Specificity of the river flow formation of small mountain streams of the Baikal Natural Territory resulting from wildfires

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Abstract. In recent years, a catastrophic situation has arisen in the Baikal natural area associated with forest fires. In 2015-2017, there were catastrophic forest fires. In the work, the key sites of the western coast of the Lake Baikal, which were the most suffered from the fires of 2015-2017, are considered. We studied the most suffered from the fires watersheds of the Yator, Ulan-Khan and Elokhin streams. The results based on modern hydrological and hydrochemical monitoring is discussed. The modern measuring complexes RAP-G-01 (IMKES, Tomsk) are used. Its automatically register the elements of the water regime (water level, conductivity and temperature) every 30 minutes. The chemical composition of water samples after forest fires recorded significant differences from background streams. Changes in the chemical composition of the rivers water take place after the forest fires: the concentrations of nitrates, nitrites, phosphates, and bicarbonates increase; the transfer of water from the hydrocarbonate to the sulphate class of the calcium group is noted. At the pyrogenically disturbed watersheds, the temperature regime of the water changes due to an increase in daytime temperatures and differences between daytime and nighttime temperatures, the mineralization regime is not stable, and the amplitudes of level fluctuations are higher.

1. Introduction
Wildfires in recent years made the picture in the Baikal natural territory catastrophic. There were catastrophic fires in 2015-2017, which have not been here for decades. 38 fires were recorded in 2015 only in the territory of the Pribaikalskii National Park, which accounted for 73% of all forest fires in the Zapovednoe Pribaikalie (preserved territories of the Baikal region). The fire area amounted 34423.83 ha or 8.2% of the entire territory of the Pribaikalskii National Park [1]. The largest centers of fires were registered near the Peschanaya Bay, Primorski Range, Olkhon Island, as well as in the Baikalo-Lenskii Nature Reserve. The main reason for the fire danger increase in recent years is considered to be the low water, dry period, with frequent dry thunderstorms.

2. Objects, data and methods
The paper considers the key sites of the western coast of Lake Baikal, in which the catchments of the Yator, Ulan-Khan and Elokhin streams have been most affected by the fires of 2015-2017 (Figure 1). The streams Yator and Ulan-Khan flow from the Primorski Range on the Maloe Sea, and the catchment of the Yelokhin stream flows down from the Baikal Range on the northern border of the Baikalo-Lenskii Nature Reserve. Almost the entire catchment area of the headwaters of the Ulan-Khan
and Yator streams is the burnt are of different age. During expeditionary research in the summer of 2018, it was revealed that a large area was exposed to the burns of 2016-2017. The steep slopes of this area are covered by burnt dead wood of pine, less often birch, aspen with willow-tea and celandine. The flattened tops are covered with burnt elfin wood, dwarf birch with a poor herbaceous-subshrub cover. On the border of the forest there are Siberian pine groves with dwarf pine willowherb.

The forest performs the natural function of surface runoff regulation and contributes to smoothing the peaks of maximum runoff and its maintaining during the low water period. Destruction of forest leads to the decrease in annual runoff (or increase due to continuing burning and logging and, hence increasing snow-accumulating functions [2-4]), but also to a significant intra-annual redistribution of runoff due to an increase of maxima discharge and levels and decrease of its minima. The pattern of flow levels of the river in variability of forest cover of catchment areas is practically not studied. The effect of variability of forest cover on the average or maximum annual flow is considered more often. After catastrophic fires a certain transformation of the chemical composition of water streams takes place. In [5], it was shown that a year after the fire, 240 kg of nitrate nitrogen and 15.5 kg of phosphates were additionally supplied to the channel network from one km$^2$ of burnt area. Crown fires cause concentration of nitrate nitrogen in water, and dead wood fires the hydrocarbonate ion and calcium ion, sulfate and phosphate ions. Wildfires have been found to have the greatest impact on the content of nitrate nitrogen, sulphate ion and phosphates [6-8]. The greatest amount of ash substances enters the channel network in the high water phases of the runoff, i.e. during snowmelt and prolonged rains.

Figure 1. The catchments of the streams Ulan-Khan (a) and Elokhin (b) after wildfires of 2016-2017.

3. Results and discussion

This paper summarizes the results obtained on the basis of modern hydrological and hydrochemical monitoring. The objects of investigation were small river catchments, which are the primary link in the formation of river runoff and are most sensitive to the wildfire impact. Modern measuring complexes RAP-G-01 (IMKES, Tomsk) are used, which can automatically register the elements of the water regime (level, water conductivity and temperature) of 30 min resolution. Such an instrument complex was installed on the catchment area of the Laninskii stream since 2013. This catchment has not been subjected to fires; therefore, we are considered it as background, preserving the natural runoff regime.
In 2018 the same instrument complex was installed on the fire-disturbed catchment of the Yator stream. Therefore we obtained the monitoring data of hydrological and hydrochemical characteristics of natural waters in the territory of the Preolkhon region for the period 2013-2018. The program of hydrochemical monitoring included: pH measurement, electrical conductivity, temperature, water sampling to determine the concentrations of major ions and trace elements. Laboratory analyzes were carried out by generally accepted methods in the licensed chemical-analytical center of the V.B. Sochava Institute of Geography SB RAS.

According to the results of hydrochemical analysis of this territory, the water of watercourses and other water sources is poorly mineralized; the sum of ions in water of most of the tested rivers varies from 30 to 70 mg/dm³. According to the classification of O. A. Alyokin (1970), the rivers of the territory belong to the second and third types of hydrocarbonate-calcium waters. The chemical composition of water samples after fires recorded significant differences from background watercourses. In the Ulan-Khan stream, an increased content of nitrate nitrogen is noted, in the Yator stream there is an increased content of bicarbonate ion and nitrate nitrogen. One year after the fire, the waters of the Elokhin stream have a sulphate-calcium composition uncharacteristic for the waters of the territory, and an increased concentration of nitrate, nitrite nitrogen and phosphates. There also was an increase (compared with other watercourses) mineralization - about 85 mg/dm³. The water in the stream is turbid, whitish, with a large number of suspended substances. Table 1 shows the results of chemical analysis of river water samples after fires in fire-disturbed watercourses (compared with the background).

Previously, using the example of the Laninskii stream, the detailed hydrochemical and hydrological data were used to characterize the elements of river runoff in natural (undisturbed by fires) conditions. Based on the model of mixing three sources using GCM modeling, the proportions of stream power sources are quantified. These include rainwater, the proportion of which is insignificant, underground water, which tend to predominate in the low water period, and the so-called aufeis water. Water, called aufeis, are in fact the water of the upper soil horizons, which are formed in the specific conditions of extremely high stony and ice content of soil and the thawing process continuing during the summer [9-10]. The mode of the Elokhin stream after the crown fire in September 2016 was changed due to runoff increase in low water period (low rainfall). During the fire, the vegetation cover of the catchment area of the Yelokhin stream was completely destroyed, a year after the fire, the catchment was covered with phytoleims and ash, and the vegetation cover has not restored (figure 1b). It can be assumed that due to the complete destruction of vegetation, more intensive thawing of the lenses of subsurface ice and focal permafrost degradation occurs and the stream is fed with melt water from the thawing upper soil horizons. The participation of permafrost moisture from periodically thawing upper soil horizons in the formation of the runoff of the rivers of Central Siberia in September is mentioned in [2].

Overlapping graphs of the river runoff parameters of the autumnal low water period of the Yator stream, disturbed by fires and the background Laninskii stream show a number of significant differences.

Both absolute values and amplitudes of daily fluctuations of water temperature are higher within the burnt catchment area. This is especially true for daytime temperatures. Obviously, the surface of the burnt catchment of the Yator stream is warming up during the daytime hours (figure 2a).

The conductivity values on the burnt stream are lower, however, daily and diurnally fluctuations are more pronounced. At the same time, a steady increase in mineralization is observed on the background stream during the low water period (figure 2b).

The pattern of changes in the water levels of the streams is essentially the same, which indicates the same conditions of the runoff formation. However, the temperature swing is higher on the burnt stream. The high levels are higher; the lows are lower than of the background stream (figure 2c).
4. Conclusion

Several changes in the chemical composition occur after the fires on the rivers, namely, the concentrations of nitrates, nitrites, phosphates, and bicarbonates increase, the transition of water from the bicarbonate to the sulfate class of the calcium group is noted.

At the fire-disturbed watersheds, the temperature regime of water changes due to an increase in daytime temperatures and differences between daytime and nighttime temperatures, the salinity regime is not stable, and the temperature swing is higher.

Figure 2. Overlapping graphs of temperature fluctuations (a), conductivity (b) and levels (c) of the water of the Yator and Laninskii streams.
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