ISSN 1075-7007, Studies on Russian Economic Development, 2019, Vol. 30, No. 3, pp. 327–333. © Pleiades Publishing, Ltd., 2019.
Russian Text © The Author(s), 2019.

SOCIAL PROBLEMS

Impact of Temperature Waves on the Health of Residents in Cities of the Northwestern Region of Russia

B. A. Revich[a, *], **D. A. Shaposhnikov**[a], **O. A. Anisimov**[b], **and M. A. Belolutskaya**[c]

[a] *Institute of Economic Forecasting, Russian Academy of Sciences, Moscow, Russia*
[b] *State Hydrological Institute, Rosgidromet, St. Petersburg, Russia*
[c] *Pavlov St. Petersburg First State Medical University, St. Petersburg, Russia*
**e-mail: brevich@yandex.ru*

Received May 11, 2018; revised September 24, 2018; accepted November 26, 2018

Abstract—Local trends in meteorological indicators in the northwestern cities (St. Petersburg, Arkhangelsk, and Murmansk) were analyzed. Over the last two decades, the trends have demonstrated a nearly 0.9°C per decade increase in St. Petersburg and Murmansk and a more than 1.5°C per decade increase in Arkhangelsk. The health effects of cold waves on mortality were stronger than those of heat waves. Relative predictive powers of ambient air temperature and apparent temperature were compared in the study of the effects of heat waves on mortality. Ambient air temperature was more informative predictor. Wind chill index better than ambient air temperature explained variations in daily mortality during cold spells.

DOI: 10.1134/S1075700719030158

Introduction. Global climate change increases the frequency of extreme weather events, including heat waves. This has become a new factor in human health risk. Climate changes are unevenly distributed across the territory of Russia and most expressed in the Arctic [1–4]. The northwestern region where the anomalous heat wave in summer 2010 led to increased population mortality is particularly representative. Adapting to changing climate has become a global challenge for national health care systems. Examples of adaptation measures include creating teams of aid volunteers for persons with limited mobility, rapid response teams, and cool rooms at centers of social protection. The planning of these measures should be based on quantitative assessments of expected human losses during heat and cold waves. Pilot studies in the northwestern region of Russia were carried out in Arkhangelsk within the project of the WHO Regional office for Europe using the data on daily mortality during the first decade of the 21st century for that city [5]. A new methodical tool has now been created to study the impact of meteorological factors on human mortality, including the analysis of temperature waves, wind chill index, and other indicators. This tool was already applied in the planning of measures for the adaptation of the healthcare system to climate change in Moscow. There were no assessments of climate impact on the health of residents in St. Petersburg, Russia's second largest city. This paper fills this gap and analyzes the dependence between heat waves, cold spells (together called temperature waves) and daily mortality in St. Petersburg, Murmansk, and Arkhangelsk. The results of this analysis will be used to draw some generalized conclusions for the North-western region of Russia.

Sources and study methods. This study was based on the daily human mortality data of the Russian Federal State Statistics Service (Rosstat) for St. Petersburg, Murmansk, and Arkhangelsk for 1999–2016 and the meteorological data on the eight daily measurements of ambient temperature, relative humidity, and wind velocity for 1961–2017, with estimated mean values. The meteorological data were taken from the website of the Russian Research Institute of Hydrometeorological Information (RIHMI) [6]. These long-term series of meteorological observations were used to assess how the climate was changing across the northwestern region and how it correlated with past decades. All data have passed the quality and completeness control. Some lethality causes were excluded from the study for St. Petersburg due to systematic errors found in the raw daily statistical data.

The climate-dependent diseases chosen for the analysis of the effect of extreme temperatures on increased human mortality included the following four groups: ischemic heart disease (IHD); cerebrovascular diseases (CVDs), including stroke; other diseases of circulatory systems (CSDs); and respiratory system diseases (RSDs). The total mortality due to all causes, excluding external events, has also been studied. Two age groups were formed from the age categories of 30–64 years and 65 and over. The daily meteorological data were analyzed at the first stage to identify heat and cold waves and estimate their main parameters. Heat and cold waves are understood as periods lasting continuously at least 5 days with temperatures exceeding or falling below threshold values, respectively. Apart from the ambient air temperature, some studies frequently use tactile parameters as temperature indicators characterizing the body's physiological response to the combined effect of several meteorological factors [7, 8]. Among these parameters were effective (apparent) temperature T_e and the wind chill index T_v, which were considered in this paper.

The effective temperature for hot climatic conditions has been determined [9]: it characterizes a combined tactile effect of the ambient air temperature, wind velocity, arriving solar radiation flow, and water vapor resilience on the human body. A certain contribution to the effective temperature is made by the arriving solar radiation, but the significance of this factor is significant for the population of southern countries and not so strong in Russia's northern regions. Specialists began to assess the effect of cold waves on the human body already in 1941 on the initiative of the US military forces being trained for cold winters in Europe, and this task required the elaboration of temperature indices. These studies were continued into further decades. The wind chill index described in our paper on the Krasnoyarsk data is now widely recognized [10].

The question about the optimal technique for determining the threshold values of temperature indicators based on which heat and cold waves can be identified is quite important. There is no clear answer to this question so far, but this can be made by two categorically different ways. The first one requires the presence of universal threshold values based on the universal human physiological features independent of any local climate. The second way includes the adaptation of population to a local climate on which threshold values must depend. Like a majority of other researchers [11–12], the authors of this study are more inclined to utilize the second approach. To distinguish heat and cold waves in our study, we used, respectively, the values of the 97th and third percentiles of locally specific distributions of the mean daily temperatures for all days of the study duration.

The study of the overall statistics of temperature waves (excluding the abnormal heat of 2010 in St. Petersburg) allowed us to assess the relative average mortality growth rate for all days belonging to this sample compared with all remaining days (the same was performed in relation to cold waves). We also took into consideration a possible delayed lethal case due to a change in temperature. The generally accepted term for such a delay is a "time lag" between the course of temperature and the course of mortality." To calculate the expected mortality growth rate during heat or cold waves, the Poisson generalized linear regression of daily mortality was used [13] in correlation with the dependence of mortality from a season, a weekday, and a long-term trend for the period from 1999 to 2016. The predictive performance of the models were compared for each of the cities using the ordinary temperature (T_a) and effective temperature (T_e) as well as the wind chill index (T_v). The choice criterion for the best mortality predictor was the maximization of statistical significance in a model assessment relative to mortality growth rate—the Fisher test (i.e., the z-test value).

Results. When analyzing temperature waves, it is important to know to what level the climate is changing and how its current condition correlates with past decades. The figure shows changes in the mean values of the main meteorological parameters, effective temperature, and the wind chill index parameters for summers and winters in three cities under the study for the long 1961–2017 period, while their trends calculated for this entire period, as well as for the last two (1999–2016) decades, are given in Table 1. In view of the significant interannual changeability (Fig. 1), the mean winter air temperature has considerably increased over the last 50 years in all three cities and the trend grew nearly 0.5°C per decade. The trend has also increased over the last two decades and grew nearly 0.9°C per decade in St. Petersburg and Murmansk and more than 1.5°C per decade in Arkhangelsk. The summer temperature trend for the entire period was also positive everywhere but nearly two times lower than for winter temperatures. This trend has been reduced by half over the last two decades in Arkhangelsk, but changed for the negative one in St. Petersburg and Murmansk. The *effective temperature* and *wind chill index* have changed in a similar way. Wind velocity has decreased everywhere and during all seasons, but has slightly increased only in St. Petersburg in the summer during the last period. Partial water vapor pressure has been increasing, while it has been decreasing in St. Petersburg and, insignificantly, in Murmansk only over the last two decades. The observed changes in all meteorological parameters analyzed act in the same direction, enforcing the physiological effect of heat waves and increasing effective temperature relative to ambient temperature. It is not so simple in these conditions to determine the threshold values of temperature indicators, since these values will depend on the chosen period of observations.

The annual total number of heat and cold waves lasting for over 5 days in the three cities under the study was calculated using 97 and 3% threshold values of air temperature over the 1961–2017 period. Temperature waves are rare events, which do not happen every year.

It is difficult to analyze and predict individual waves, and, therefore, it is expedient to consider the characteristics of samples of waves, such as the number of waves over the entire period under the study and their average duration. These characteristics estimated

Table 1. Trends in ambient air temperature (T_a), wind velocity, and water vapor pressure, which were calculated over both the long-term observational period and the last two decades in winter (W) and summer (S)

City	T_a ,°C per decade				Wind velocity, m/s per decade				Partial vapor pressure, mbars per decade			
	1966–2017		1999–2017		1966–2017		1999–2017		1966–2017		1999–2017	
	W	S	W	S	W	S	W	S	W	S	W	S
St. Petersburg	0.51	0.33	0.94	–0.28	–0.07	–0.01	–0.09	0.13	0.15	0.20	0.15	–0.47
Murmansk	0.49	0.15	0.88	–0.05	–0.30	–0.09	–0.31	–0.02	0.10	0.14	0.11	–0.04
Arkhangelsk	0.54	0.26	1.53	0.12	–0.34	–0.30	–0.02	–0.02	0.12	0.26	0.33	0.40

Table 2. Characteristics of the samples of heat and cold waves for the two time intervals*

Criteria	St. Petersburg				Murmansk				Arkhangelsk			
	hot		cold		hot		cold		hot		cold	
	T_a	T_e	T_a	T_v	T_a	T_e	T_a	T_v	T_a	T_e	T_a	T_v
	1966–2016											
Threshold value (°C)	21.4	22.1	–14.1	–17.8	16.9	14.4	–19.3	–27.9	19.9	19.5	–23.3	–29.3
Number of waves	28	36	32	32	24	24	31	27	34	34	34	31
Average duration (d.)	8.4	8.3	8.1	7.6	6.9	6.8	6.5	6.8	7.7	7.6	6.6	7.1
	1999–2016											
Threshold value (°C)	22.4	23.3	–13	–16.5	17.2	14.9	–17.9	–26	20.7	21.1	–21.9	–26.7
Number of waves	11 (16)	13 (17)	15 (11)	9 (8)	6 (6)	7 (10)	10 (8)	5 (5)	14 (17)	12 (20)	15 (11)	10 (5)
Average duration (d.)	7.0 (9.6)	7.7 (10.4)	7.7 (7.9)	8.1 (7.9)	6.2 (6.2)	7.0 (6.4)	6.8 (6.9)	6.2 (6.5)	6.7 (7.2)	7.1 (7.7)	6.4 (6.7)	7.0 (7.0)

* The values in the parentheses are calculated for the 1999–2016 period based on threshold values for the 1966–2016 period.

for two periods by the 97 and 3% threshold values of ambient air temperature T_a, effective temperature T_e, and the wind chill index T_v are given in Table 2.

In terms of the number of heat waves, Murmansk can be noted among three cities for a small number of heat waves over 18 years, which is the evidence of substantial differences between the types of weather conditions (cyclonal activities) in the cities. No significant differences have been found between three cities in terms of number of cold waves, but we can note that Murmansk had a very windy winter, which was manifested by differences between the T and T_v thresholds. The risk assessment results for mortality, due to the effect of temperature waves in St. Petersburg with the population size of 5.2 million, are given in Table 3. The most informative predictors are given in the last column.

As seen from Table 3, ordinary temperature in this case should be recognized as the most closely associated with daily mortality than effective temperature. When studying the effect of cold waves on mortality, it is more preferable to use the wind chill index than the ordinary air temperature. On the whole, the results of the cold wave risk assessment for St. Petersburg appear more solid than the heat wave risk assessment results. The assessments for cold waves were statistically more significant.

An abnormal heat wave lasting for 42 days from July 5 to August 15 was observed in St. Petersburg in the hot summer of 2010. This heat was studied separately from the series of ordinary heat waves (Table 4). As was expected, the relative mortality growth rates per heatwave day in 2010 were significantly higher than the growth rates per day from the set of ordinary waves. For example, the obtained assessments for natural death causes at the age of 65 and older differed threefold—mortality increased 26% during the 2010 heat, whereas it increased 9%, on average, during ordinary heat waves.

Analysis and conclusions. The climate of the largest northwestern cities differs not only in terms of temperature patterns but also in terms of stability in weather conditions, which is manifested in differences in the average duration of heat and cold waves. This leads also to substantial climate risks, and excess mortality values (Table 5).

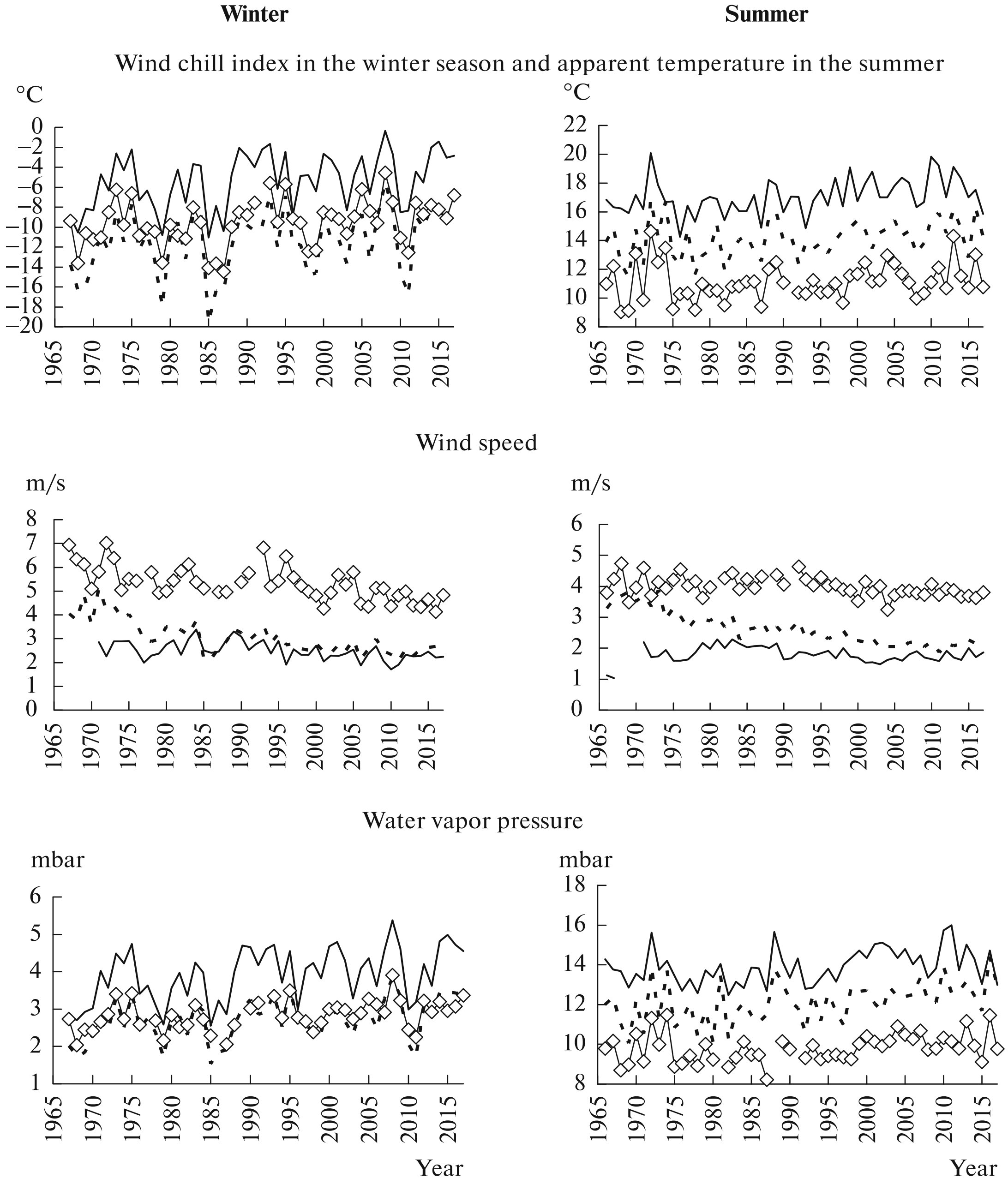

Fig. 1. Changes in meteorological parameters over the 1966–2017 period: ——— St. Petersburg; —◆— Murmansk; ---- Arkhangelsk.

The first conclusion of this study is that the independent choice of the same mortality predictors as the "best" predictors was made in all three cities. The ordinary air temperature in periods of heat waves has appeared to be more closely associated with mortality than effective temperature. More accurate assessments of the effects of cold waves can be obtained if the wind chill index is used to identify the waves.

The second conclusion is that, on the whole, risks associated with cold waves are more expressed than those of heat waves. The comparison between cold wave and heat wave risk assessments has shown that the effects of cold waves were stronger than those of heat waves for eleven of fifteen mortality indicators in three cities presented in Table 5. We should note that considerably more statistically significant risk assessments have been obtained for cold waves than for heat waves (nine significant assessments for cold waves and only five significant assessments for heat waves). We can trace certain regularities in risk assessments between the cities. The risk assessments for the majority of the indicators have proved to be the highest in

Table 3. Relative mortality risk during the selected ensembles of heat and cold waves in St. Petersburg

Death cause and age	Lag	Relative risk		Lag	Relative risk		Most informative indicator
	L	RR	95% CI	L	RR	95% CI	
HEAT WAVES							
	Air temperature—T_a			Effective temperature—T_e			
IHD, 30–64	0	1.00	0.94–1.06	0	1.00	0.94–1.06	–
Other CSDs, 30–64	1	0.96	0.88–1.05	1	0.95	0.87–1.04	–
Natural, 30–64	1	1.01	0.97–1.04	1	1.01	0.98–1.05	T_e
RSDs, 65+	2	1.19*	1.01–1.40	2	1.16	0.98–1.38	T_a
Natural, 65+	0	1.09*	1.07–1.11	0	1.09*	1.06–1.11	T_a
COLD WAVES							
	Air temperature—T_a			Wind chill index—T_v			
IHD, 30–64	1	1.20*	1.14–1.27	3	1.24*	1.18–1.32	T_v
Other CSDs, 30–64	2	1.01	0.93–1.10	2	1.05	0.97–1.15	T_v
Natural, 30–64	1	1.09*	1.05–1.12	3	1.10*	1.06–1.13	T_v
RSDs, 65+	11	1.07	0.92–1.25	11	1.09	0.93–1.28	T_v
Natural, 65+	8	1.07*	1.05–1.09	8	1.07*	1.04–1.09	T_a

The following mortality indicators were excluded from the analysis for St. Petersburg due to the revealed systematic errors in the data: cerebrovascular diseases in both age groups, other CSDs at the age of 65 and older, RSDs at the age of 30–64 years, and IHD at the age of 65 and older. Designations: L—most probable lag between temperature and mortality (in days); RR—relative mortality risk; 95% CI—borders of 95% risk confidence interval; *—statistically significant at the 95% level.

terms of absolute values in Arkhangelsk, for example, for three of five during heat and four of five indicators during cold. The largest number of significant assessments was also obtained in Arkhangelsk. For example, all five risk assessments for cold waves in this city were statistically significant. Unfortunately, the duration of the study period was different in all three cities. It is in Arkhangelsk that the largest number of years (18 years since 1999 through 2016) has fallen under the study. The years of 2013 and 2016 were excluded from the study in Murmansk, and this study period lasted for 16 years, compared with 10 years from 2001 to 2010 in St. Petersburg. The fact that the values of *significant* risk assessments obtained for the same mortality indicators were close in different cities serves as an indirect confirmation of significance in the risk assessments presented in Table 5. For example, significant risk assessments for cold waves have been established for the "IHD at the age of 30–64 years" indicator in all three cities, and their values were close: 1.24, 1.14, and 1.29. The highest dispersion has been established for RSDs-associated lethality at ages of 65 and more years, but this result is explained by comparatively low values for daily mortality in this age category (0.09 cases a day in Murmansk and 0.34 cases a day in Arkhangelsk).

The relative mortality growth rates during abnormal heat events may two or even three times exceed the analogous growth rates during the ordinary heat waves. The questions about what kind of heat waves can be termed abnormal and with what probability we may expect the future waves are beyond the goal of this study. However, the results of risk assessment during the abnormal heat in 2010 in St. Petersburg, which were obtained for the first time in this study (Table 4), allowed us to revise the primary data obtained immediately after 2010. The study [14] reported that the total mortality during the heat wave of 2010, due to all causes, exceeded the analogous indicator for the same calendar days of 2009 by 30.2% (an excess of 1533 deaths). Comparing the "expected" loss estimated under the mortality model in 1546 extra deaths with actual cases calculated by the statistical data, we can conclude that the very model and the obtained risk assessments are high quality. The data given in Table 4

Table 4. Relative risks of mortality during the abnormal heat wave in St. Petersburg between July 5 and August 15, 2010

Cause and age of death	L	RR	95% CI
IHD, 30–64	3*	1.11*	1.02–1.20
Other CSDs, 30–64	0	1.04	0.91–1.19
Natural, 30–64	0	1.14*	1.09–1.20
RSDs, 65+	2	1.34*	1.08–1.68
Natural, 65+	0	1.26*	1.22–1.30

Designations: L—most probable lag between temperature and mortality (in days); RR—relative mortality rate; 95% CI—borders of the 95% risk confidence interval; * statistically significant at the 95% level.

Table 5. Comparison of relative mortality risks during heat and cold waves in the northwestern cities

Best predictor Death cause and age, years	Heat			Cold		
	St. Petersburg	Murmansk	Arkhangelsk	St. Petersburg	Murmansk	Arkhangelsk
	T_a	T_a	T_a	T_ν	T_ν	T_ν
IHD, 30–64	<1	1.08	1.03	124*	1.14*	1.29*
Other CSDs, 30–64	<1	<1	1.33*	1.06	1.18	1.35*
Natural, 30–64	1.01	1.09	1.08	1.10*	1.08	1.12*
RDs, 65+	1.19*	1.39	1.54*	1.09	1.49	1.42*
Natural, 65+	1.09*	1.03	1.12*	1.07*	1.07	1.18*

* Statistically significant at the 95% level.

do not allow us to evaluate the number of excess deaths in summer 2010 due to all causes since there are no data on external causes (for example, it is a known fact that suicides grow in number during heat). However, natural causes contribute to an overwhelming part of excess mortality during heat. The contribution of external causes to the total mortality is relatively small, and the share of external causes in the total mortality in St. Petersburg reached 8.1% according to the "unperturbed" data over the first half of 2010 (before the onset of abnormal heat). For men, this share was somewhat higher—12.2%. Table 4 gives us a possibility to assess the total excess mortality during the heat waves in 2010 for persons exceeding 30 years due to natural causes, which is a satisfactory assessment of the total loss (the contribution of ages below 30 years and the contribution of external causes to this statistic does not exceed 10%). This is a practical advantage of the estimated indicators relative to the mortality risks. The difference (designated by Δ) between the expected and actual mortality values for the period from July 5 to August 15, 2010, in the presence or absence of this heat wave can be calculated by the following equation:

$$\begin{gathered}\Delta = (\mu_{30-64}[(RR]_{30-64} - 1) \\ + \mu_{65+}[(RR]_{65+} - 1)) \times 42 \text{ days} = 1546, \qquad (1) \\ \text{or } 24.0\%,\end{gathered}$$

where μ is the daily average mortality due to natural causes for the unperturbed period from September 1, 2007, to July 4, 2010 (this period in the study of the 2010 wave was accepted to exclude the effect of the previous heat wave in summer 2007; no heat waves were observed in the summers of 2008 and 2009). It is obvious that this loss assessment was not calculated relative to the preceding year. Having the observed mortality data at one's disposal, one can easily calculate the excess mortality relative to the preceding year:

$$\begin{gathered}\Delta = \sum_{5.07.2010}^{15.08.2010} [(M_{30-64}] + M_{65+}) \\ - \sum_{5.07.2009}^{15.08.2009} [(M_{30-64}] + M_{65+}) = 1558, \text{ or } 24.2\%, \qquad (2)\end{gathered}$$

where M is the observed daily mortality values.

The study results confirm the necessity to develop the plans for the adaptation of healthcare units and other sectors of the social sphere to climate changes, as well as the early prediction for the onset of periods with abnormally high or low temperatures. Certain measures in this direction have been taken in Moscow, the residents of which suffered most from the persisting summer heat of 2010. The Plan of Measures for Municipal Executive Authorities for Reducing the Effects of Abnormal Heat and Pollution of the Ambient Air on the Population's Health has been elaborated in the megalopolis, including messages of precautions about health risks due to hazardous situations and informing the residents about the onset of heat as well as about other measures [15]. The measures for the population's protection from abnormal heat events are contained in detail in the plans of the Moscow Health Department, including those in specialized medical aid, such as ambulance service, polyclinic outpatient aid, etc. It is necessary to develop analogous plans for measures in the cities of the northwestern region taking into account the local climatic patterns (frequencies of temperature heat and cold waves, etc.) and socioeconomic and demographic situations.

ACKNOWLEDGMENTS

The paper was supported by the Russian Science Foundation (project 14-17-00037 Assessment of Critical Levels in the Impact of Climate Change on the Regional Natural Key Processes in Russia's Territory for the Development of Adaptation Strategies at the Russian State Hydrological Institute (RSHI).

We thank T.L Khar'kova (PhD in Econ.) and E.A. Kvasha (PhD in Econ.), researchers of the Institute of Demography, National Research University—Higher School of Economics (NRU–HSE) for the preparation of the population mortality data.

REFERENCES

1. *The Second Assessment Report of Roshydromet on Climate Change and Its Consequences on the Territory of the Russian Federation. Technical Summary* (Rosgidromet, Moscow, 2014) [in Russian].
2. V. M. Kattsov, et al., *Arctic Climate Change: The Place of Climate Science in Adaptation Planning: A Monograph,* Ed. by V. M. Kattsov (Klim. Tsentr Rosgidrometa, St. Petersburg, 2017) [in Russian].
3. *Report on Climate Features in the Territory of the Russian Federation for 2018* (Rosgidromet, Moscow, 2018) [in Russian].
4. *Report on Climate Risks in the Territory of the Russian Federation,* Ed. by V. M. Kattsov (St. Petersburg, 2017) [in Russian].
5. Zh. L. Varakina, E. D. Yurasova, B. A. Revich, D. A. Shaposhnikov, and A. M. Vyaz'min, "Influence of air temperature on the mortality of the population of Arkhangelsk in 1999–2008," Ekol. Chel., No. 6, 28–36 (2011).
6. O. N. Bulygina, N. N. Korshunova, and V. N. Razuvaev, Systematic data sets for climate research. http://meteo/ru/publications/125-trudy-vniigmi/trudy-vniigmi-mtsd-vypusk-177-2014-g/518-spesializirovannye-massivy-dannykh-dlya-climaticheskikh-issledovanij.
7. D. D'Ippoliti, P. Michelozzi, C. Marino, et al., "The impact of heat waves on mortality in 9 European cities: Results from the EuroHEAT project," Environ. Health **9**, 37 (2010). doi 10.1186/1476-069X-9-37
8. S. P. Almeida, E. Casimiro, and J. Calheiros, "Effects of apparent temperature on daily mortality in Lisbon and Oporto, Portugal," Environ. Health **9**, 12 (2010). doi 10.1186/1476-069X-9-12
9. R. G. Steadman, "A universal scale of apparent temperature," J. Clim. Appl. Meteorol. **23**, 1674–1687 (1984). http://www.climate.weatheroffice.ec.gc.ca/prods_servs/normals_documentation_e.html.
10. B. A. Revich and D. A. Shaposhnikov, "Features of the impact of heat and cold waves on mortality in cities with a sharply continental climate," Sib. Med. Obozr., No. 2, 84–90 (2017).
11. L. S. Kalkstein and K. E. Smoyer, "The impact of climate change on human health: Some international implications," Experiencia **49** (11), 969–979 (1993).
12. B. A. Revich, D. A. Shaposhnikov, and G. Pershagen, "A new epidemiological model for assessing the impact of abnormal heat and polluted atmospheric air on the mortality of the population (using the example of Moscow 2010)," Profil. Med., No. 5, 15–19 (2015).
13. B. A. Revich, D. A. Shaposhnikov, M. A. Podol'naya, T. L. Khor'kova, and E. A. Kvasha, "Heat waves in southern cities of European Russia as a risk factor for premature mortality," Stud. Russ. Econ. Dev. **26** (2), 142–150 (2015).
14. B. A. Revich, "Heat waves, air quality, and mortality in the European part of Russia in the summer of 2010: Preliminary assessment results," Ekol. Chel., No. 7, 3–9 (2011).
15. Report on the State of the Environment in the City of Moscow in 2013. The Government of Moscow. Department of Environmental Management and Environmental Protection of the City of Moscow (2014). http://www.mos.ru.

Translated by N. Tarasyuk