Data Article

Dataset on the content of major, trace, and rare-earth elements in the bottom sediments and bivalve mollusks of the Kara Sea (Arctic Ocean)

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ABSTRACT

The ability of bivalve mollusks to accumulate chemical elements from the environment makes them an important object for environmental monitoring and assessments of anthropogenic impact on marine ecosystems. The paper presents the data on the content of 65 chemical elements in soft tissues and shells of five species of bivalve mollusks (*Astarte crenata, Ciliatocardium ciliatum, Portlandia arctica, Chlamys islandica, Hiatella arctica*), as well as in the upper layer (0-5 cm) of bottom sediments of the Kara Sea, the Arctic Ocean. The content of major-, trace and rare-earth elements was determined by atomic emission and inductively coupled plasma mass spectrometry (ICP-AES; ICP-MS). The age, size, and weight of mollusks were measured. There were differences in the content of chemical elements accumulated in soft tissues and shells of mollusks, as well as the significant interspecific difference in the chemical composition of the studied mollusks. The soft tissues of mollusks were accumulated with toxic metals (Hg, Ag, and Cd) in comparison with the content of these elements in bottom sediments. In *Chlamys islandica* and *Hiatella arctica*, the shell was accumulated in Cd in contrast to other species. The data obtained may be used for a comprehensive assessment of the state

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of ecosystems in the seas of the Siberian sector of the Arctic Ocean under changing environment and for studying the fundamental base of the accumulation of chemical elements by marine organisms.

Specifications Table

Subject	Oceanography
Specific subject area	Biogeochemistry of marine environments
Type of data	Table
	Graph
	Figure
How data were acquired	Sampling: Sigsbee trawl and Niemisto gravity corer.
	Biological characteristics: *Leica* stereomicroscope, *Acculab La-60* analytical balance (accuracy 0.1 mg), electronic caliper.
	Chemical elements' analysis: Inductively coupled plasma atomic emission spectroscopy, *iCAP-6500* (ICP-AES), and inductively coupled plasma mass spectrometry, *X-7* (ICP-MS).
	Data statistics: *Statistica 10.0; Excel 2013*.
Data format	Raw
	Filtered
	Analyzed
Parameters for data collection	Sampling was carried out in the Kara Sea during the summer season (August) of 2014. The samples were stored at -18°C. All the samples were freeze-dried before chemical analyses. Analytical procedure was performed at normal laboratory conditions (22…24°C).
Description of data collection	Samples of bivalve mollusks and bottom sediments were collected in the Kara Sea by the Sigsbee trawl and Niemisto gravity corer.The tissues of the mollusks were freeze-dried to constant weight and weighed. The length, width, and height of the shell were measured with an electronic caliper. The age of mollusks was determined by visual counting of annual growth rings on the shells under a stereomicroscope. Standard methods (ICP-AES and ICP-MS) were applied to determine the content of chemical elements. Statistical analysis was conducted to assess the differences between the variables studied.
Data source location	Latitude and longitude of the sampling sites are given in Table 1
	Preparing the samples and data analysis were conducted at the P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, Russia Analytical procedure was carried out at the Institute of Microelectronics Technology and High Purity Materials, Russian Academy of Sciences, Chernogolovka, Moscow Region, Russia.
Data accessibility	With the article and available on a public repository.
	Repository name: Mendeley Data, V.2
	Data identification number: 10.17632/vj3ydt45zg.2
	Direct URL to data: http://dx.doi.org/10.17632/vj3ydt45zg.2

Value of the Data

- Knowledge about the content of toxic metals in the components of the Arctic ecosystems is necessary for the development of mechanisms for the prevention of chemical pollution and the implementation of sustainable development goals in the Arctic Ocean.
- The data obtained are necessary in the fields of biogeochemistry, ecotoxicology, and marine ecology to extend the open database on the accumulation, dynamics and, fate of chemical elements in hard-to-reach ecosystems of the Arctic.
- The obtained data may be used for improving the methods of biological monitoring and bioindication of chemical pollution and for assessing ecological risks in the Arctic ecosystems.
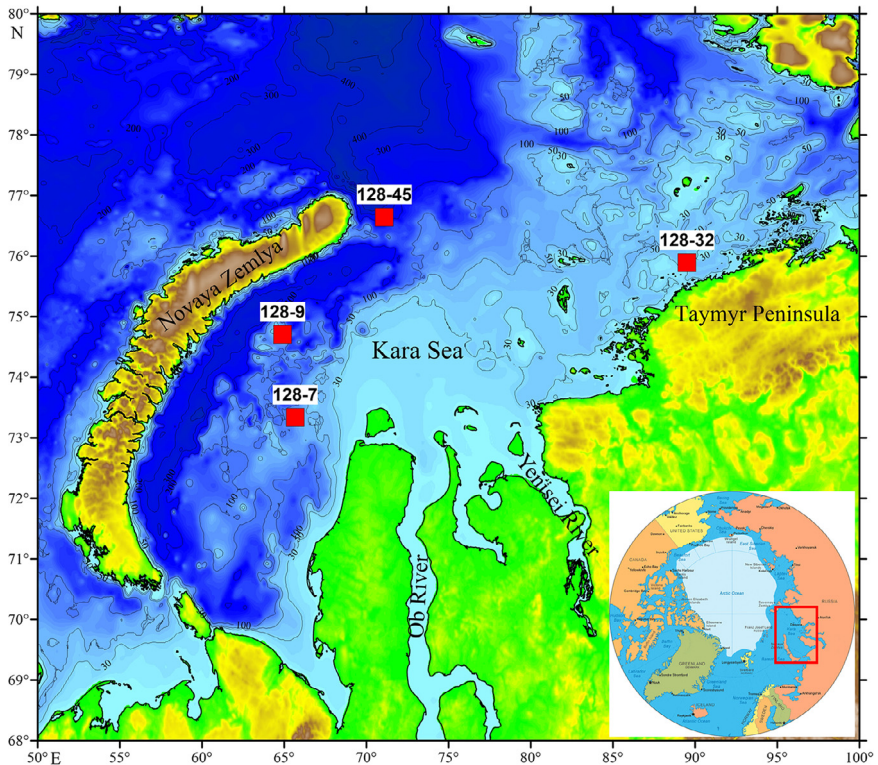
Fig. 1. Location of the sampling sites in the Kara Sea (Arctic Ocean).

- Geochemical proxies recorded in the bivalves' shells can be used for the assessment of dynamics of some environmental parameters.

1. Data Description

The content of 65 chemical elements was studied for five species of bivalve mollusks and bottom sediments of the Kara Sea at four stations (Fig. 1). *Astarte crenata, Ciliatocardium ciliatum, Portlandia arctica, Chlamys islandica*, and *Hiatella arctica* were considered as model biotic components. Shell morphometry, weight and, age of mollusks are presented in a supplementary file (Appendix A, Table S1), as well as the data on the content of chemical elements in soft tissues (Appendix A, Table S2) and shells (Appendix A, Table S3) of the studied mollusks. The content of Rh, Pd, Te, Re, Ir, and Pt in the soft tissues of mollusks was below the detection limit in most of the analyzed samples; therefore, these elements were excluded from the later analyses. In most samples of mollusk shells, the content of Be, Sc, Co, Se, Rh, Pd, Ag, Te, Lu, Hf, Ta, W, Re, It, Pt, Au, and Hg was also below the detection limit; these data were thus omitted in Table S3. The data on the content of chemical elements in bottom sediments, i.e. the habitat of the studied mollusks, are presented in Table 2, except the content of Se, Rh, Pd, Te, Re, Ir, Pt, and Au (below the detection limit in all analyzed samples).

A non-metric multidimensional scale (NMDS) evidences that the content of chemical elements differs in soft tissues and shells of five species of bivalve mollusks (Fig. 2) and between the species (Fig. 3). No differences in element content have been found for *Astarte crenata*, sampled at two stations (128-7 and 128-9) with probably different abiotic conditions (Fig. 2).

Table 1
Some characteristics of the sampling sites.

Station	Date	Location	Depth, m	Bivalve species
128-7	14 Aug, 2014	N 73.33667 E 65.66667	64	*Astarte crenata*
128-9	15 Aug, 2014	N 74.70500 E 64.90000	61	*Astarte crenata*
128-32	23 Aug, 2014	N 75.88833 E 89.50833	50	*Ciliatocardium ciliatum Portlandia arctica*
128-45	28 Aug, 2014	N 76.64330 E 71.08666	274	*Chlamys islandica Hiatella arctica*

The bioconcentration factors (BCF) for soft tissues and shells of the studied mollusks in regard to bottom sediments were calculated (Fig. 4). The soft tissues of mollusks accumulate biologically significant elements (P, S, and, to a lesser extent, Na and Ca), as well as toxic metals (Hg, Ag, and especially Cd: BCF 4-276). Minor bioconcentration of Cu, Zn, and As (BCF 1.5-3.0) was registered in the soft tissues of *Astarte crenata*. The shells of mollusks were naturally accumulated in Ca and Sr in regard to bottom sediments; moderate bioconcentration of Cd was found for *Chlamys islandica* and *Hiatella arctica* (BCF up to 5.0).

2. Experimental Design, Materials and Methods

2.1. Sampling and preparation

Sampling was performed during the scientific cruise no. 128 of the R/V *Professor Shtokman* in the Kara Sea in August 2014. A Sigsby trawl was used to collect bivalve mollusks. The surface layer of the bottom sediment (0-5 cm) was sampled using a Niemisto gravity corer, equipped by inner PVC pipe, a 50-mm diameter. The mollusks were washed with distilled water, using a plastic brush to remove sea salts, sediment residues, and organic debris from the shell surface. The samples were stored and transported in plastic bags at -18°C.

Samples of mollusk tissues and bottom sediments were freeze-dried to constant weight and weighed using an analytical balance *Acculab La-60* (0.1-mg accuracy). The length, width, and height of the mollusk shell were measured with an electronic caliper (0.1-mm accuracy). The mollusk age was determined by counting the annual growth rings on shells under a stereomicroscope (Leica Microsystems, Germany). The growth rings were visually distinguishable from the outside of the shell valves in *Chlamys islandica, Ciliatocardium ciliatum*, and *Hiatella arctica*, [1,2]. In *Astarte crenata* and *Portlandia arctica*, the growth rings were visible only on the cleavage plane, so their shells were preliminarily cut along the line starting from the protoconch area and lasting to the middle of the ventral margin of the shell [3,4]. The samples were crushed and homogenized in an agate mortar for further chemical analysis.

2.2. Analytical procedure

Sample decomposition and chemical analysis were performed at the Analytical Certified Testing Center of the Institute for Problems of Microelectronics Technology and High Purity Materials of the Russian Academy of Sciences according to the accepted method [5].

The samples were digested in the autoclave systems equipped with the *MKP-05* module and developed by scientific-and-production implementation company *ANKON-AT-2* (Russia). Each sample (100-200 mg) was transferred into 30-mL *Teflon* cups, 2 mL of concentrated HNO_3 (nitric acid 65%, max. 0.0000005% Hg, GR, ISO, *Merck*) and 0.5 mL of concentrated $HClO_4$ (perchloric acid 70%, Suprapure, *Merck*) were added. The autoclaves were operated for 1 hour at 160°C,

Table 2
Concentrations of major, trace and rare elements in the bottom sediments of the Kara Sea in August 2014.

Element	D.L.	Station 128-7	128-9	128-32	128-45
		Major elements, %			
Na	0.003	1.9	2.1	3.5	1.5
Mg	0.001	0.6	0.5	1.5	1.2
Al	0.01	4.1	4.4	6.3	6.1
P[a]	0.002	0.06	0.05	0.12	0.08
S_{total}[a]	0.002	0.098	0.079	0.26	0.13
K	0.0004	1.8	2.1	2.0	2.2
Ca	0.005	0.62	0.83	0.92	0.50
Ti	0.0004	0.26	0.27	0.39	0.33
Mn	0.0001	0.35	0.24	1.2	0.038
Fe	0.002	3.0	2.2	6.5	4.6
		Trace and rare elements, mg kg^{-1}			
Li	0.01	18.4	14.7	40.9	46.5
Be	0.01	1.2	1.2	1.8	2.2
Sc	0.1	6.5	5.2	12.7	12.3
V	0.7	98	69	176	141
Cr	0.7	41.5	33.6	75.0	68.2
Co	0.09	10.7	8.1	20.8	8.5
Ni	0.7	18.7	18.6	49.9	29.5
Cu	0.9	8.7	7.0	28.3	15.3
Zn	0.4	46	36	91	104
Ga	0.04	9.0	8.6	14.6	14.9
As	0.08	37.1	19.7	42.6	22.0
Rb	0.05	59.7	55.3	48.3	96.9
Sr	0.04	158	185	160	100
Y	0.04	12.2	9.8	14.1	16.2
Zr	0.07	63.4	59.2	82.0	92.5
Nb	0.02	6.7	7.0	8.3	8.9
Mo	0.05	6.1	4.3	21.9	1.3
Ag	0.03	0.041	< DL	0.043	0.093
Cd	0.04	0.53	< DL	0.14	0.068
Sn[a]	0.08	0.48	0.39	1.0	1.1
Sb	0.04	0.99	0.66	1.7	0.68
Cs	0.01	2.2	1.3	4.0	4.8
Ba	0.03	484	567	407	883
La	0.01	19.5	18.4	13.6	25.7
Ce	0.01	39.1	35.6	26.4	54.4
Pr	0.006	4.7	4.3	3.9	6.1
Nd	0.01	17.5	16.4	17.0	23.9
Sm	0.006	3.9	3.4	3.9	5.3
Eu	0.009	0.93	0.77	0.94	1.10
Gd	0.008	3.2	2.6	3.8	4.4
Tb	0.004	0.50	0.42	0.58	0.64
Dy	0.007	2.7	2.3	3.4	3.4
Ho	0.004	0.51	0.44	0.67	0.64
Er	0.003	1.4	1.3	1.9	1.9
Tm	0.004	0.19	0.17	0.27	0.27
Yb	0.007	1.4	1.2	1.9	1.9
Lu	0.006	0.19	0.17	0.27	0.28
Hf	0.008	2.0	1.9	2.6	3.0
Ta	0.01	0.47	0.46	0.59	0.64
W	0.02	1.0	0.71	1.8	1.0
Hg	0.01	0.025	0.019	0.060	0.046
Tl	0.01	0.38	0.31	0.47	0.60
Pb	0.04	13.2	11.5	13.9	23.2
Bi	0.012	0.11	0.065	0.17	0.19
Th	0.008	4.0	4.0	5.1	6.7
U	0.007	1.1	1.2	1.6	2.7

D.L. – detection limit
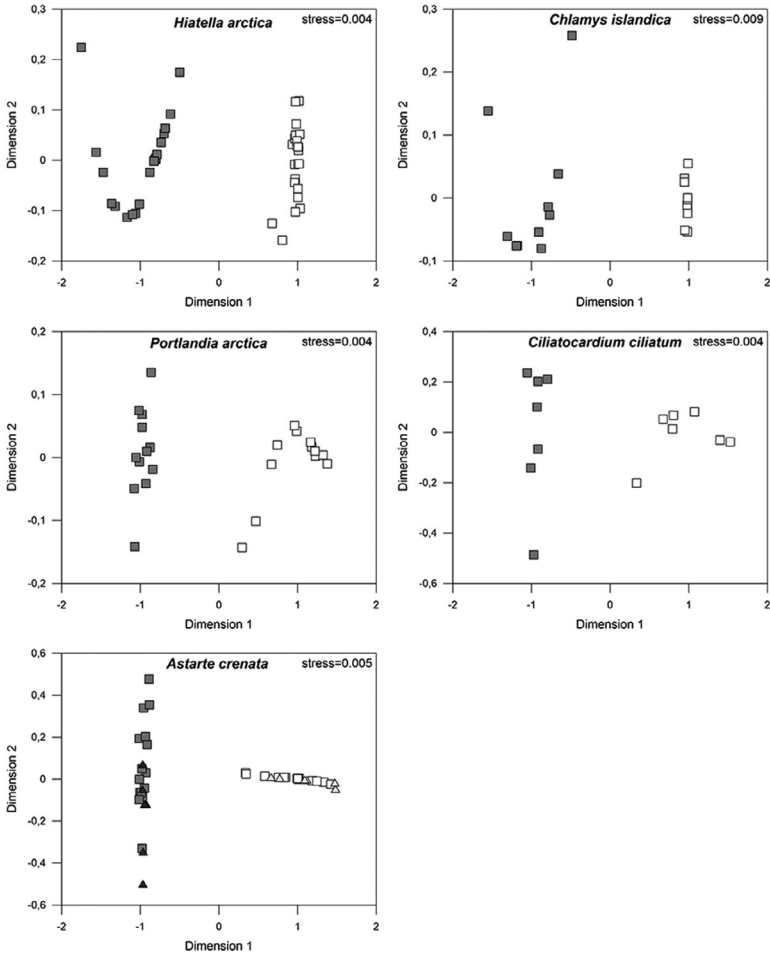[a] – non-analytic (rank) data.

Fig. 2. Non-metric multidimensional scale comparing chemical elements content in the soft tissues (filled shapes) and shells (unfilled shapes) of five species of bivalve mollusks from the Kara Sea. Data for *Astarte crenata* are given for two stations, 128-9 (squares) and 128-7 (triangles).

1 hour at 180°C, and 1 hour at 200°C. After cooling the autoclaves, the resulting solutions were transferred into polyethylene bottles. In each pre-weighted bottle, 0.1 mL of an internal indium standard (concentration of 10 mg/L) was added; the solution volume was brought to 10 mL with deionized water. Blanks were prepared by the same procedure without adding a sample material. When analyzing bottom sediments, 0.05-0.10 mL of concentrated HF (hydrofluoric acid 40%, Suprapure, GR, ISO, *Merck*) was added to the cups to dissolve the aluminosilicate minerals. Stable highly enriched isotopes ^{146}Nd (98.8%), ^{161}Dy (94.8%), and ^{174}Yb (98.2%) were used to control possible losses during the decomposition of sediment samples. The laboratory glassware was pre-cleaned with 10% HNO_3 solution.

The concentrations of chemical elements were measured by atomic emission spectrometry (ICP-AES) and mass spectrometry with inductively coupled plasma (ICP-MS) at the *iCAP-6500* and *X-7* spectrometers (*Thermo Scientific*, USA), respectively. Major elements (Na, Mg, Al, P, S, K, Ca, Ti, Mn, and Fe) were measured by ICP-AES; trace - and rare-earth elements (Li, Be, B, Sc, V, Cr, Co, Ni, Cu, Zn, Ga, As, Se, Rb, Sr, Y, Zr, Nb, Mo, Rh, Pd, Ag, Cd, Sn, Sb, Te, Cs, Ba, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, W, Re, Ir, Pt, Au, Hg, Tl, Pb, Bi, Th, and U), by
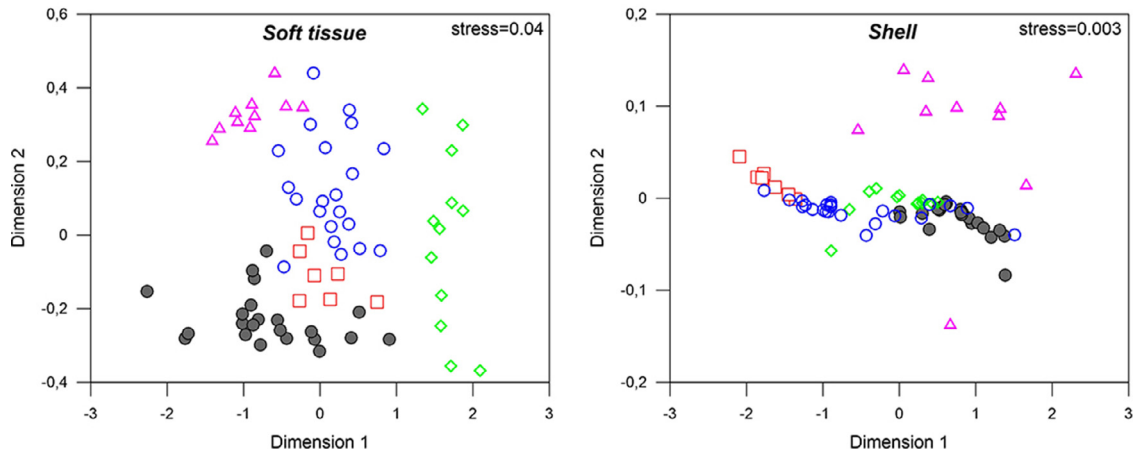
Fig. 3. Non-metric multidimensional scale comparing chemical elements content in the soft tissues and shells of *Astarte crenata* (filled circles), *Ciliatocardium ciliatum* (squares), *Portlandia arctica* (diamonds), *Chlamys islandica* (triangles), and *Hiatella arctica* (unfilled circles) from the Kara Sea.
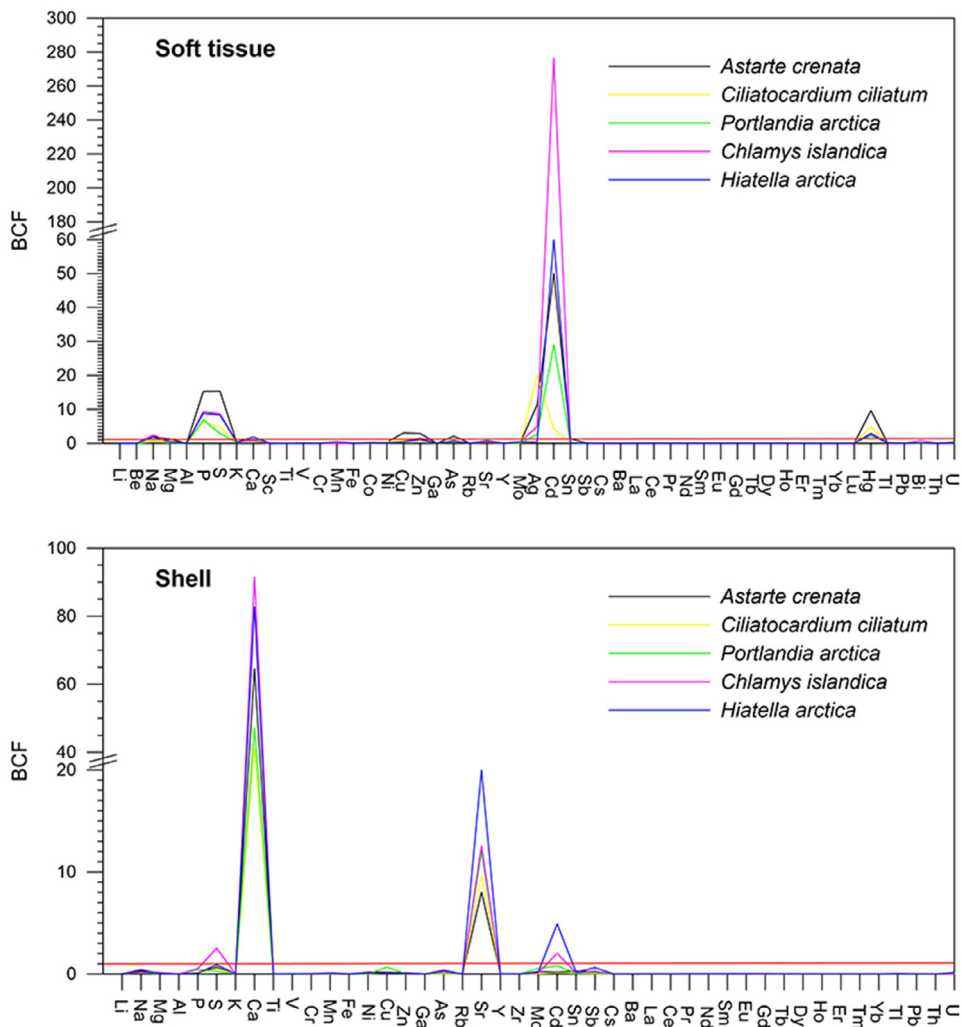
Fig. 4. Bioconcentration factors of chemical elements in the soft tissues and shells of five bivalve mollusk species from the Kara Sea.

ICP-MS. Some elements (Li, V, Cr, Mn, Co, Ni, Cu, Zn, Sr, and Ba) were determined independently by both methods in all solutions for verification of the measurement correctness for each analyzed sample. The content of Zr, Nb, Hf, Ta, and W in soft tissues and the content of B in mollusk shells and bottom sediments were not measured.

The accuracy of the mollusk sample analysis was controlled using standard reference material (SRM) NIST® SRM® 2976 Mussel Soft Tissues (National Institute of Standards and Technology, USA) and MODAS-3 Herring Tissue (Institute of Nuclear Chemistry and Technology, Warsaw, Poland). Measured values for most elements in these SRM fell within the confidence intervals of certified values (Table 3). NIST® SRM® 2702 inorganics marine sediments were used for the analysis of bottom sediments. The recovery observed between certified and measured values of NIST 2702 is 85-113%, except for Sn (50%) presented as non-analytic (rank) data (Table 3).

Table 3

Measured and certified values of element concentrations in reference materials.

Element	DL	NIST 2976 Measured	Certified	M-3 HerTis Measured	Certified	NIST 2702 Measured	Certified
Concentration, %							
Na	0.0007	3.59±0.04	3.5±0.1	1.88±0.05	1.94±0.17	0.71	0.68±0.02
Mg	0.0005	0.500±0.001	0.53±0.05	0.30±0.01	0.30±0.02	0.95	0.990±0.074
Al	0.0017	0.016±0.001	0.013±0.003	0.003±0.003	n.d.	8.46	8.41±0.22
P	0.0014	0.700±0.002	0.83	2.45±0.07	2.35±0.39	0.16	0.155±0.007
S	0.002	1.760±0.002	1.9	0.99±0.04	0.93±0.10	1.6	1.5
K	0.0006	1.01±0.01	0.97±0.05	1.18±0.04	1.18±0.13	1.99	2.05±0.07
Ca	0.0019	0.71±0.01	0.76±0.03	4.28±0.22	3.69	0.36	0.34±0.02
Concentration, mg kg^{-1}							
Li	0.006	0.62	n.d.	0.93±0.02	0.90±0.11	80.4	78.2
Sc	0.08	< DL	0.0146±0.0003	< DL	0.0032±0.0004	22.9	25.9±1.1
V	0.4	0.93	n.d.	0.91±0.31	0.78±0.11	346	358±9
Cr	0.3	< DL	0.50±0.16	0.99±0.08	0.90±0.11	294	352±22
Mn	0.3	35.3	33±2	5.58±0.19	5.78±0.61	1704	1757±58
Fe	4	175	171±5	195±12	190±13	73182	79100±2400
Co	0.08	0.69±0.01	0.61±0.02	0.08±0.02	0.08±0.012	24.4	27.8±0.6
Ni	0.4	0.84±0.02	0.93±0.12	0.42±0.10	0.32±0.049	72.3	75.4±1.5
Cu	0.6	4.3±0.2	4.0±0.3	3.30±0.28	3.20±0.22	111	117.7±5.6
Zn	0.6	144.0±1.4	137±13	112±4	111±6	495	485±4
Ga	0.04	0.050±0.004	n.d.	0.083±0.005	n.d.	21.2	24.3±1.9
As	0.01	13.6±0.1	13.3±1.8	9.8±0.6	9.2±0.8	38.4	45.3±1.8
Se	0.1	1.7±0.1	1.8±0.2	2.6±0.4	2.60±0.25	4.9	4.95±0.46
Rb	0.003	4.4±0.1	4.1±0.1	2.3±0.1	n.d.	117	127.7±8.8
Sr	0.009	71.0±0.8	93±2	192±7	192±15	103	120±3
Y	0.001	0.06	n.d.	0.01±0.03	0.0096*	28.8	n.d.
Mo	0.01	0.49	n.d.	0.14±0.01	0.13±0.02	9.8	10.8±1.6
Ag	0.004	0.008±0.001	0.011±0.005	0.033±0.001	0.036±0.005	0.58	0.622±0.078
Cd	0.008	0.78±0.01	0.82±0.16	0.32±0.01	0.33±0.03	0.82	0.817±0.011
Sn	0.005	0.083	0.096±0.040	0.09±0.07	n.d.	14.6	31.6±2.4
Sb	0.003	0.01	n.d.	0.02±0.01	0.016±0.0038	5.6	5.6±0.24
Cs	0.001	0.025±0.002	0.027±0.001	0.084±0.002	0.085±0.0078	6.7	7.1
Ba	0.006	0.82	n.d.	2.7±0.15	2.7±0.28	353	397±3
La	0.01	0.060±0.003	n.d.	0.017±0.024	n.d.	63.6	73.5±4.2
Ce	0.001	0.095±0.007	0.109±0.008	0.03±0.05	n.d.	102	123.4±5.8
Eu	0.0011	0.0022±0.0008	0.0024±0.0003	< DL	n.d.	1.7	n.d.
Hg	0.003	0.065±0.007	0.061±0.004	0.23±0.02	0.23±0.02	0.37	0.447±0.007
Tl	0.000	0.0015±0.0004	0.0013	0.0012±0.0002	n.d.	0.75	0.827±0.006
Pb	0.005	1.25±0.04	1.19±0.18	0.12±0.03	0.10±0.013	137	133±1
Th	0.001	0.014±0.003	0.011±0.002	0.005±0.007	n.d.	17.8	20.50±0.96
U	0.0002	0.22	n.d.	0.08±0.01	0.075±0.008	9.2	10.4

DL – detection limit; < DL – below detection limit; n.d. – no data

2.3. Data analysis

The method of non-metrical multidimensional scaling was applied to compare the chemical composition of soft tissues and shells of mollusks and to search for interspecies differences in the content of chemical elements. The pattern of the object remoteness at two-dimensional image evidences on the significant differences between the compared samples, vice versa, the proximity of the objects on the scale indicates their similarity. This analysis was performed in *Statistica 10.0* software package.

The accumulation of chemical elements in the tissues of mollusks and bottom sediments was compared by the bioconcentration factor (BCF) according to the equation [6,7]:

$$BCF = element_{organism} / element_{environment}$$

where element $_{organism}$ is the content of a chemical element in the mollusk tissue, element $_{environment}$ is the content of the same chemical element in bottom sediments.

Ethics Statement

The authors declare that they have followed the general ethics rules of scientific research performance and publishing. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

CRediT Author Statement

Dmitry F. Budko: Writing original draft, Formal analysis, Visualization, Funding acquisition; **Nikolay V. Lobus:** Resources, Writing review & editing; **Andrey A. Vedenin:** Investigation, Writing review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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Supplementary Materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2021.107087.

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