**Conference paper**

Natalia I. Ianchenko* and Ekaterina I. Kotova

# Methodological aspects of snow cover sampling for chemical analysis

https://doi.org/10.1515/pac-2021-0310

**Abstract:** At present there is a steady increase in scientific publications on studying the chemical composition of snow cover. At the same time, there are practically no modern publications on the methods of snow cover sampling for chemical analysis. The rapid development of analytical ways to determine the composition of samples in general justifies the need to improve the methodology of snow cover sampling. Today, researchers use a variety of adapted sampling methods depending on the goal, the geographic location of the study area, and the analyzed component. Each publication contains a rationale for the sampling method used. This article describes the methodology of sampling snow cover to determine its density. Methods of taking snow cover samples to determine its chemical composition most often depend on the chosen practices. The primary systematization of snow cover sampling methods has been carried out. Synthesis of literature reveals some problems, including the need for improved standardized techniques of snow sampling for chemical analysis and for the development of applied instrumentation to address snow geochemistry.

**Keywords:** Aerosols; atmospheric precipitation; chemical component; chemistry and climate; method; sampler; sampling; snow cover.

## Introduction

It is known that snow provides part of the world's population with melt water, and almost the entire population of the planet benefits from maintaining a thermal balance, since snow reflects solar energy. The chemical composition of the snow cover is studied for fundamental and applied purposes. For example, for the purpose of assessing air quality, surface water quality, condition of adjacent environments, limits of the dispersion of emissions, effectiveness of companies' environmental protection measures, etc. In the Russian Federation, most publications are devoted to the chemical composition of snow cover in cities or in nearby areas influenced by technogenic air pollution. Foreign scientists are more actively studying the presence of black carbon, biota components, and chemicals in the ice and snow of the Arctic, Antarctic, mountain ranges and urban areas.

Snow cover studies have always been a challenge. Snow as a natural phenomenon presents a huge number of varieties. The properties of snow depend on many factors, such as physical and geographical features of the environment, climatic characteristics of the territory, specific weather conditions during its formation and fallout, as well as its accumulation conditions [1]. In the process of its formation and development, snow goes through different stages, accompanied by constantly ongoing transformation processes, which, ultimately, creates many varieties of this seemingly simplest natural phenomenon. In order to create

**Article note:** Snow cover, atmospheric precipitation, aerosols: chemistry and climate: reports of the III Baikal international scientific conference endorsed by IUPAC (March 23–27, 2020).

***Corresponding author: Natalia I. Ianchenko**, Irkutsk National Research Technical University, 83, Lermontov Street, Irkutsk, 664074, Russia, e-mail: fduecn@bk.ru

**Ekaterina I. Kotova,** P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences, 36, Nahimovskiy Prospect, Moscow, 117997, Russia

unified methods for describing snow and measuring its physical parameters the International Classification for Seasonal Snow on the Ground (a guide to describe the snow mass and snow cover) was developed.

A review of research data on the chemical composition of the snow cover in the Russian Federation indicates that there is a steady increase in publications on this topic. The search query "chemical composition of the snow cover" aimed at publications available in the scientific electronic library of the Russian Federation on the eLIBRARY platform would find 110 publications of a total of 32 791 911 in 2014, 131 in 2015, 161 in 2016, 190 in 2017, 224 in 2018 [date of query: 07.12.2019]. The search terms were as follows. Where to look – in the title of publications, in the annotation, in keywords; type of publication – articles in journals, books, conference materials, deposited manuscripts, dissertations, reports, patents; parameters – taking into account the morphology, submitted for the entire period.

At the same time, there are practically no modern publications on the methodology and practices of snow cover sampling for chemical analysis, despite the relevance of the topic and the increasing availability of multiple analytical studies, as well as the expansion of the list of compounds under study.

Sampling is one of the important stages of the analysis. The reliability of research data about the chemical composition of snow cover depends not only on modern equipment, qualified researchers, but also on compliance with the sampling methodology. The results of chemical analysis, obtained on the basis of unreliable, incorrect sampling, can lead to misinterpretation of the analysis results and conclusions.

All Russian researchers refer to one of the publications from 1971 to 2019 [2–12] describing the methodology and recommendations for snow cover sampling for chemical analysis. Those recommendations refer to a device for snow sampling called BC-43 snow meter [6, 12, 13]. However, it should be noted that the device was designed to determine physical properties of the snow cover (density).

An important component of snow research is to study its chemical composition for assessing air quality, surface water quality, condition of adjacent environments, as well as for conducting paleoclimatic studies. The relevance of studying the snow cover chemical composition is currently increasing due to the fact that the nature of pollution distribution will change significantly with climate change, in particular, with an increase in temperature and changes in precipitation in certain regions [14]. V.N. Vasilenko et al. write [5] that "the picture of the spatial distribution of pollutants in the snow cover can be conveniently characterized by three maps: the distribution of pollutant concentrations (mg/l); the amount of pollutants that fell during the time from the formation of the snow pack to the moment of accumulation of the maximum moisture content in the snow – its surface density (t/km$^2$); and the intensity of pollutant deposition (kg/km$^2$ day)". Therefore, to determine the surface density and intensity of pollutant deposition, it is important to know not only the pollutant concentration, but also the amount of snow water, moisture content, date of sampling, date of the snow cover accumulation and the area of sampling. Physical properties of the snow cover, necessary for estimating the pollution scale of the territory, can be easily obtained with a BC-43 snow meter.

## Instruments and devices for determining the density of snow cover

A review of scientific and technical data shows that methods used for snow cover sampling [13, 15–34] are predominantly copyrighted or modified. This is due to the fact that there is no modern unified standard methodology. The methods used have both commonalities and differences depending on the geographical location of the sampling site and other specific sampling conditions.

There is a snow cover sampler to determine its physical properties (density) known as BC-43 snow meter. This device consists of a metal cylinder and scales mechanically connected by a weigher. According to [13], the WS-43 weight snow meter is registered in the State Register of Measuring Instruments and designed to measure the height, density, and water equivalent of the snow cover. The author group of G.G. Gulyakin proposes "a method and device for snow sampling" [15]. A.M. Zomaraev et al. [16] propose a "snow sampling device" and the authors indicate that "the invention relates to meteorological, hydrological, hydrochemical and environmental studies and can be used to study the density, deposits and chemical composition of snow, as well as the snow dumps". There is also a snow-measuring sampler [17] of A.P. Sergeeva, A.G. Buevich and D.B. Berg.

The authors present "a snow meter with a plastic cylinder of an increased diameter and the possibility of sample compaction directly in the cylinder, which increases the accuracy of determining physical and chemical properties of the snow cover and reduces the time for sample taking".

In his work researcher I.D. Kopanev [2] reports that in 1917 observations of the snow cover density were carried out using a volumetric snow meter. A vertical sample of snow was cut out with a cylinder and then emptied into a vessel for melting. Since 1922, snow density was measured by a weight snow meter, which is a cylinder 60 cm high with a cross-sectional area of 50 $cm^2$. The Recommendations of 2016 [12] propose the use of "a weight snow meter WS-43" [13] and "a assembled snow meter M-78" [12].

The US National Water and Climate Center, which is part of the Natural Resources Conservation Service of the United States Department of Agriculture (USDA) [18] developed snow cover sampling guidelines with the purpose of promoting efficient and accurate snow surveying and establishing consistent sampling procedures. The guide is aimed at surveyors who use sampling equipment to measure snow accumulation. It also describes the use of an assembled sampler.

David Dixon, Sarah Boon in their article [19] present three types of water equivalent measuring samplers in order to assess the accuracy of their measurements. Three samplers of different design were compared in conditions of fine and highly stratified snow. The results were compared with other sampling results obtained by the pit method. Researchers N.J. Kinar and J.W. Pomeroy [20] reviewed methods for measuring physical parameters of snow cover. They write that the snow tube, which is used by most snow cover researchers, can be made of metal or nontransparent plastic with a toothed cutting edge. The Western Snow Conference website [21] indicates that many types of samplers have been investigated. Samplers have different sampling surface area depending on the type and depth of snow.

Roberta Pirazzini [22] presented the results of a survey on studying physical properties of the snow cover. One hundred twenty-five participants from 99 institutions answered the questionnaire, and only 13 % of respondents measured chemical impurities and isotopes mainly for research purposes.

## Tools, devices, equipment used for snow cover sampling to conduct chemical analysis

*Sampling of snow cover with a plastic cylinder*. This sampler has various modifications. General recommendations [11] indicate that the snow sampler is a plastic tube (800–1000 mm long) with a fixed diameter (80–100 mm). Some authors [23] use a plastic tube of 14.5 cm in diameter. Others [24] refer to taking samples with a plastic tube with a diameter of 5 cm. In the article [25] the sampler was a 30-cm plastic tube with the cross-sectional area of 78.5 $cm^2$. Researchers N.V. Saltan, E.P. Shlapak et al. [26] pointed out that mixed snow samples were taken using a plastic tube 1.15 m long and 10 cm in diameter. There also is a sampler of A.R. Valetdinov [27].

*Snow cover sampling by core drilling*. S. Kutuzov et al. indicate that a special method for analyzing pollution horizons in snow pits was developed [28] when carrying out work to determine the effect of surface pollution on ice melting in the Caucasus. In the article [29] it is indicated that in winter 2014 samples of new snow, as well as integral samples from snow pits were taken in the vicinity of the Barentsburg river and the village of Longyearbyen. To get a uniform sample from the pit they used a drill (similar to the one for drilling ice) [29].

*Taking a snow pack sample in the form of a rectangular parallelepiped*. This method practiced in Yakutia is presented in [30]. It's about cutting a rectangular parallelepiped through the entire snow depth from the day surface down to the ground or ice.

*Frame sampling of snow cover*. In [31], a snow column with measurements of its area and height taken was cut out of its entire depth. With a plastic shovel, the snow was transferred into plastic bags for transportation to the laboratory. A.V. Ukraintsev in his study [32] sampled snow through the entire pack, with the exception of the layer directly in contact with the soil. The site for snow sampling was marked with a square-shaped frame with the sides of 0.5 m.

*Layer-by-layer sampling of snow cover* was described by M.P. Tentyukov [33].

As a result of two international seminars, the Norwegian Polar Institute issued "Protocols and recommendations for the measurement of snow physical properties, and sampling of snow for black carbon, water isotopes, major ions and microorganisms" [34]. The Protocols were developed for seasonal snow cover on glaciers to eliminate the complexity of soil-snow interaction and focus on snow-air interaction instead.

## Conclusions

Based on a review of scientific and technical literature, it is shown that the practices of snow cover sampling for determining its chemical composition are mainly of research and author's character, however based on recommendations of regulatory documents and well-known monographs. The applied methods have both commonalities and differences depending on the geographical point of sampling, requirements for sample preparation for chemical analysis or other research. It is shown that most researchers of the chemical composition of the snow cover make reference to the use of a weight snow meter or a plastic tube made of an inert material, as well as other auxiliary tools and devices. It would be helpful to develop consistent and standard methods of snow cover sampling for chemical analysis in order to increase reliability and comparability of research results. The development of applied instrumentation engineering for chemical snow science is also in demand.

**Research funding:** The results of the studies were obtained within the state task (No. 0128-2019-0006). The reported study was funded by RFBR according to the research project № 19-05-00938.

## References

[1] E. I. Kotova. Evaluation of the influence of factors on the composition of snow cover in the Russian Arctic, *Adv. Curr. Nat. Sci.* **10**, 158–163 (2019).
[2] I. D. Kopanev. *Methods for Studying Snow Cover*, Gidrometeoizdat, Leningrad (1971).
[3] B. A. Revich, Yu. I. Say, R. S. Smirnova, E. P. Sorokina. *Methodological Recommendations for the Geochemical Assessment of Urban Pollution with Chemical Elements*, IMGRE, Moscow (1982).
[4] A. I. Kuzin, S. A. Melnikov, S. V. Vlasov, S. N. Vodovatova. In *Temporary Guidelines for the Production of Sampling and Processing of Snow Cover Samples in Cities and Their Environs for a Complex of Pollutants*, Goskomgidromet USSR, Moscow (1985).
[5] V. N. Vasilenko, I. M. Nazarov, Sh. D. Fridman. *Monitoring of snow cover pollution*, Gidrometeoizdat, Leningrad (1985).
[6] E. Y. Bezuglaya, M. E. Berlyand, N. S. Volberg, A. S. Zaitsev, G. I. Sidorenko, M. A. Pinigin. In *Manual for the Control of Atmospheric Pollution* (RD 52.04.186-89), Goskomgidromet SSSR, Moscow (1991).
[7] Yu. E. Saet, I. L. Basharkevich, B. A. Revich. In *Methodological Recommendations for the Geochemical Assessment of Sources of Environmental Pollution*, IMGRE, Moscow (1982).
[8] B. A. Revich, Yu. E. Saet, R. S. Smirnova. In *Methodological Recommendations for Assessing the Degree of Atmospheric Air Pollution of Settlements by Metals Based on Their Content in Snow Cover and Soil*, IMGRE, Moscow (1990).
[9] Yu. E. Saet, B. A. Revich, E. P. Yanin, R. S. Smirnova, I. L. Basharkevich, T. L. Onishchenko, L. N. Pavlova, N. Ya. Trefilova, A. I. Achkasov, S. S. Sargsyan. *Geochemistry of the Environment*, Nedra Publishing House, Moscow (1990).
[10] I. A. Koloskov, G. F. Voznesensky, G. M. Chernogaeva, M. M. Novikov, V. S. Eliseev, A. M. Tsarev, B. B. Goroshko, Yu. S. Kuklin, V. M. Goncharenok, A. V. Gerasimov, T. P. Lapshina, A. S. Demchenko, N. M. Trunov, A. P. Garanzha. In *Comprehensive Survey of Pollution of Natural Environments of Industrial Areas With Intensive Anthropogenic Load* (RD 52.44.2-94), IGKE, Moscow (1988).
[11] A. T. Gorshkova, A. R. Valetdinov, F. A. Iskhakov, A. P. Shlychkov, R. K. Valetdinov, F. R. Valetdinov. In *Assessment of aerotechnogenic pollution of natural environments by chemical elements based on the results of snow cover monitoring*. Kazan, https://studylib.ru/doc/3892257/4.5–opredelenie-postuplenij-himicheskih-e-lementov (accessed Nov 10, 2019).
[12] L. S. Saraeva, L. I. Balakley, T. V. Volkova, K. N. Rudenko, V. M. Timets, N. S. Maltsev, D. A. Konovalov, V. Yu. Okorenkov, V. F. Komchatov, L.V. Ostroumov, Yu. M. Kachanovsky, E. A. Panshin, V. T. Minligareev, A. M. Balagurov. In *The Main Measuring Instruments for Hydrometeorological Purposes Used on the State Observation Network* (R 52.18.851-2016), Roshydromet, *Moscow* (2016).

[13] VS-43M Weight snow meter, https://fgis.gost.ru/fundmetrology/registry/4 (accessed Nov 10, 2019).
[14] Y. Wang, J. Bian, Y. Zhao, J. Tang, Z. Jia. Assessment of future climate change impacts on nonpoint source pollution in snowmelt period for a cold area using SWAT, *Sci. Rep.* **8**, 2402 (2018).
[15] G. Gulyakin. Method of snow sampling and device for its implementation. RF patent No. 2047121. Filed 14.01.1993. Issued 27.10.1995, http://www.findpatent.ru/patent/204/2047121.html (accessed Nov 10, 2019).
[16] A. M. Zomarev, G. M. Batrakova, N. N. Slyusar, O. A. Kapitonova, Ya. Vaisman. I.Snow sampling device. RF patent No. 2247351, https://findpatent.ru/patent/224/2247351.html (accessed Nov 1, 2019).
[17] M. Tentyukov. Snow-measuring sampler. RF patent No. RU 80587 U1, https://findpatent.ru/patent/255/2554303.html (accessed Feb 10, 2019).
[18] Snow Cover Sampling Guide, https://www.wcc.nrcs.usda.gov/factpub/ah169/ah169p05.htm (accessed Apr 17, 2018).
[19] D. Dixon, S. Boon. In *Proceedings of LXVIII Eastern Snow Conference*, pp. 207–224, Montreal, Quebec (2011).
[20] N. J. Kinar, J. W. Pomeroy. *Rev. Geophys.* **53**, 2 (2015).
[21] P. Farnes, N. Peterson, B. Goodison, R. Richards. *Paper presented at L Western Snow Conference*, pp. 120–132 (1982).
[22] R. Pirazzini, L. Leppänen, G. Picard, J. I. Lopez-Moreno, C. Marty, G. Macelloni, A. Kontu, A. Lerber, C. M. Tanis, M. Schneebeli, P. Rosnay, A. N. Arslan. *Sensors* **18** (2018), https://doi.org/10.3390/s18072016.
[23] V. A. Masloboev, T. T. Gorbacheva, G. A. Evdokimova. *Ecological State of Terrestrial and Aquatic Ecosystems in the Kola NPP Area*, Publishing House Kola Scientific Center of the Russian Academy of Sciences, Apatity (2010).
[24] N. S. Kasimov, N. E. Kosheleva, D. V. Vlasov, E. V. Terskaya. *MU Bull. Ser. 5: Geogr.* **4**, 14 (2012).
[25] T. I. Prozhorina, E. V. Bespalova, S. A. Kurolap, P. M. Vinogradov. *VGU Vest. Ser. 11: Nat. Sci.* **3**, 28 (2014).
[26] N. V. Saltan, E. P. Shlapak, V. K. Zhirov, O. B. Gontar, E. A. Svyatkovskaya. *MSTU Bull.* **18**, 328 (2015).
[27] Snegootbornik. RF patent No. 53436. Filed 19.07.2005. Issued 10.05.2006.
[28] S. Kutuzov, M. Shahgedanova, V. Mikhalenko, I. Lavrentiev, S. Kemp. Desert dust deposition on Mt. Elbrus, Caucasus Mountains, Russia in 2009–2012 as recorded in snow and shallow ice core: high-resolution "provenancing", transport patterns, physical properties and soluble ionic composition, *Cryosphere Discuss.* **7**, 1621–1672 (2013).
[29] A. A. Petriga, N. V. Goryunova. Composition of snow in the impact regions of the Arctic on the example of settlements in the Isfjord Bay of the Svalbard Archipelago, *Bull. Sci. Educ.* **2**, 106 (2016).
[30] V. N. Makarov, N. F. Fedoseev, V. I. Fedoseeva. *Geochemistry of the Snow Cover of Yakutia*, Institute of Permafrost Studies SB RAS of the USSR, Yakutsk (1990).
[31] O. G. Netsvetaeva, T. V. Khodzher, L. P. Golobokova. *Geogr. Nat. Resour.* **1**, 66 (2004).
[32] A. V. Ukraintsev. In *Snow Cover, Atmospheric Precipitation, Aerosols: Climate and Ecology of the Northern Territories and the Baikal Region: Materials of the I International Scientific and Practical Conference*, pp. 139–142, Irkutsk (2017).
[33] M. P. Tentyukov. Features of layer-by-layer variability of integral physico-chemical parameters of snow cover in the Middle taiga zone in the north-east of the European plain, *Cryosphere Earth* **XXII. 2**, 61 (2018).
[34] J.-Ch. Gallet, M. P. Björkman, C. Larose, B. Luks, T. Martma, C. Zdanowicz. Protocols and recommendations for the measurement of snow physical properties, and sampling of snow for black carbon, water isotopes, major ions and microorganisms, https://brage.npolar.no/npolar-xmlui/browse?type=author&value=Gallet%2C+Jean-Charles (accessed May 26, 2019).