Rain Precipitation Parameters for the Design of Surface Effluent Treatment Facilities from the Territory of Industrial Enterprises

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Abstract. Data on the maximum layer of precipitation for rain, the drain from which is allocated to treatment facilities from the territories of industrial enterprises in the conditions of the Russian Federation, are presented. The results are analysed and summarized. The average layer of precipitation with a period of single excess equal to 1 year according to 195 weather stations is determined. The average precipitation layer for the entire area under consideration was 27.8 mm, with a variation range of 12.3 to 72.0 mm. The obtained parameters are intended and can be used for design of surface runoff treatment facilities.

1. Introduction
Surface runoff is considered one of the main sources of pollution, which forms the qualitative composition of water bodies [1-5], including those that are sources of household and drinking water supply [6, 7].

Qualitative composition of surface runoff is sufficiently studied [1, 2, 8-11]. It has certain seasonal patterns [3, 4] characteristic of a certain terrain. In quantitative terms, surface runoff formation depends on climatic conditions [12-16] and catchment area characteristics [17-25]. At the same time, in the conditions of modern cities there is an increase in runoff costs with an increase in their urbanization [26, 27].

Thus, protecting water bodies from the effects of surface runoff is now very relevant.

2. Problem specification
The selection of the cleaning scheme depends both on the quality of surface runoff and on the volume of runoff entering the structures, which is determined by the accepted layer of rain precipitation (Hr).

For the enterprises from which drain may contain specific pollution the layer of rainfall has to be accepted with the period of single excess of P ≥ 1 year on curves of security of Hr =f (p) which are characterized by three standard statistical parameters: average H_mid value, in coefficient of a variation of cv and in coefficient of asymmetry of cs. Curves are built according to the data of weather stations closest to the sewerage facility with a long observation period (at least 25 years) or according to a combined series of annual maximum daily precipitation at several neighboring weather stations.

At cs≥3cv, for the analytical expression of the curves of availability of daily layers of precipitation, a logarithmically normal curve of availability is used, at cs≤3cv - a binominal curve. In the absence of
long series of observations of the amount of precipitation for specific territories, it is allowed to use statistically processed data from meteorological directories during calculations.

A meteorological station shall be considered representative of the area under consideration if the following conditions are met:
- the distance from the station to the catchment area of the object is less than 100 km;
- the difference between the elevation of the catchment area above sea level and the weather station does not exceed 50 m.

3. Research results
On the basis of reference data on the above-mentioned parameters, the authors determined the values of precipitation layers with a period of one excess of 1 year for most of the territory of the Russian Federation (table). The average layer of precipitation varies from 16.5 to 90.3 mm (average 35.1 mm), the design layer (P = 1) is within the range from 12.3 to 72.0 mm. The average value of the design layer for the whole territory is 27.8 mm.

Table 1. Rainfall parameters.

| №  | Arrangement of a meteorological station | Layer of rainfall, mm | №  | Arrangement of a meteorological station | Layer of rainfall, mm |
|----|----------------------------------------|-----------------------|----|----------------------------------------|-----------------------|
|    | Hmid  | Hr  |    | Hmid  | Hr  |
| 1  | Adler  | 78.9 | 66.3 | 29  | Vladikavkaz  | 56.6 | 46.5 |
| 2  | The Sakhalin Aleksandrovsk  | 39.2 | 31.3 | 30  | Vladimir  | 34.0 | 27.7 |
| 3  | Alushta  | 36.1 | 25.9 | 31  | Volograd  | 26.1 | 20.8 |
| 4  | Anadyr  | 18.9 | 14.6 | 32  | Vologda  | 31.3 | 25.3 |
| 5  | Apatity  | 23.0 | 19.0 | 33  | Volokolamsk  | 35.8 | 27.2 |
| 6  | Ardatov  | 28.7 | 24.1 | 34  | Volkov  | 29.9 | 24.3 |
| 7  | Arzamas  | 29.6 | 22.4 | 35  | Voronezh  | 33.3 | 22.8 |
| 8  | Arkhangelsk  | 29.7 | 23.4 | 36  | Vborg  | 34.0 | 26.0 |
| 9  | Astrakhan  | 26.7 | 18.0 | 37  | Vyazma  | 33.5 | 28.0 |
| 10 | Achinsk  | 30.0 | 21.6 | 38  | Gorno-Altaysk  | 36.3 | 30.8 |
| 11 | Balashov  | 28.7 | 23.6 | 39  | Crystal goose  | 36.0 | 29.1 |
| 12 | Barguzin  | 29.5 | 22.8 | 40  | Dmitrov  | 36.8 | 31.6 |
| 13 | Barnaul  | 27.7 | 21.2 | 41  | Yevpatoriya  | 32.8 | 24.5 |
| 14 | Belgorod  | 35.4 | 27.6 | 42  | Yorsk  | 36.5 | 29.1 |
| 15 | Belorechensk  | 41.8 | 33.0 | 43  | Yekaterinburg  | 31.2 | 25.9 |
| 16 | Berezniki  | 31.4 | 25.7 | 44  | Yelabuga  | 30.4 | 24.4 |
| 17 | Biysk  | 28.5 | 23.8 | 45  | Yelabuga  | 49.1 | 41.1 |
| 18 | Birsk  | 28.1 | 22.2 | 46  | Elatma  | 30.5 | 24.9 |
| 19 | Blagoveshchensk  | 49.4 | 39.0 | 47  | Yelets  | 29.3 | 23.4 |
| 20 | Bolon  | 63.2 | 43.1 | 48  | Yelnya  | 36.7 | 28.9 |
| 21 | Bratsk  | 32.0 | 22.6 | 49  | Yeniseisk  | 24.8 | 20.6 |
| 22 | Bryansk  | 34.7 | 28.7 | 50  | Yessentuki  | 39.6 | 32.9 |
| 23 | Bugulma  | 31.6 | 25.8 | 51  | Efremov  | 31.4 | 23.9 |
| 24 | Velikiye Luki  | 32.9 | 27.1 | 52  | Zheleznovodsk  | 47.9 | 38.0 |
| 25 | Veliky Ustug  | 30.5 | 25.1 | 53  | Ivanovo  | 31.9 | 25.2 |
| 26 | Verkhoyansk  | 16.5 | 12.3 | 54  | Yoshkar-Ola  | 30.2 | 24.1 |
Table 2. Rainfall parameters (continuation).

| №  | Arrangement of a meteorological station | Layer of rainfall, mm | №  | Arrangement of a meteorological station | Layer of rainfall, mm |
|----|----------------------------------------|-----------------------|----|----------------------------------------|-----------------------|
| 57 | Kalatch                                | 28.5                  | 91 | Maloyaroslavets                        | 34.3                  |
| 58 | Kalevala                               | 24.6                  | 92 | Mamadysh                               | 28.7                  |
| 59 | Kaluga                                 | 40.3                  | 93 | Minusinsk                              | 24.6                  |
| 60 | Kandalaksha                            | 23.7                  | 94 | Minevo                                 | 34.3                  |
| 61 | Kargapolye                             | 34.2                  | 95 | Mogocho                                | 41.7                  |
| 62 | Kargopol                               | 29.5                  | 96 | Monchegorsk                            | 25.6                  |
| 63 | Kasymov                                | 32.8                  | 97 | Morshansk                              | 30.2                  |
| 64 | Kashira                                | 31.6                  | 98 | Moscow                                 | 33.2                  |
| 65 | Kem                                    | 28.1                  | 99 | Murmansk                               | 24.1                  |
| 66 | Kerch                                  | 46.1                  | 100| Murom                                  | 32.2                  |
| 67 | Kineshma                               | 31.1                  | 101| Nalchik                                | 49.2                  |
| 68 | Kiritlov                               | 29.8                  | 102| Naro Fominsk                           | 35.9                  |
| 69 | Kirov                                  | 32.7                  | 103| Nerchinsk                              | 31.8                  |
| 70 | Kirsanov                               | 30.5                  | 104| Nizhny Novgorod                        | 30.3                  |
| 71 | Kislovodsk                             | 50.8                  | 105| Nikolaevsk on Amur                     | 39.8                  |
| 72 | Wedge                                  | 36.7                  | 106| Veliky Novgorod                        | 32.8                  |
| 73 | Carpets                                | 34.5                  | 107| It is new Pyatigorsk                   | 43.0                  |
| 74 | Kolomna                                | 33.6                  | 108| Novorossiysk                          | 51.7                  |
| 75 | Komsomolks-on-Amur                     | 46.3                  | 109| Novosibirsk                           | 29.3                  |
| 76 | Kondopoga                              | 26.5                  | 110| New Oskol                              | 31.7                  |
| 77 | Kostroma                               | 30.5                  | 111| Norilsk                                | 24.4                  |
| 78 | Krasnaya Polyna                       | 67.0                  | 112| Omsk                                   | 28.3                  |
| 79 | Krasnodar                              | 41.1                  | 113| Eagle                                  | 35.9                  |
| 80 | Krasnoufimsk                           | 31.0                  | 114| Orenburg                               | 25.1                  |
| 81 | Krasnoyarisk                           | 34.0                  | 115| Ostashkov                             | 32.2                  |
| 82 | Krymsk                                 | 44.3                  | 116| Ostrogozhsk                            | 36.2                  |
| 83 | Kulebaki                               | 30.3                  | 117| Pavlovsk                               | 33.3                  |
| 84 | Barrow                                 | 25.8                  | 118| Pavlovsky posad                        | 33.5                  |
| 85 | Kursk                                  | 39.6                  | 119| Penza                                  | 36.2                  |
| 86 | Kuschevskaia                           | 38.4                  | 120| Perm                                   | 30.6                  |
| 87 | Lipetsk                                | 32.3                  | 121| Petrozavodsk                          | 34.4                  |
| 88 | Bald-coots                             | 34.3                  | 122| Petropavlovsk-Kamchatsky               | 69.7                  |
| 89 | Lukoyanov                              | 35.6                  | 123| Petushki                               | 35.4                  |
| 90 | Magnitogorsk                           | 31.1                  | 124| Pochinki                               | 32.0                  |
Table 3. Rainfall parameters (end).

| №  | Arrangement of a meteorological station | Layer of rainfall, mm | №  | Arrangement of a meteorological station | Layer of rainfall, mm |
|----|----------------------------------------|------------------------|----|----------------------------------------|------------------------|
| 125 | Primorsk                               | 31.7                   | 161 | Tobolsk                                | 32.5                   |
| 126 | Primorsk Akhtarsk                      | 47.7                   | 162 | Tomsk                                  | 31.3                   |
| 127 | Pskov                                  | 36.8                   | 163 | Torzhok                                | 29.6                   |
| 128 | Pushkin                                | 30.3                   | 164 | Totma                                  | 23.3                   |
| 129 | Pyatigorsk                             | 43.1                   | 165 | Troytysk                               | 30.7                   |
| 130 | Rzhev                                  | 34.8                   | 166 | Troitsk                                | 47.0                   |
| 131 | Roslav                                 | 35.6                   | 167 | Tuapse                                 | 87.3                   |
| 132 | Rossosh                                | 30.8                   | 168 | Tula                                   | 31.2                   |
| 133 | Rostov Veliky                          | 34.7                   | 169 | Tuma                                   | 34.0                   |
| 134 | Rostov-on-Don                          | 41.0                   | 170 | Turginovo                              | 30.6                   |
| 135 | Rybinsk                                | 34.8                   | 171 | Tyumen                                 | 33.8                   |
| 136 | Ryazhsk                                | 30.0                   | 172 | Uglich                                 | 33.9                   |
| 137 | Ryazan                                 | 32.9                   | 173 | Ulagan                                 | 21.4                   |
| 138 | Salekhard                              | 27.3                   | 174 | Ulan-Ude                               | 31.1                   |
| 139 | Samara                                 | 28.1                   | 175 | Lips Kamchatsk                         | 26.5                   |
| 140 | St. Petersburg                         | 30.4                   | 176 | Ufa                                    | 28.5                   |
| 141 | Saransk                                | 36.6                   | 177 | Ukhta                                  | 28.8                   |
| 142 | Saratov                                | 30.2                   | 178 | Feodosiya                              | 35.9                   |
| 143 | Sevastopol                             | 30.5                   | 179 | Khabarovsk                             | 47.3                   |
| 144 | Sergiyev of positions                  | 35.7                   | 180 | Khibiny Mountains                      | 27.2                   |
| 145 | Serpukhov                              | 33.2                   | 181 | Holmogora                              | 28.4                   |
| 146 | Simferopol                             | 41.4                   | 182 | Cheboksary                             | 31.3                   |
| 147 | Smolensk                               | 35.1                   | 183 | Chelyabinsk                            | 31.1                   |
| 148 | Sovetskaya Gavan                       | 64.9                   | 184 | Chemal                                 | 29.4                   |
| 149 | Solikamsk                              | 29.4                   | 185 | Cherepovets                            | 32.5                   |
| 150 | Sochi                                  | 78.3                   | 186 | Chita                                  | 32.8                   |
| 151 | Sretensk                               | 35.2                   | 187 | Shadrinsk                              | 29.6                   |
| 152 | Stavropol                              | 40.6                   | 188 | Sharya                                 | 35.7                   |
| 153 | Pike perch                             | 33.4                   | 189 | Shilka                                 | 33.1                   |
| 154 | Suzdal                                 | 33.3                   | 190 | Shuya                                 | 29.6                   |
| 155 | Surgut                                 | 29.7                   | 191 | Yuzhno-Sakhalinsk                      | 50.6                   |
| 156 | Syktyvkar                              | 28.5                   | 192 | Yuryivts                               | 31.3                   |
| 157 | Taman                                  | 39.7                   | 193 | Yakutsk                                | 21.7                   |
| 158 | Tambov                                 | 32.8                   | 194 | Yalta                                 | 43.4                   |
| 159 | Tver                                   | 32.1                   | 195 | Yaroslavl                              | 33.6                   |
| 160 | Tikhoretsk                             | 39.7                   |      |                                        | 30.6                   |
4. Conclusion
For the territory of the Russian Federation, the estimated layers of rainfall with a period of one excess of 1 year, calculated for 195 weather stations, range from 12.3 to 72.0 mm (average value 27.8 mm).

In work [12], the authors obtained calculated values of the sediment layer according to observations at 238 weather stations located on the territory of the Russian Federation, necessary for calculating the productivity of surface effluent treatment facilities from settlement territories (ensuring the diversion of at least 70% of the annual volume of effluent to treatment facilities). The values of these layers of precipitation range from 2.2–12.8 mm (average is 6.4 mm).

Thus, the estimated value of the precipitation layer (and, accordingly, the volume of structures) for industrial enterprises is approximately 5.6 times (or 4.3 times by average values) higher than similar values for residential areas (4.3).

The estimated value of the sediment layer used in the design of surface runoff treatment facilities from the territories of industrial enterprises is about 20-25% (86% for settlement territories) lower than the average sediment layer for this area.

The presented data can be used for the design of surface runoff treatment plants from industrial plants (runoff from which contains specific contaminants), for which the corresponding weather station is representative.

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