Natural and Anthropogenic contamination analysis of the sediments collected around Novaya Zemlya

RAJAN JAKHU

POST DOCTORAL FELLOW

SECTOR OF NEUTRON ACTIVATION ANALYSIS

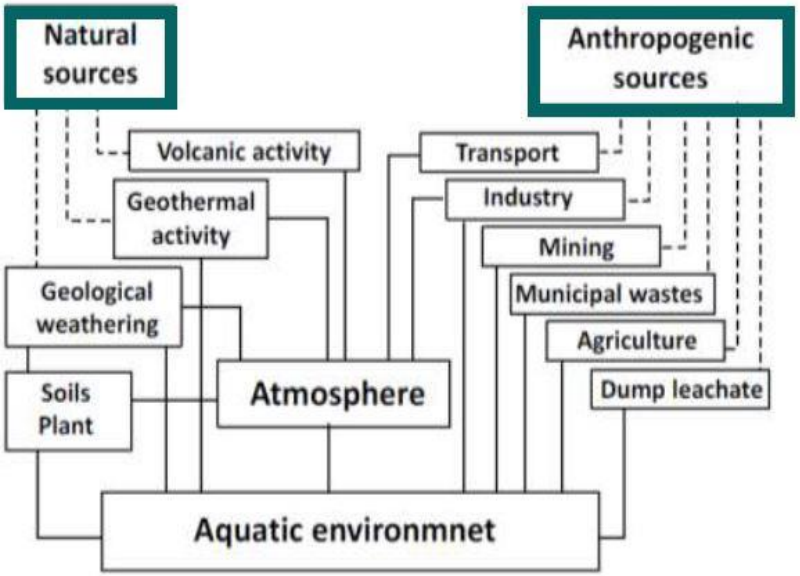
AND APPLIED SCIENCE, FLNP, JINR

Introduction

Inorganic contaminants

Non-degradable

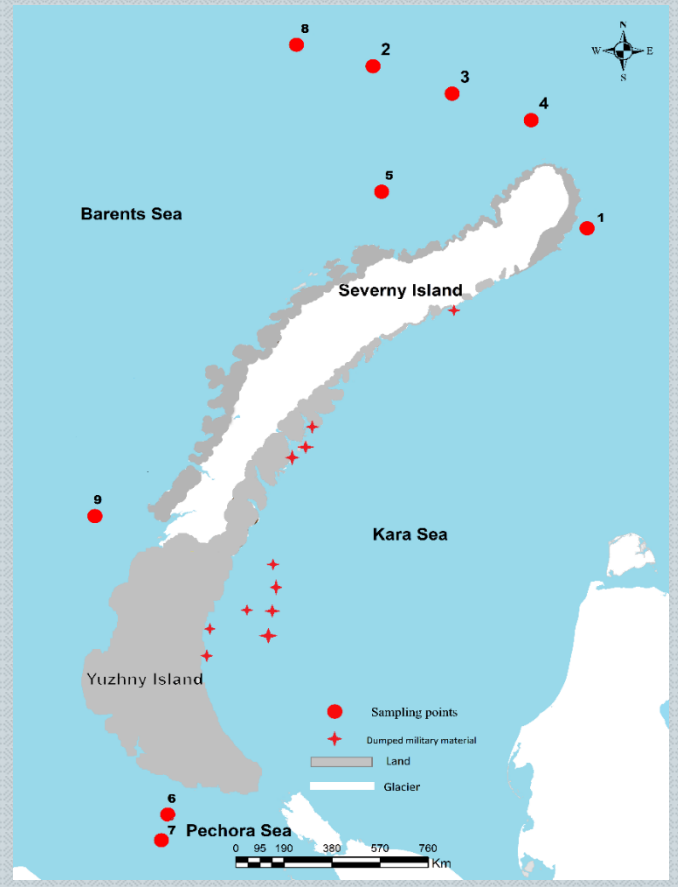
Bioaccumulation and biomagnification



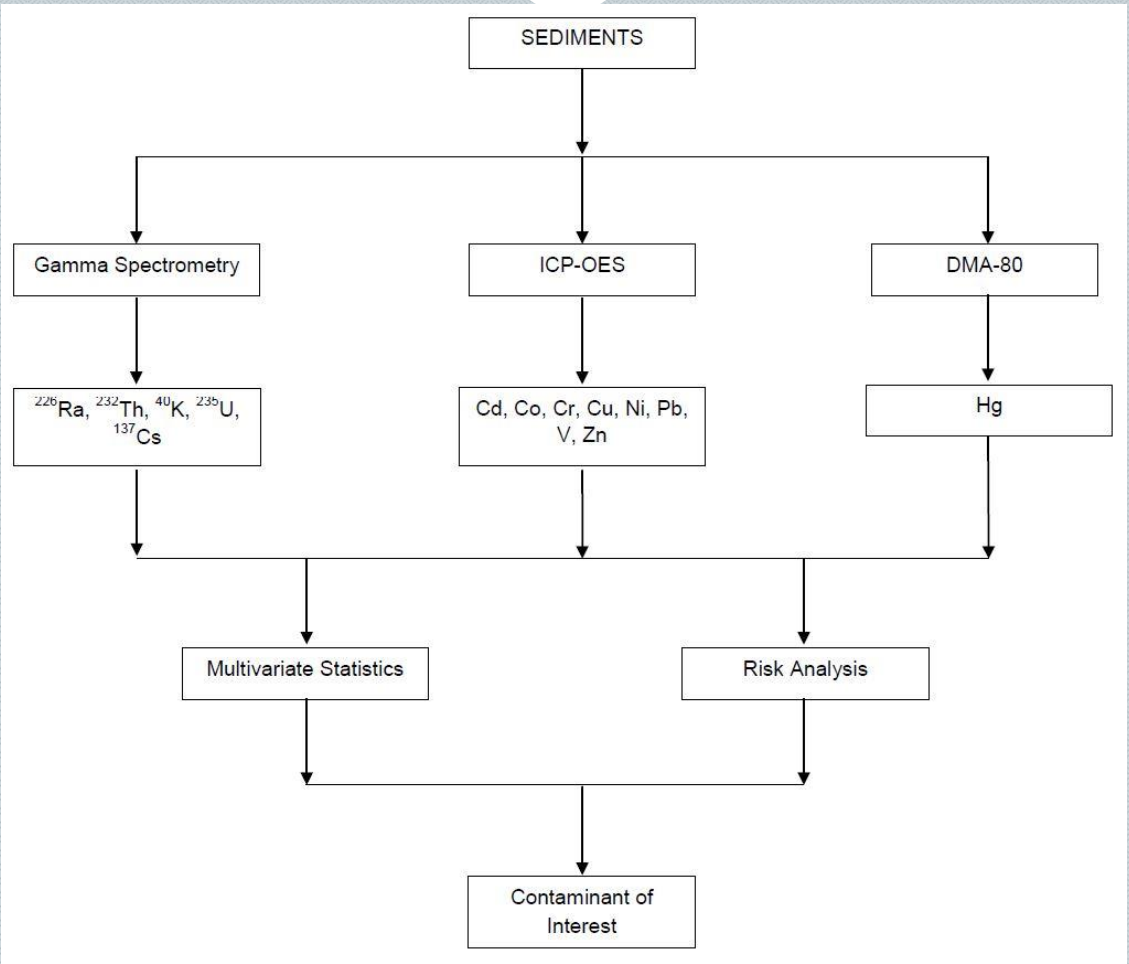
Gaillardet et al., 2013

Study Area and Sampling

- Novaya Zemlya is a bow-shaped widened island, having length and width of 600 miles and 60 miles respectively. In the Russian arctic circle.
- It's Complex geology and historical perspective makes it a prominent region of study.
- Sediment samples were collected in June-July 2022 in the framework of scientific and educational project "Arctic Floating University 2022: The Changing Arctic".

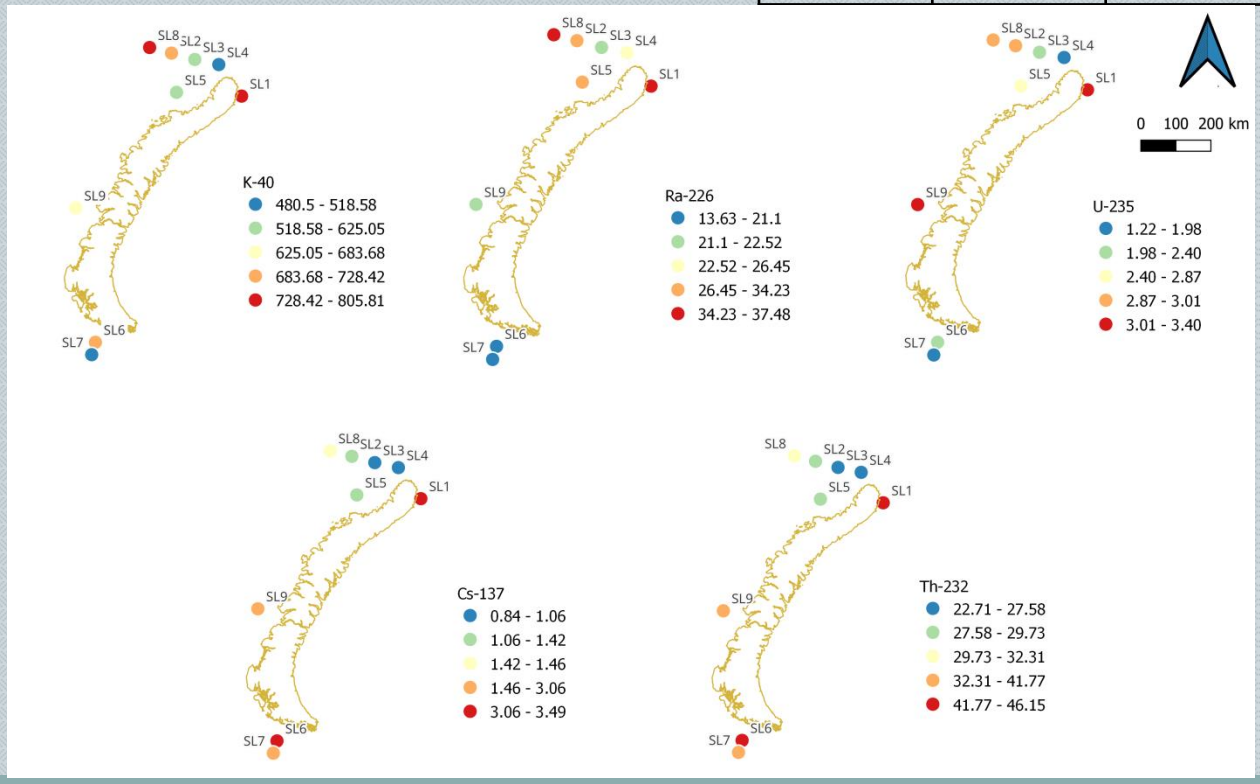


Analytical Approach



Results: 1. Radioactivity Measurements in Bq/kg

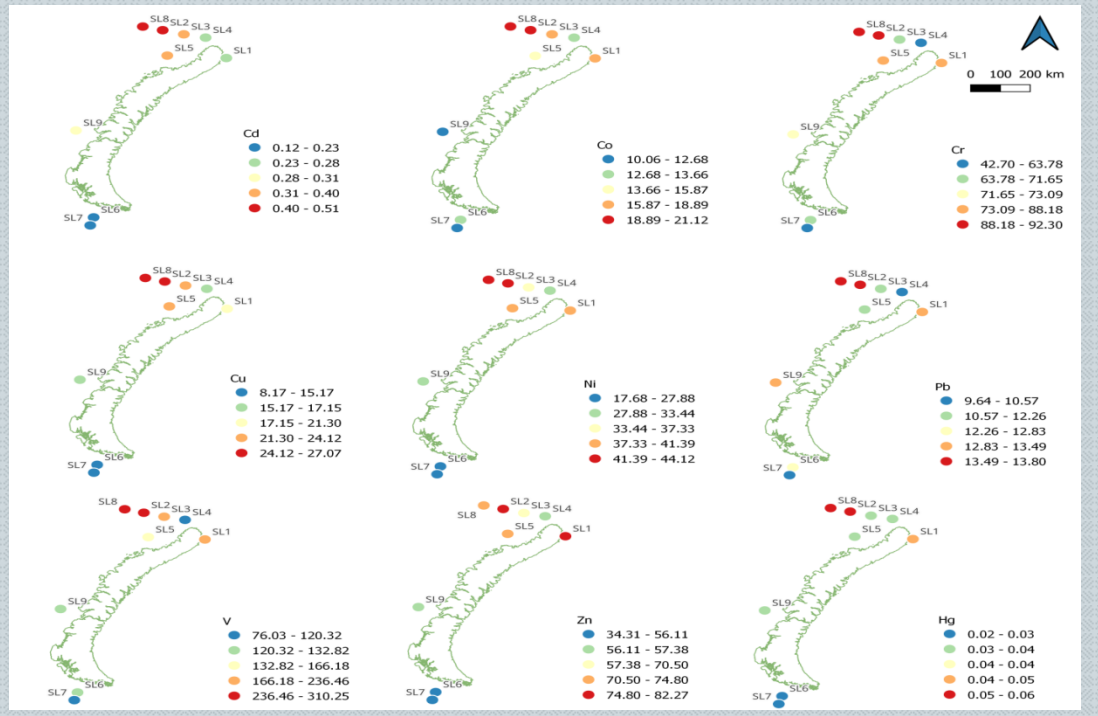
Parameter	^{40}K	^{137}Cs	^{226}Ra	^{235}U	^{232}Th
Activity (Average)	618.90	1.75	25.19	2.37	32.39
@World Activity (Average)	400	-	35	-	30
Activity (Minimum)	445.82	0.83	12.68	0.97	21.11
Activity (Maximum)	805.81	4.37	37.48	3.40	46.15
Skewness	0.16	1.36	0.16	-0.22	0.56
Kurtosis	-1.16	1.23	-0.53	-0.58	-0.76
*COV	18.29%	60.63%	29.31%	30.2%	23.62%



*Coefficient of variation @UNSCEAR, 2008

2. Potentially toxic elements(PTE)concentrations

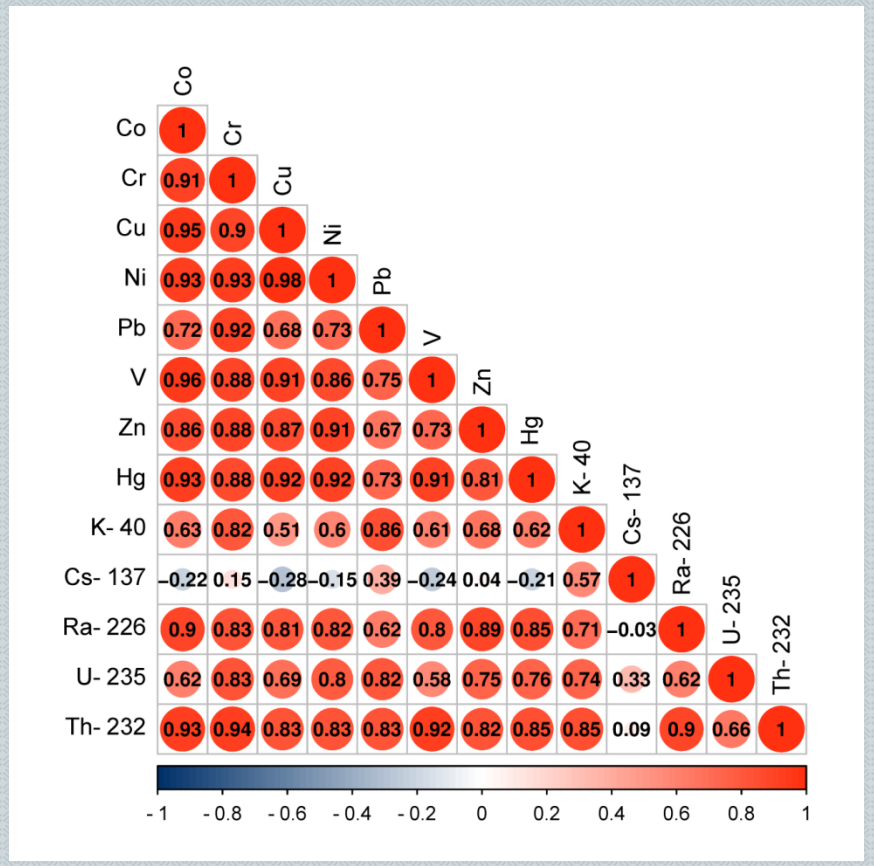
Location	pH	Organic content (%)	Cd (mg/kg)	Co(mg/kg)	Cr(mg/kg)	Cu(mg/kg)	Ni(mg/kg)	Pb(mg/kg)	V(mg/kg)	Zn(mg/kg)	Hg(mg/kg)
#Class-I concentrations			0.8	-	100	35	35	85	-	140	0.3
Minimum	6.63	0.51	0.12	10.06	42.70	8.17	17.68	9.64	76.03	34.31	0.02
Maximum	7.43	3.15	0.51	21.12	92.30	27.07	44.12	13.80	310.25	82.27	0.06
Average	7.12	1.30	0.31	15.50	72.63	19.20	34.16	12.11	174.66	63.25	0.04
COV			40.35	24.09	22.73	32.14	25.15	13.09	47.20	23.18	37.50

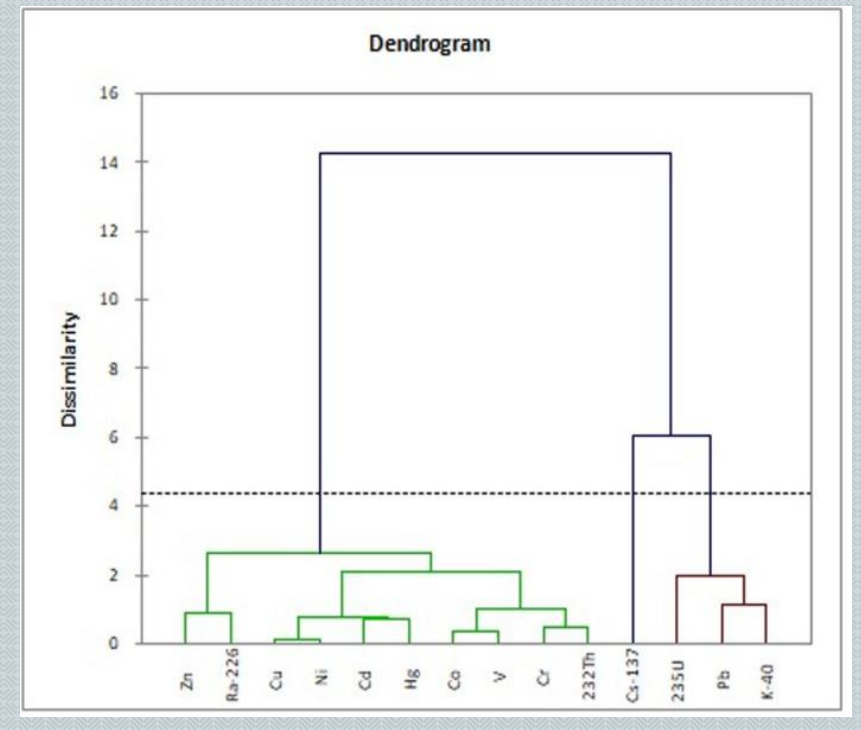


Spatial distribution of potentially toxic elements, mg/kg

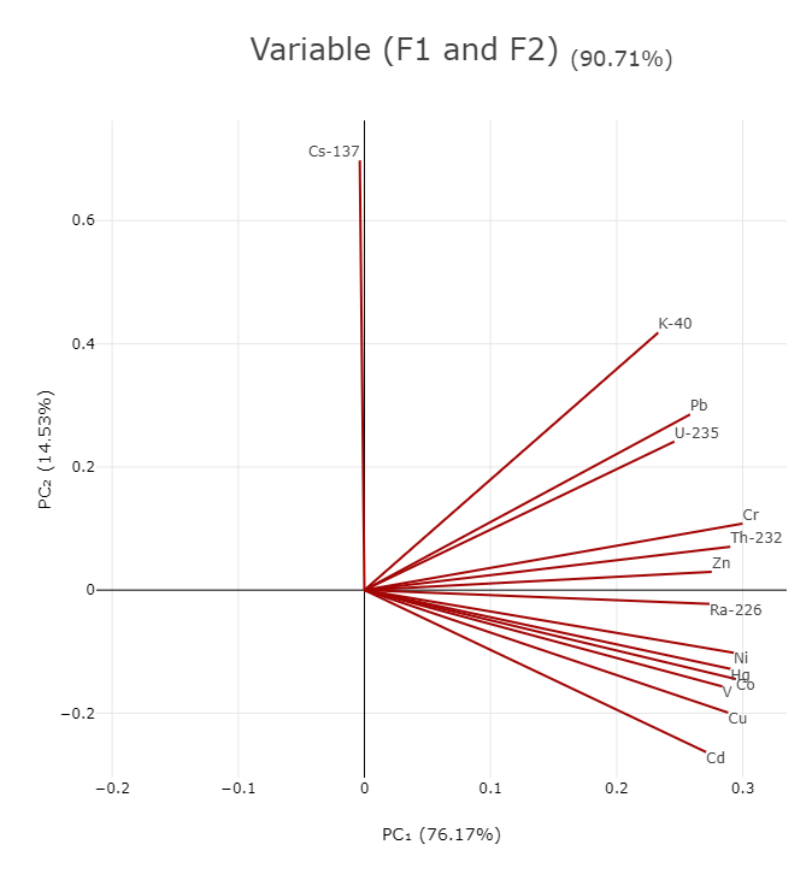
class-I stands for slightly polluted Pollution classification w.r.t Russian sediment guidelines(Kurakina and Shlygina, 2017)

3. Multivariate Statistics



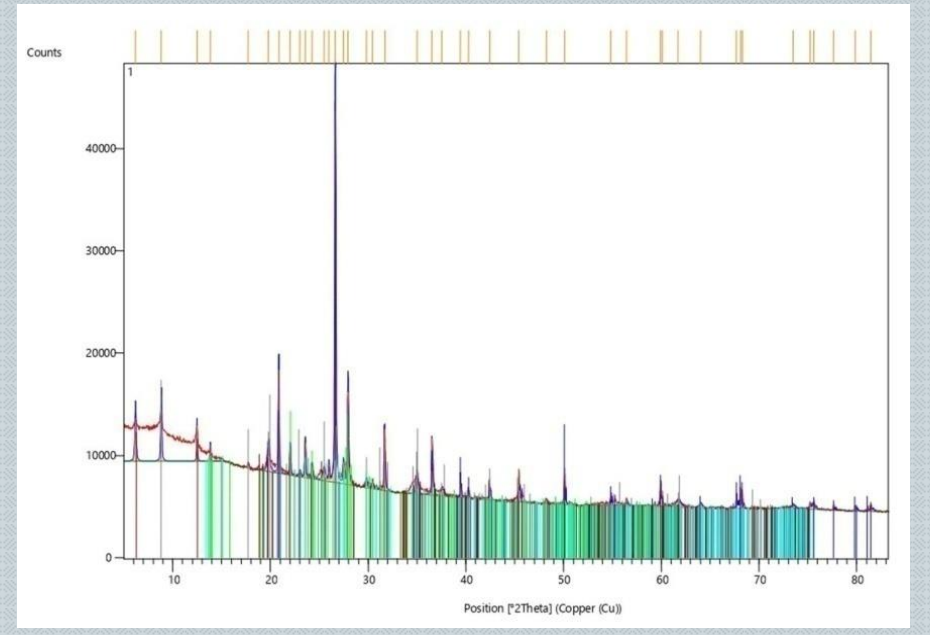


Correlation and Cluster Analysis



PCA Analysis

4. XRD Analysis



✓In the XRD spectrum of the sediment were identified different minerals including quartz, feldspar, mica and chlorite.

5. Contamination and Risk assessment of PTE

- The contamination factor (CF) and it was computed as follows:
- CF = Cs/Cb

  Where Cs is the content of the element in the sediment and Cb is its regional value without the anthropogenic input.

The interpretations of these results can be found from the following contamination scale: CF<1 (little contamination); 1≤CF<3 (average contamination); 3≤CF<6 (substantial contamination); CF≥6 (elevated contamination).

Location	Contamination factor							
	Cd	Co	Cr	Cu	Ni	Pb	Zn	Hg
1	4	1	4	2	2	1	2	1
2	7	1	4	2	2	1	2	1
3	5	1	3	2	1	1	1	1
4	4	1	3	1	1	0	1	0
5	4	1	3	2	2	1	2	0
6	3	1	3	1	1	1	1	0
7	2	1	2	1	1	0	1	0
8	7	1	4	2	2	1	2	1
9	4	1	3	1	1	1	1	0

Pollution load index (PLI) and Degree of contamination (DC)

- PLI is another index used to estimate the level of hazardousness. It is calculated from the CF values of all the PTE at a particular location as follows:

  PLI = $(CF1 * CF2 * CF3 * \ldots\ldots CFn)^{1/n}$

  Where CF1, CF2….CFn are the values of the contamination factors for the Ist, 2nd….nth metal as calculated above. The result obtained if it less than zero, it is considered no pollution; 1 for baseline level contamination and 2 for high contamination.
- DC is a hazard index similar to PLI which utilizes the CF values of various heavy metals and it can be calculated from the below given equation:

  DC = CF1+CF2+CF3+……+CFn

  The comparison scale for DC has four levels: DC<n corresponds to low pollution, n≤DC<2n is for medium pollution, 2n≤DC<4n for significant pollution, DC>4n for lethal order of pollution.

Location	PLI	DC
1	2	16
2	2	20
3	1	15
4	1	12
5	1	15
6	1	11
7	1	7
8	2	20
9	1	14

Geo accumulation index (I_{geo})

- I_{geo} is based on the background elemental content. Similar to CF, it utilizes the uncontaminated levels of chemical elements in soil or sediments to determine the pollution level at a specific location. The formula is given below

$$I_{geo} = \log_2\left(\frac{Cn}{2 * Bn}\right)$$

- I_{geo} = 0 is for low contamination and $0 < I_{geo} \leq 1$ corresponds to moderate contamination levels.

Location	Cd	Co	Cr	Cu	Ni	Pb	Zn	Hg
1	1	0	1	0	0	-1	0	-1
2	2	0	2	1	0	-1	0	-1
3	2	0	1	0	0	-1	0	-1
4	1	-1	1	0	0	-2	0	-2
5	2	0	1	0	0	-1	0	-2
6	1	-1	1	0	0	-1	0	-3
7	0	-1	0	-1	-1	-2	-1	-3
8	2	0	2	1	0	-1	0	-1
9	2	-1	1	0	0	-1	0	-2
Average	1	-1	1	0	0	-1	0	-2

Sediment quality guidelines

- The biological threat evaluation of the exposed elements from the sediments under consideration, can be evaluated using Sediment merit recommendations like Threshold effect level (TEL) and Probable effect level (PEL)

		Cd	Cr	Cu	Ni	Pb	Zn	Hg	%increase Cr	%increase Ni
Location	^TEL level (mg/kg)	0.59	37.3	35.7	18	35	123	0.174		
1			85.74		37.69				130	109
2			91.85		43.65				146	143
3			71.62		35.89				92	99
4			53.93		28.02				45	56
5			73.41		39.88				97	122
6			70.35		27.68				89	54
7			42.70						14	
8			92.30		44.12				147	145
9			71.79		32.83				92	82

		Cd	Cr	Cu	Ni	Pb	Zn	Hg	%increase Cr	%increase Ni
Location	^PEL level (mg/kg)		90		36					
1					37.69					5
2			91.85		43.65				2	21
3										
4										
5					39.88					11
6										
7										
8			92.30		44.12				3	23
9										

^MacDonald et al., 2000.Arch. Environ. Contam. Toxicol. 39, 20–31.

5. Conclusions

- At some locations, ^{226}Ra, ^{232}Th, ^{40}K activities are greater than the global average values.
- The anthropogenic ^{137}Cs has a moderate activity concentration.
- Ni and Cr are the predominant contaminant elements.
- Apart from ^{137}Cs, all other detected elements are of natural origin.
- In estimating the hazard from a particular PTE, its bioavailability and tendency to accumulate at the point of interest is foremost.
- Ni is a much important micronutrient than the Cr for the plants and animals, making it the major contaminant out of all detected PTE.

Marine Pollution Bulletin 194 (2023) 115346

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Natural and anthropogenic radionuclides concentration with heavy metals analysis of the sediments collected around Novaya Zemlya

Nikita Yushin [a], Rajan Jakhu [a,*], Omari Chaligava [a,b], Dmitrii Grozdov [a], Inga Zinicovscaia [a,c]

[a] Joint Institute for Nuclear Research, Joliot-Curie 6, 141980 Dubna, Russia
[b] Faculty of Informatics and Control Systems, Georgian Technical University, 77 Merab Kostava Street, 0171 Tbilisi, Georgia
[c] Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, 30 Reactorului Str., Magurele, Romania

ARTICLE INFO

Keywords:
Sediments
Radionuclides
Potentially toxic elements
^{137}Cs
Pollution source

ABSTRACT

The Dispersal profile of the radioisotopes (^{226}Ra, ^{232}Th, ^{235}U, ^{40}K, ^{137}Cs) along with potentially toxic elements (Cd, Co, Cr, Cu, Ni, Pb, V, Zn, and Hg) in the sediments around the Novaya Zemlya was determined. The task was fulfilled with the aid of HPGe gamma spectrometry, inductively coupled plasma optical emission spectroscopy, DMA-80 Direct Mercury Analysis System, X-ray diffraction and statistical tools. At most of the locations, the radionuclides activity was higher than the world average activity concentration for the respective nuclei, ^{40}K being the most abundant. From all the potentially toxic elements detected, Cr and Ni were usually observed on higher levels compared to their background values, indicating the probability of the detrimental biological effects. Thus, the present situation at the studied area might be a threat to the neighboring marine life.

Thank you for your Attention!

Any Questions?

rajan.jakhu@gmail.com