ENVIRONMENTAL ENGINEERING

The 8th International Conference
May 19–20, 2011, Vilnius, Lithuania
Selected papers

ISSN 2029-7106 print / ISSN 2029-7092 online
ISBN 978-9955-28-826-8 (1 Volume)
ISBN 978-9955-28-827-5 (3 Volumes)
http://enviro.vgtu.lt

EVALUATION OF DRINKING WATER ACCORDING TO GEOCHEMICAL COMPOSITION OF ITS SALT DEPOSITION

Leonid Rikhvanov[1], Natalya Baranovskaya[2], Bulat Soktoev[3], Tatiana Mongolina[4]

[1, 2, 3, 4]*Geoecology and Geochemistry Department, Tomsk polytechnic university, Lenina str. 30, Tomsk, Russia.*
E-mail: [2]natalya.baranovs@mail.ru

Abstract. Salt depositions of drinking water in three regions – Irkutsk, Tomsk and Cheljabinsk- were examined and analyzed. The total amount of analyzed samples included 416 items. The element composition analysis showed inheritance of the water element composition in salt depositions. The content level of macro- and micro elements in the scale depends on the geochemical peculiarities of that or another area. Natural (deposits, ore occurrences) and anthropogenic (industrial enterprises, urbanization) sources strongly effect the composition formation, It was determined that the element composition of depth drinking water sources included only natural element source inflow, while, in the case of surface drinking water sources, it is the result of natural and anthropogenic source impact. Obtained salt deposition data can be correlated with the data from other deposited environments.

Keywords: salt deposition, scale, under- and upper aquifer, microelements, geochemical specialization.

1. Introduction

Beginning from the 90's, in the course of complex geochemical monitoring in the south of the Tomsk oblast the salt formations (scale) on the dishware used to boil drinking water (samovars, tea-pots, etc.) have been chosen as an object of investigation for the first time. The results of the investigation have shown that the element composition of salt deposition in drinking water demonstrate clearly the changes in geochemical situations conditioned by the natural-technogenic factors (Язиков 2002; 2004; 2007; 2009; Рихванов 2006).

On the territory of Tomsk oblast a great deal of researchers were engaged in ground water studies, and the drinking water monitoring is performed annually. Besides, the studies of depositions formed in water-supply system have been made (Покровский 2002; Архипенко 1986; Телеснецкий 1969; Вологдина 1998). The study of drinking water scale element composition from dishware is comparably new trend in geochemistry with a restricted number of researchers (Язиков and Рихванов), though many hydrogeochemical researches included such methods as evaporation and precipitation with reagents, e.g. TPI co-precipitation technique (Удодов 1983). The main advantage of using scale as an investigation object consists in the fact that medium is depositing and shows long time period of its accumulation (months, years), hence, it gives not one-moment indicator, but present a long-time picture of drinking water chemical composition (Язиков 2007). Scale composition depends on the composition of drinking water from aquifer, type of water supply, washed geological structures, degree and character of man-made water transformation.

2. Materials and research methods

At present sampling is made in all regions of Tomsk oblast. To obtain the comparative characteristic of regional peculiarities in salt deposition the studies in Chelyabinsk, Irkutsk oblasts have been performed. The general number of salt deposition samples is 416.

There are no standards in scale sampling, therefore, in the course of investigation we used patent №2298212 "The way of determining uranium contaminated areas in the environment" (Рихванов 2007). The scale was carefully taken from the walls of dishware (tea-pot, pot, kettle, bucket) by tapping or with a knife made of stainless steel. In the register the type and material of dish, approximate depth of aquifer were fixed. The sample was dried at the room temperature, then it was grated in an agate mortar to powder, the scale was packed in 100 mg aluminum foil packages and sent for instrumental neutron-activation analysis (INAA). Instrumental neutron-activation analysis was performed in certified nuclear-geochemical laboratory (NGL) of Tomsk polytechnic University using certified methods, the content of 27 elements was determined. The limits of element determination by INAA are presented in Table 1.

Note: as a control sample a standard sample (GSO 7126-94) of Baikal sludge composition BIL-1 was used (Table 2).

Table 1. The limits of element determination in different objects (rocks, soil, plants etc.)

Element	Limit of determination, mg/kg	Element	Limit of determination, mg/kg	Element	Limit of determination, mg/kg
Na	10	Rb	0.5	Eu	0.004
Ca	300	Cs	0.01	La	0.01
Fe	100	Sr	100	Ce	0.06
As	0.3	Hf	0.009	Yb	0.009
Co	0.1	Zn	10	Lu	0.001
Cr	0.2	Ta	0.01	U	0.06
Sb	0.05	Sc	0.02	Th	0.01
Ba	10	Tb	0.005	Au	0.005
Br	1	Sm	0.01	Ag	0.3

Table 2. Comparative evaluation of element analysis by INAA method with the published data of BIL-1

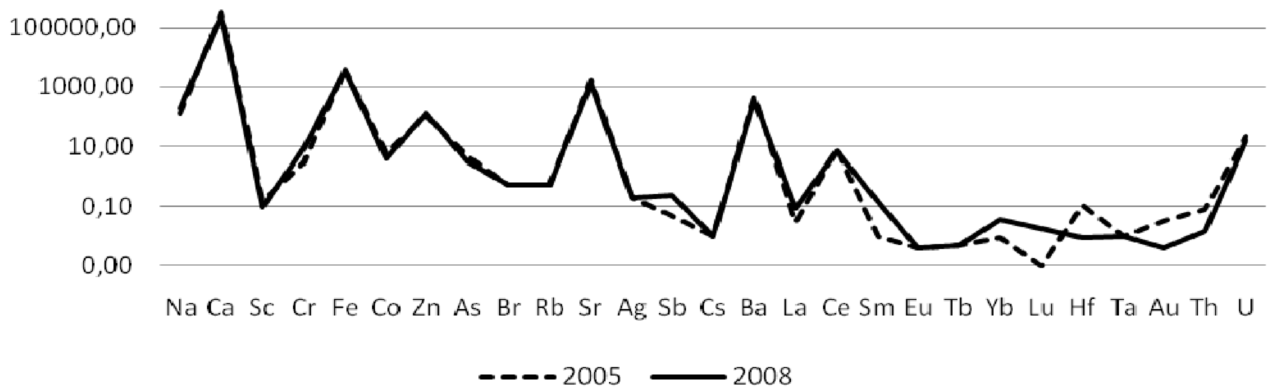
Element	**BIL – 1 (Russia)**		**Element**	**BIL – 1 (Russia)**	
	Published data	NGL		Published data	NGL
Na (%)	1.93	1.74	Ba	670	864
Ca (%)	1.86	6.76	La	51	40
Sc	13	16	Ce	81.5	70
Cr	67	69	Sm	7.9	6.79
Fe (%)	7.01	7.13	Eu	1.65	1.96
Co	18.5	17	Tb	0.95	0.94
Zn	-	-	Yb	3	2.44
As	-	-	Lu	0.44	0.46
Br	-	-	Ta	0.9	0.9
Rb	96	118	Hf	4.1	5.13
Sr	-	-	Th	12	12.5
Sb	1.5	1.52	U	12	10.7
Cs	5.9	6.7			

The analysis was performed by senior staff scientists A. F. Sudyko and L. V. Bogutskaya. The inner control allowed us to register the satisfactory convergence (Fig 1), insignificant discrepancies can be explained by the fact that the sample lay for three years, as well as the quality of analysis got better, the limits of element determination decreased.

The research at DRON-3M device has shown that the scale has 90 % composition of calcite with admixture of iron carbonates, magnesium, silicon, and it is identical in composition to carbonate depositions from the thermal spring of Pamukkale (Turkey). It is one of the geological wonders of the world. The water from the thermal springs is erupted onto the volcanic plateau bubbling from the ground and the water stream of 35 degrees C temperature including calcium carbonate flows down the slopes, cooling and transforming into dazzling white travertine deposition. Water composition in Pamukkale: Calcium – 349.1 mg/kg; Magnesium – 135.2 mg/kg; Soda – 189.2 mg/kg; Chlorine – 42.8 mg/kg; Sulfate – 921.3 mg/kg; Hydrocarbonate – 999.6 mg/kg; Nitrite (less than) – 0.003 mg/kg; Nitrate – 0.06 mg/kg.

3. Results and discussion

The average element composition of drinking water scale of Tomsk oblast is presented in Table 3. When calculating the average element composition (X) “the hurricane samples” were excluded, but they were shown in spread of particular values.



Note: Logarithmic scale

Fig 1. The inner control of instrumental neutron-activation analysis

Table 3. Element composition (mg/kg) in drinking water scale of Tomsk oblast

№	Element	N	X ± λ / min – max	№	Element	N	X ± λ / min – max
1	Na	316	230±15 / 10-16000	15	Ba	316	352±18 / 10-10056
2	Ca	279	275417±6107 / 2000-940000	16	La	316	0.72±0.09 / 0.006-103
3	Sc	316	0.25±0.03 / 0.004-21	17	Ce	316	1.8±0.2 / 0.04-95
4	Cr	316	10±1.5 / 0.1-1358	18	Sm	316	0.22±0.02 / 0.001-32
5	Fe	316	12457±1372 / 100-568000	19	Eu	316	0.03±0.01 / 0.002-7.3
6	Co	316	29±5 / 0.04-4727	20	Tb	316	0.014±0.003 / 0.005-2.6
7	Zn	238	1380±163 / 6-77939	21	Yb	316	0.05±0.008 / 0.004-5.9
8	As	316	2.7±0.13 / 0.1-96	22	Lu	316	0.01±0.003 / 0.0004-2.3
9	Br	289	1.9±0.1 / 0.3-57.3	23	Hf	316	0.06±0.009 / 0.003-8.6
10	Rb	316	0.7±0.07 / 0.5-49	24	Ta	316	0.03±0.008 / 0.01-9.2
11	Sr	296	924±47 / 10-4770	25	Au	316	0.1±0.03 / 0.001-40.2
12	Ag	316	0.89±0.29 / 0.05-862	26	Th	316	0.1±0.01 / 0.003-7.5
13	Sb	316	0.45±0.07 / 0.03-62	27	U	316	1.9±0.2 / 0.02-66.4
14	Cs	316	0.015±0.001 / 0.01-1.3				

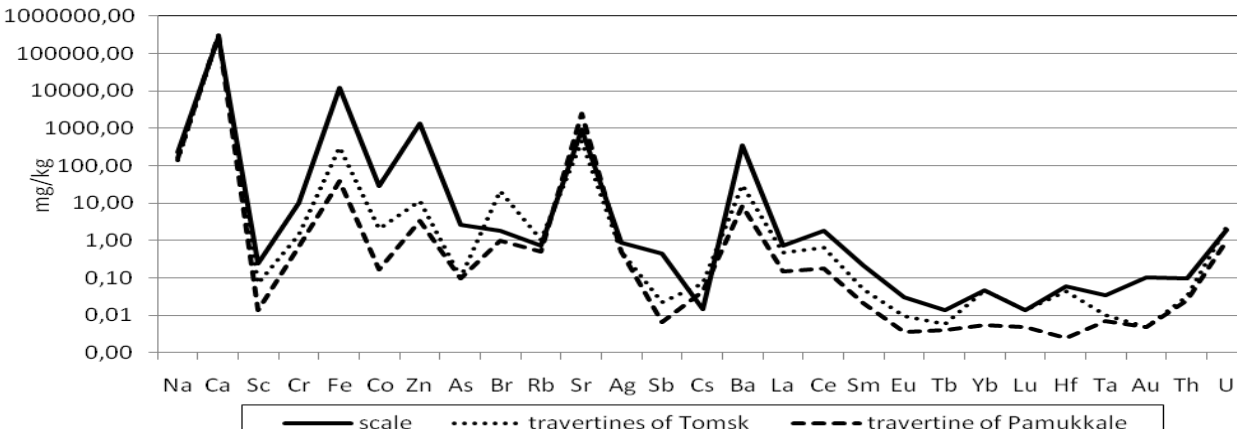
Note: N – a number of samples; X ± λ – average and standard error (calculated without taking into account “the hurricane samples”); min–max – minimum and maximum.

The analysis of the table pointed out the wide interval in spread of values of element composition. Such wide variation can be explained by different chemical composition of aquifers from which the water supply is performed as well as by the factors influencing the formation of water chemical composition. The problem of chemical composition formation of ground water is one of the most complex in hydrogeology since its composition is regulated by a great deal of factors and processes. Among the former, with respect to the upper zone, climate, relief, rock type, presence of organic compounds and their derivatives (precipitation, evaporation, temperature, permeability, water cycle etc.) are usually mentioned, among the second there are dissolution, bleaching, exchange reactions, evaporation concentration, sorption, mixing, hydrolysis etc (Шварцев 1982; 1998).

To reveal the peculiarities in scale chemical composition the natural lime formations – travertines have been analyzed (Fig 2). In travertines of Pamukkale the concentration of nearly all elements is lower than that of travertines from Tomsk except for Sr. In composition of Tomsk travertines particular emphasis is placed upon the high concentration of Br (21 mg/kg). The scale composition differs from the natural formations in high concentration of Sc, Fe, Co, Zn, As, Sb, Ba, La, Ce, Sm, Eu, Tb, Ta, Au, Th.

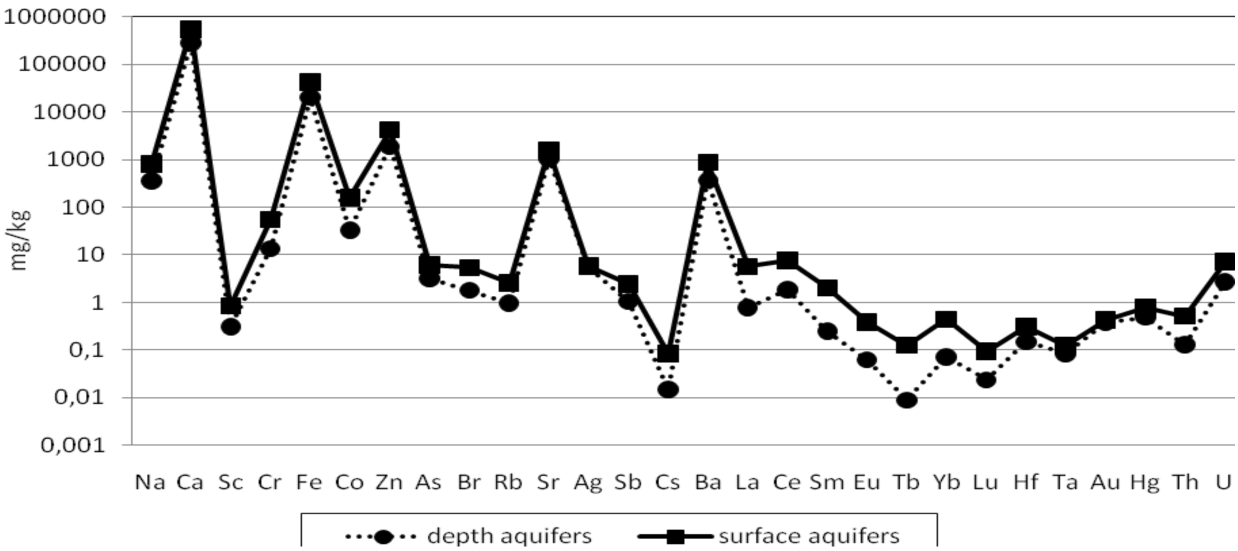
The result of research in drinking water scale from different aquifers shows that the depth of occurrence has a significant impact on its composition (Язиков 2006; Монголина 2009). For comparative analysis we have made two sampling: salt deposition from the dishware of inhabitants with individual water supply of aquifer occurrence depth not more than 40 m and drinking water scale of under aquifers. A wider range of elements is accumulated in drinking water scale of upper aquifers (Fig 3), including groups of rare-earth (La, Ce, Sm, Eu, Tb, Yb, Lu) and natural radioactive elements (Th, U). The given feature of chemical element accumulation in ground waters was noted by V. A. Zuyev and S. L. Шварцев (Рихванов 1997).

Ground water of surface springs are slightly protected from anthropogenic pollutants, that, in combination with natural factors, forms their composition, mosaic and unstable in space and time, which is often extrinsic to natural waters and does not meet standard requirements in many respects. A significant role in water supply of such aquifers is played by infiltration of rain and snow water.



Note: Logarithmic scale

Fig 2. Comparative analysis of scale chemical composition and natural lime formations



Note: Logarithmic scale

Fig 3. Comparative characteristic of element composition in drinking water scale of depth and surface aquifers

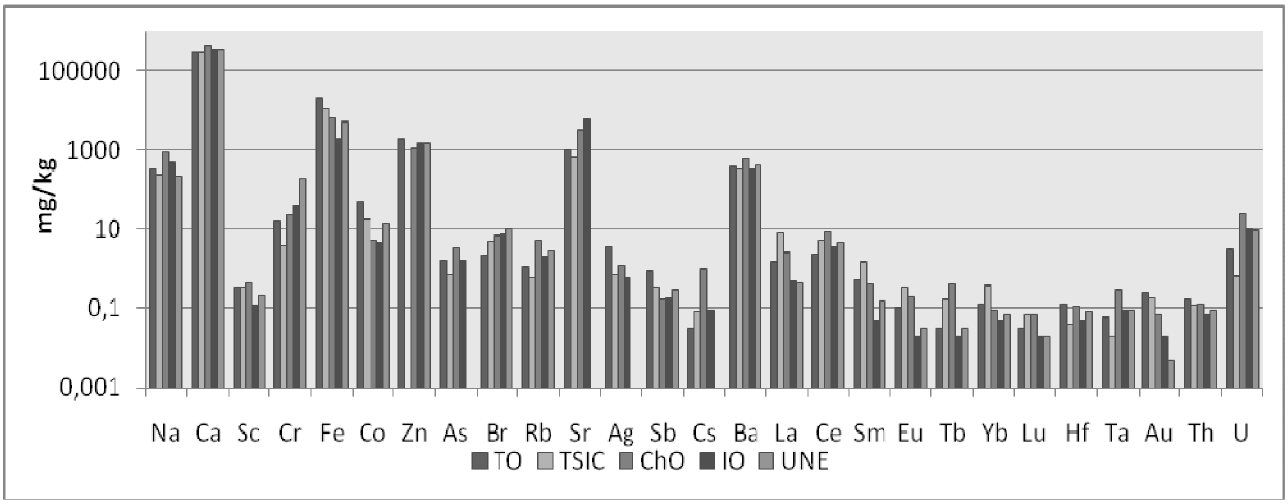
Besides, there is a wide range of elements in atmospheric precipitation which, passing through the soil, are enriched with the elements from soil solutions. Soil solutions are accumulators of various microelements carrying out by infiltrating water.

In the case of upper aquifers the accumulation site of rare-earth elements are clearly fixed in those inhabited areas where samples were taken from inhabitants using individual water supply (well, hole) for drinking water. Thus, in Moryakovskiy zaton village the highest concentrations of rare-earth elements are pointed out in the upper aquifers (La – 102 mg/kg, Ce – 95 mg/kg, Sm – 19 mg/kg, Eu – 4.5 mg/kg, Tb – 2.6 mg/kg, Yb – 5 mg/kg, Lu – 0.85 mg/kg), but in the depth the concentration of those elements is lower the limit of determination. The given fact allows for speaking about possible anthropogenic source of these elements.

In the depth aquifers rare-earth elements are accumulated mostly and more intensively in the south and south-east part of Tomsk oblast. On those aquifers of the given regions the coal, bauxite and zircon-ilmenite deposits are located. Besides, on the boundaries with Kemerovo oblast and Krasnoyarsk Territory the areas are rich in mineral resources that can influence the water composition of aquifers in the south-east part of Tomsk oblast, which is reflected in salt deposition composition from the dishware.

To reveal the regional peculiarities in salt deposition (scale) of drinking water the comparative analysis of drinking water scale composition was performed in Tomsk, Chelyabinsk and Irkutsk oblasts (Fig 6).

In Chelyabinsk oblast three settlements located in vicinity to the large nuclear-fuel plant “Mayak” (Muslumovo, Khudayberdinsk, Argayash) were investigated. In Irkutsk oblast more than 64 samples were studied including the settlements located within the area of the underground nuclear explosion “Rift-3”.



Note: Logarithmic scale, TO – Tomsk oblast, TSIC – Tomsk-Seversk Industrial Complex, ChO – Chelyabinsk oblast, IO – Irkutsk oblast, UNE – underground nuclear explosion, average composition (mg/kg) is calculated taking into account «the hurricane» samples.

Fig 4. Regional peculiarities of drinking water scale composition

The calculation of average concentrations in the regions has shown that Chelyabinsk and Irkutsk oblasts are distinguished by higher concentrations of U and Br in comparison with Tomsk. Besides, the elevated concentrations of rare-earth elements in comparison with other studied oblasts are to be referred to the geochemical peculiarities of drinking water scale composition in Chelyabinsk oblast. In Tomsk oblast the elevated concentrations of iron and cobalt were observed, which account for general geochemical feature of the region conditioned by elevated concentrations of the given elements in water due to occurrence of ores of Western-Siberian iron-ore basin (*Рудные месторождения*... 1978).

As was shown by our research, element composition of scale clearly accounts for technogeneous constituent of the impact. To present this fact strictly the average element composition was calculated for selected settlements located under the constant influence of Tomsk-Seversk industrial complex: Georgievka, Naumovka, Chernaya Rechka (Yuksa), Samus, Orlovka, Kizhirovo, Moryakovka, Kozyulino. The results have shown that in these settlements the concentrations of such elements as Br, Cs, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf are higher as compared to the values of Tomsk oblast in general. With the same purpose the settlements located in the zone of nuclear explosion in Irkutsk oblast were studied separately: Khandagay, Obusa, Borokhol. Calculation of average value has shown that the concentrations of Sc, Cr, Fe, Co, Zn, Br, Rb, Sb, Ba, Ce, Sm, Yb, Hf, Th in those settlements is higher than in Irkutsk oblast in general.

4. Conclusion

The presented data allows for speaking about the fact that scale from house dishware of different settlements can give significant information about peculiarities of ground water microelement composition. This medium is indicating and reflects the features of anthropogenic and natural constituents of impact on the studied objects. Besides, scale element composition accounts for the degree of anthropogenic load. Drinking water scale composition permits the regional peculiarities of the studies area to be revealed.

References

Tapkhaeva, A. E.; Taisaev, T. T.; Rikhvanov, L. P.; Yazikov, E. G.; Baranovskaya, N. V. 2010. Geochemical Specializationof Limescale of WaterSources Illustrated by Two Regions in Siberia. *Sibirskii Ekologicheskii Zhurnal*, 4: 685–696.

Архипенко, Д. К. *et al.* 1986. Исследование осадка, образующегося на фильтрах обезжелезивания [Study of deposition formed on the iron removal filters]. *Химия и технология воды*. 8: 62–64.

Вологдина, И. В.; Лычагин, Д. В.; Покровский, Д. С. *et al.* 1998. Изучение минеральных новообразований подземных водозаборов г. Томска [Study of mineral formations in ground aquifers of Tomsk city]. In *Актуальные вопросы геологии и географии Сибири: Материалы научной конференции 1-4 апреля 1998.* Томск: Изд-во ТГУ, 3: 38–42.

Монголина, Т. А. 2009. Содержание элементов в накипи питьевых вод разных водоносных горизонтов Томской области [Element composition of drinking water scale from different aquifers of Tomsk oblast] In *Проблемы геологии и освоения недр: Труды XIII Международного симпозиума студентов и молодых ученых имени академии М.А. Усова, посвященного 110-летию со дня рождения профессора, Лауреата государственной премии СССР К.В. Радугина, Томск, ТПУ, 6-11 апреля.* Томск: Изд. ТПУ, 730–732.

Покровский, Д. С. *et al.* 2002. *Минеральные новообразования на водозаборах Томской области* [Mineral formations in water supply points of Tomsk oblast]. Томск: Изд-во НТЛ. 176.

Рихванов, Л. П. 1997. *Общие и региональные проблемы радиоэкологии* [General and regional problems of radioecology]. Томск: Издательство ТПУ, 384.

Рихванов, Л. П. *et al.* 2006. *Эколого-геохимические особенности природных сред Томского района и заболеваемость населения* [Ecological-geochemical peculiarities of natural media in Tomsk region and population disease rate]. Томск: Изд-во „Курсив“. 216.

Рихванов, Л. П.; Язиков, Е. Г.; Барановская, Н. В.; Янкович, Е. П. 2007. № 2298212 Способ определения участков загрязнения ураном окружающей среды [The way of determining uranium contaminated areas in the environment]. Заявка № 2005120840 от 04.07.2005. Зарегистрирован в Госрегистре изобретений РФ 27.04.2007.

Рудные месторождения СССР [Ore deposits in the USSR]. 1978. М.: Недра, 1: 87.

Телеснецкий, А. Ф.; Тимашев, В. В.; Волкова, А. В. 1969. Исследование состава осадков водопроводных станций с целю использования их для производства строительных материалов [Study of water-pipe depositions in water supply stations with the purpose to use them in manufacture of building materials]. *Труды Московского химико-технологического института. Сер. Силикаты,* 39: 283–285.

Удодов, П. А. 1983. *Гидрогеохимия поисков рудных месторождений* [Hydrogeochemistry of ore deposit exploration]. М.: Недра, 199.

Шварцев, С. Л. 1998. *Гидрогеохимия зоны гипергенеза* [Hydrogeochemistry of hypergenesis zone]. М.: ОАО “Издательство “НЕДРА“, 366.

Шварцев, С. Л.; Пиннекер, Е. В.; Перельман, А. И. *et al*. 1982. *Основы гидрогеологии. Гидрогеохимия* [Bases of hydrogeology. Hydrogeochemistry]. Новосибирск: Наука. 286.

Шевченко, Л. Я. 1985. Утилизация осадков водопроводных станций [Utilization of water station depositions]. *Водоснаб. и санит. техника,* 4: 21.

Язиков, Е. Г. 2006. *Экогеохимия урбанизированных территорий юга Западной Сибири* [Ecogeochemistry of urbanized territories in the South of western Siberia]: диссертация на соискание ученой степени доктора гелого-минералогических наук. Томск: Б.и., 423.

Язиков, Е. Г.; Барановская, Н. В.; Рихванов, Л. П. 2007. Использование солевых образований (накипи) для целей геохимического районирования территорий. *Материалы Международной научной конференции, посвященной 100 – летию со дня рождения академика К.И. Лукашева „Современные проблемы геохимии, геологии и поисков месторождений полезных ископаемых“, 14–16 марта 2007 г.* Минск, 252–254.

Язиков, Е. Г.; Рихванов, Л. П.; Барановская, Н. В. 2002. Солевые образования – индикатор загрязнения среды при геохимическом мониторинге [Salt formations as indicators of environmental pollution at geochemical monitoring]. In *Доклады 2 Международной научно – практической конференции „Тяжелые металлы, радионуклиды и элементы – биофилы в окружающей среде“.* Семипалатинск, 426–432.

Язиков, Е. Г.; Рихванов, Л. П.; Барановская, Н. В. 2004. Индикаторная роль солевых образований в воде при геохимическом мониторинге [Indicating role of salt formations in water at geochemical monitoring]. *Известия высших учебных заведений,* 1: 67–69.

Язиков, Е. Г.; Рихванов, Л. П.; Барановская, Н. В.; Янкович, Е. П. 2009. Особенности элементного состава солевых образований питьевых вод юга Томской области [Peculiarities of element composition of salt formation in drinking water of the South of Tomsk Oblast]. *Геоэкология. Инженерная геология. Гидрогеология. Геокриология*, 4: 375–381.