/^{127}\text{I}$ ratio and total iodine concentration of IAEA-414 were $(1.6\text{--}2.0) \times 10^{-7}$ (mean value: $(1.82 \pm 0.02) \times 10^{-7}$) and 4.3–4.9 ppm (mean value: 4.55 ± 0.02 ppm), respectively (Table 2). ^{129}I activity was 4.49–5.19 mBq/kg (mean value: 4.92 ± 0.05 mBq/kg). These results were reasonably constant, independent of the treated weight (Fig. 2), which implies that the treatment of fish samples in this study was effective and provided a constant recovery rate for the whole process. The $^{129}\text{I}/^{127}\text{I}$ ratio in IAEA-414 was in the range of that in surface seawater of the North Sea and the Irish Sea, $10^{-8}\text{--}10^{-6}$ (where this isotopic ratio is based on [16] and estimated from the ^{129}I concentration (atoms/L) in those sea areas referred from [2] and the general ^{127}I concentration in seawater [6]).

Our results were 40%–60% lower than those reported in [13, 14], 8.0–12 mBq/kg. This discrepancy would be due to 1) a low recovery rate of iodine in this study or 2) the reported value being an overestimation of the true activity of ^{129}I in IAEA-414. It is necessary to

determine the recovery rate of the extraction of iodine in fish samples employing pyrohydrolysis or other methods such as alkaline fusion.

3.3. $^{129}\text{I}/^{127}\text{I}$ ratio of fish samples from Sta. SBD

The treatment method adopted in this study was applied to actual fish samples collected at the Sta. SBD in the Western Pacific Ocean. Fig. 3 shows the results for the fish samples compared with the results for seawater and IAEA-414. The $^{129}\text{I}/^{127}\text{I}$ ratios of the fish samples and seawater samples were consistent in both ocean areas. The $^{129}\text{I}/^{127}\text{I}$ ratio of IAEA-414 was ca. 10^4 times that of fish at the Sta. SBD. The $^{129}\text{I}/^{127}\text{I}$ ratio of fish in IAEA-414 (collected in the North Sea and the Irish Sea) is considered to reflect clearly pollution by the nuclear fuel reprocessing plants at Sellafield and La Hague. Thus, the $^{129}\text{I}/^{127}\text{I}$ ratio in fish body is a straight indicator of pollution in the habitat region. Since the $^{129}\text{I}/^{127}\text{I}$ ratio in seawater generally has a remarkable depth profile, it is a potential indicator of the depth of the fish habitat.

4. Summary

The $^{129}\text{I}/^{127}\text{I}$ ratios of fish samples were successfully measured employing the pyrohydrolysis method. It was found that it was important to take 60 min to combust a fish sample, to check the background before sample combustion, and to use a washed quartz tube or a new quartz tube. The results obtained in the present study are summarized as follows.

- 1) The ^{129}I background of the pyrohydrolysis with a washed and preheated quartz tube and quartz wool was less than $(1.5 \pm 0.3) \times 10^5$ atoms. This ^{129}I background is sufficiently low to observe ^{129}I in a fish sample.
- 2) In sequential combustion treatments, ca. 0.5% of the ^{129}I amount of the previous sample remains in the quartz tube, especially in the quartz wool, as a memory of the previous sample. Additional heating for 30 min reduces the memory to 0.1%. By washing the quartz tube and refreshing the quartz wool, the memory is almost completely eliminated.
- 3) The $^{129}\text{I}/^{127}\text{I}$ ratio of IAEA-414 was determined as $(1.82 \pm 0.02) \times 10^{-7}$, which agreed with that of surface seawater from the Irish Sea and the North Sea (10^{-6} – 10^{-8}). ^{129}I activity of IAEA-414 measured in this study was 4.92 ± 0.05 mBq/kg. The evaluation is considered sufficiently reliable because the results of IAEA-414 obtained by repeated treatments were constant, independent of the treated weight. However, the result was 40%–60% lower than those of previous reports [13, 14].
- 4) The $^{129}\text{I}/^{127}\text{I}$ ratio of two fish samples collected from the Sta. SBD in the Western Pacific Ocean agreed with the $^{129}\text{I}/^{127}\text{I}$ ratio of surface seawater at the Sta. SBD. The ratio for fish at the Sta. SBD differed from that of fish in the North Sea and the Irish Sea (IAEA-414). This suggests that $^{129}\text{I}/^{127}\text{I}$ ratio is a potential tracer for marine biota.

Acknowledgments

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Reference

- [1] V. Alfimov, A. Aldahan, and G. Possnert, NIMB (2013) 542.
- [2] P. He, A. Aldahan, G. Possnert, and X. L. Hou NIMB 294 (2013) 537.
- [3] P. P. Povinec, B. Oregioni, A. J. T. Jull, W. E. Kieser, and X. L. Zhao. NIMB 172 (2000) 672.
- [4] T. Suzuki, S. Ootosaka, J. Kuwabara, H. Kawamura, and T. Kobayashi, Biogeosciences 10 (2013) 3839
- [5] P. P. Povinec, S. H. Lee, L. Liong Wee Kwong, B. Oregioni, A. J. T. Jull, W. E. Kieser, U. Morgenstern, and Z., Top, NIMB 268 (2010) 1214.
- [6] H. B. Li, X. R. Xu, and F. Chen, Comprehensive Handbook of Iodine, ed. V. R. Preedy, G. N. Burrow, and R. Watson (Academic Press, 2008) p. 1334.
- [7] S. Jarque and B. Piña, Envi. Res. 15 (2014) 361.
- [8] D.A. Koutras, J. Matolinovic, and R. Vought, Endemic Goitre and Endemic Cretinism.

Iodine Nutrition in Health and Disease (J.B. Stanbury and B.S. Hetzel), Wiley Eastern Limited, New Delhi, (1985) p. 290.

[9] V. Alfimov, A. Aldahan, G. Possnert, and P. Winsor (2004) *Marine Poll. Bull.*, 49, 1097-1104.

[10] V. Hansen, P. Roos, A. Aldahan, X. Hou, and G. Possnert (2011) *J. Envi. Rad.*, 102, 1096-1104.

[11] H. Matsuzaki, C. Nakano, H. Kusuno, Y. Miyake, Y. S. Tsuchiya, M. Honda, H. Tokuyama, A. B. Tugade, S. Ito, A. Moita, M. Kawamoto, these proceedings (the thirteenth international conference on accelerator mass spectrometry), NIMB.

[12] Y. Muramatsu, Y. Takada, H. Matsuzaki, and S. Yoshida, *Quat. Geoch.* 3 (2008) 291.

[13] M.K. Pham, J.A. Sanchez-Cabeza, P.P. Povinec, D. Arnold, M. Benmansour, R. Bojanowski, F.P. Carvalho, C.K. Kim, M. Esposito, J. Gastaud, C.L. Gascó, G.J. Ham, A.G. Hegde, E. Holm, D. Jaskierowicz, G. Kanisch, M. Llauro, J. La Rosa, S.-H. Lee, L. Liong Wee Kwong, G. Le Petit, Y. Maruo, S.P. Nielsen, J.-S. Oh, B. Oregioni, J. Palomares, H.B.L. Pettersson, P. Rulik, T.P. Ryan, K. Sato, J. Schikowski, B. Skwarzec, P.A. Smedley, S. Tarján, N. Vajda, E. Wyse. (2006) *App. Rad. Iso.*, 64 1253-1259.

[14] M. K. Pham, J. LA Rosa, S.-H. Lee, P.P. Povinec, IAEA/AL/145; IAEA/MEL/73, IAEA, *Marine Envi. Lab.*, Monaco (2004) P81.

[15] P. Sharma, David Elmore, Thomas Miller, and Stephan Vogt. (1997) *NIM B*, 123, 347-351.

- [16] C. Schnabel, V. Olive, M. Atarashi-Andoh, A. Dougans, R. M. Ellam, S. Freeman, C. Maden, M. Stocker, H. -A. Synal, L. Wacker, S. Xu. (2007) *App. Geochem.*, 22, 619-627.

Figure captions (all figures are 1 column)

Fig. 1. ^{129}I abundance in blank samples.

^{129}I abundance of BLK0, 3, and 4 is mean value of repeated experiment.

Fig. 2. ^{129}I activities and $^{129}\text{I}/^{127}\text{I}$ ratio in the 9 IAEA-414 samples with their treatment weight.

Fig. 2a. The ^{129}I activities (mBq/kg), fig. 2b. The $^{129}\text{I}/^{127}\text{I}$ ratio.

The error bars due to the statistics errors. The dashed lines show mean value of ^{129}I activities and $^{129}\text{I}/^{127}\text{I}$ ratio.

Fig. 3. The $^{129}\text{I}/^{127}\text{I}$ ratio in the fish samples and seawater samples from and the Sta. SBD and IAEA-414.

2a

2b

Table

I (1 column)

II (2 column)

III (1 column)

I

^{129}I concentration in blank samples for evaluation of background and cross contamination of pyrohydrolysis.

⁽¹⁾ This ^{129}I atoms was canceled ^{129}I atoms in Woodward iodine carrier added to each blank sample (4×10^4 - 1×10^5 atoms in 0.6-1.5 mg of Woodward iodine carrier).

Name	^{129}I [10^4 atoms] ⁽¹⁾
BLK0	10.3 ± 4.2
	15.4 ± 3.3
BLK1	409.2 ± 24.3
BLK2	88.9 ± 9.8
BLK3	65.9 ± 5.2
	103.9 ± 6.3
	22.8 ± 3.3
	54.4 ± 4.8
	175.7 ± 8.5
	94.6 ± 6.3
BLK4	1.1 ± 1.1
	19.0 ± 3.0
	1.3 ± 0.7
	1.8 ± 2.0

II

Total iodine concentrations, ^{129}I activities, and $^{129}\text{I}/^{127}\text{I}$ ratio in IAEA-414 samples.

IAEA414-005, -010, and 020 mean that they were treated with 0.005 g, 0.1 g, and 0.2 g of samples. Total iodine was measured by ICP-MS. $^{129}\text{I}/^{127}\text{I}$ ratio and ^{129}I activity were based on the results measured by AMS method. The errors due to statistical error of each method.

Name	Sample	Total iodine concentration			^{129}I abundance in sample			$^{129}\text{I}/^{127}\text{I}$ ratio			^{129}I activity		
IAEA-414-	[g]	[ppm DW]			[10^8 atoms]			[10^{-7}]			[mBq/kg DW]		
005A	0.0558	4.662	±	0.047	2.25	±	0.05	1.82	±	0.04	5.07	±	0.10
005B	0.0516	4.509	±	0.047	1.92	±	0.05	1.74	±	0.05	4.69	±	0.11
010A	0.1022	4.904	±	0.095	4.23	±	0.26	1.78	±	0.11	5.19	±	0.31
010B	0.0992	4.851	±	0.095	3.55	±	0.22	1.55	±	0.10	4.49	±	0.27
020A	0.2071	4.318	±	0.030	8.20	±	0.13	1.93	±	0.03	4.97	±	0.08
020B	0.2467	4.440	±	0.028	9.82	±	0.18	1.89	±	0.04	5.00	±	0.09
020C	0.2616	4.438	±	0.028	10.8	±	0.13	1.96	±	0.03	5.18	±	0.06
020D	0.1991	4.492	±	0.032	7.76	±	0.16	1.83	±	0.04	4.90	±	0.10
020E	0.2014	4.354	±	0.031	7.64	±	0.13	1.84	±	0.03	4.77	±	0.08

III

¹²⁹I activities in IAEA-414 determined by AMS method.

Results of the 3 laboratories were from [14]. ⁽¹⁾ Each laboratory was assigned an individual code number to ensure anonymity. ⁽²⁾ Number of results.

Lab. Code ¹	N ⁽²⁾	Weight [g]	¹²⁹ I Activity [mBq kg ⁻¹]	Error [%]
86	6	1.086-1.099	8.0 ± 0.2	3%
89	6	2.48	9.0 ± 0.2	2%
91	3	8.1416	12 ± 3	25%
This work	9	0.0516-0.2616	4.9 ± 0.05	1%