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DISCHARGE OF TURKISH RIVERS INTO THE BLACK SEA

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Based on data published in various sources on discharges of some Turkish rivers we calculated the norm of total discharge of Turkish rivers into the Black Sea. We determined the volumes of annual discharge for 1938-1972 and its intra-annual distribution.

To study the water balance of the Black Sea we need data on the discharge of the rivers flowing into it, among which the best studied are Turkish. More than 160 rivers flow from Turkey directly into the Black Sea: about 40 rivers from the Bulgarian boundary to the Enidzhe R., at least 40 between the Enidzhe and Kyzyl-Irmak, and more than 80 between the Kyzyl-Irmak and the Chorokh. Measurements of discharge of some rivers of the Black Sea Basin of Turkey were begun in 1938 [8]. For the Chorokh and Veleka, which begin in Turkey and flow respectively through the USSR and Bulgaria into the Black Sea, data on discharge in the lower courses of these rivers have been published in Soviet (since 1928) and Bulgarian (since 1943) hydrological yearbooks.

One of the first works which present the major hydrographic characteristics, extreme and mean discharge of some Turkish rivers, has been published by Karatekin [2]. In that work the area of the Black Sea Basin in Turkey occupies 246,000 km^2, and the total discharge from 107,000 km^2 of the measured area of the catchment basin was 11.7 km^3/yr. Using these data Solyankin determined the total discharge of all rivers of the Black Sea Basin of Turkey as 25-26 km^3/year [5], and Tixeront determined it as 35.8 km^3/yr [13].

In the Hydrological Atlas of Turkey [7] the Black Sea Basin is defined as 245,000 km^2, and the discharge of rivers as 46.5 km^3/yr. Presented in [14] are results of later studies of Chechen, which determined the total discharge of this region as 39.9 km^3/yr. Also presented there are the data of Ozturgut, according to which the discharge of these rivers is 32.4 km^3/yr. These values of mean mutliyear discharge of the Black Sea rivers of Turkey from different authors differ by more than 20 km^3, i.e., they require revision. Information on interyear fluctuations and intrayear distribution of the discharge of these rivers are practically nonexistent in Soviet and foreign literature.

To estimate the total discharge of Turkish rivers of the Black Sea basin we use a well known plan for hydrological zoning [7,14]. Table 1 presents some data on the main river basins of Turkey in the Black Sea region. The areas of the basins and atmospheric precipitation are from [14], and the mean elevations of the basins are from [2]. The annual discharge of rivers in the western and eastern Black Sea regions are taken from Chechen [14].

Since small rivers of northwestern Turkey flow into the Black Sea in the area of the coastline from the Bulgarian boundary to the Sakar'ya River are related to the Sea of Marmora basin, i.e., do not enter the western Black Sea region, we have distinguished this portion of the catchment basin of Black Sea revers as an independent hydrological region: the Northwestern Black Sea region. Related to this region are the upper reaches of the Veleka and Rezovska Rivers, which have a total basin area in Turkey of 835 km^2 and a mean multiyear discharge of about 0.32 km^3/yr [6]. Also found there are rivers of like Terkos, which until recently communicated with the Black Sea, and rivers of the Marian part of the region: Riva, Sigirlik, Gok, and Chanak, which have a total discharge of 0.60 km^3/yr with a catchment basin of 2162 km^2 [11]. Using the area of the north-

Table 1

Hydrological Regions of Turkey in the Black Sea Basin

River basins	Basin area, thousand km²	Mean elevation, m	Annual precipitation, mm	Annual discharge, km³/year	Modulus of discharge, l/(sec·km²)
Sakar'ya	58,2	430	450	4,54	2,48
Kyzyl-Irmak	78,2	810	400	5,74	2,32
Eshil-Irmak	36,1	650	500	4,89	4,30
Chorokh	20,5	1080	600	6,60	10,20
Northwestern Black Sea region	5,0	200?	700?	1,53	9,60
Western Black Sea region	29,6	350	800	9,32	10,00
Eastern Black Sea region	24,1	800	1400	11,34	14,94
Total Black Sea Basin in Turkey	251,7	660	590	43,96	5,55

western Black Sea region of 5,000 km^2 according to the maps of [7], we can estimate the total discharge as 1.53 km^3/yr. The mean elevation and amount of precipitation are determined after [7].

The fullest data on discharge of Black Sea rivers of Turkey exist for the Sakar'ya River. Data on river discharge in the Ballyk section (44,000 km^2) for individual years from 1938 through 1944 are published in [8], in the Pashalar section (48,000 km^2) from 1950 through 1953 in [10], and in the Saryyar section (41,000 km^2) from 1957 through 1966 in [12]. Materials on annual precipitation in the river basins and the coefficients of discharge for various sites, presented in [9], let us calculate the discharge at the mouth of the Sakar'ya from 1945 through 1949. Using these data and the relationships of river discharge in differ sections [2-4], we can compute the discharge at the mouth by year from 1938 through 1966. Gaps in this series are filled and data for 1967-1972 come from the discharge of the Euphrates River in the Keban section [4], whose coefficient of linear correlation with the discharge of the Sakar'ya at Saryyar is 0.80. The obtained values of annual discharge of the Sakar'ya River at the mouth for 1938-1972 are given in Table 2. The mean discharge for the 35 years was 4.54 km^3/yr, and the coefficient of variation of discharge C_v = 0.30.

The Kyzyl-Irmak River has the largest catchment basin among Turkish rivers of the Black Sea basin. Its mean annual discharges in the Yakhshikhan section (30,000 km^2) were published for 1938-1944 in [8] and for 1950-1953 in [10]. According to these data and the ratios of discharge in various sections [2-4,14] the discharge at the mouth was computed by years and for individual periods for 1938-1946. The mean discharge for the 29 years is 5.74 km^3/yr. According to the relationship with the total discharge of all Black Sea rivers of Turkey for 1938-1944 and 1950-1953 (correlation coefficient r = 0.75) we determined the discharge of the Kyzyl-Irmak for 1945-1949 and 1954-1966, and tentatively for 1967-1972. The data obtained are presented in Table 2. The mean discharge for the 35 years was 5.94 km^3/yr, and the coefficient of variation of discharge C_v = 0.26. It should be noted that the higher discharge cited in [4,14] is based on observations of a short period 1961-1966.

For the Eshil-Irmak we had only data on the mean discharges in the Kale section (34,000 km^2) during the low-water year of 1939 and the high-water year of 1941 [8]. Comparison of these data with the discharges of other rivers let us establish the relationship of the discharge of the Eshil-Irmak and Kyzyl-Irmak Rivers, which is confirmed by the similar hydrometeorological conditions and hydrographic features of both basins. The graphed relationships of the discharge in the Kale site with those in other sites [2,3, 14] are adjusted for the mouth. For 1938-1966 the mean discharge was 4.89 km^3/yr.

The discharge of the Chorokh formed in Turkey is assumed proportional to the discharge in the near-mouth Erge section (in the USSR) according to data in [1]. The mean

Table 2

Discharge of Turkish Rivers of the Black Sea Basin, km^3/yr

Year	Sakar'ya River	Kyzyl-Irmak River	Total discharge of basin
1938	3,11	4,42	35,83
1939	3,27	4,73	39,24
1940	3,77	7,00	48,78
1941	4,78	8,07	55,30
1942	5,34	7,38	54,04
1943	4,58	7,06	42,68
1944	5,21	5,11	45,20
1945	2,71	6,18	41,00
1946	3,80	5,68	38,70
1947	3,49	4,64	34,35
1948	4,59	7,41	48,10
1949	3,48	4,23	32,39
1950	4,00	7,60	46,90
1951	3,56	4,20	33,62
1952	3,59	5,86	43,50
1953	4,38	4,86	45,42
1954	3,15	4,42	39,87
1955	3,34	3,25	32,52
1956	5,76	6,62	54,25
1957	5,14	4,54	40,81
1958	5,15	5,86	49,42
1959	3,05	4,42	39,87
1960	3,45	4,36	39,55
1961	3,10	4,44	35,42
1962	3,52	4,16	33,97
1963	7,16	9,52	62,94
1964	3,85	5,52	41,29
1965	6,41	7,91	54,21
1966	6,34	6,69	47,60
1967	6,94	(7,76)	54,04
1968	7,70	(8,80)	59,76
1969	7,76	(7,70)	53,78
1970	4,38	(5,71)	43,34
1971	4,23	(6,21)	45,54
1972	4,44	(5,61)	42,32
Mean	4,54	5,94	44,44

Table 3

Intrayear Distribution of Discharge of Turkish Rivers of the Black Sea Basin

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Discharge, km^3	4,22	5,45	5,84	6,69	6,51	4,00	2,20	1,32	1,41	1,62	1,62	3,08	43,96
%	9,6	12,4	13,3	15,2	14,8	9,1	5,0	3,0	3,2	3,7	3,7	7,0	100

discharge for 1938-1972 is determined as 6.60 km^3/yr, and the coefficient of variation during this period was 0.20.

The total mean monthly discharge of Turkish rivers in the Black Sea basin is estimated according to the data obtained as 43.96 km^3/yr.

To get an idea of the scale of the interyear fluctuations of total discharge of Turkish rivers of the Black Sea basin we used the data on the Kyzyl-Irmak, Sakar'ya, Yeshil-Irmak, and Chorokh Rivers, adjusted for the single 35-year period (1938-1972). Interyear fluctuations of the discharge of rivers of the northwestern Black Sea area was determined according to hydrological yearbooks of Bulgaria. For rivers of the western Black Sea region we used average data for the northwestern Black Sea area and the Sakar'ya River. Interyear fluctuations of rivers of the eastern Black Sea region were determined as proportional to the total discharge of rivers of the southwestern part of Georgia and Adzhariya (according to hydrological yearbooks of the USSR). Computed by years, the values of total river discharge from the Turkish part of the Black Sea Basin are presented in Table 2. The mean discharge during 35 years was 44.44 km^3/yr, and the coefficient of variation $C_v = 0.18$.

The mean monthly discharges of some rivers and hydrological regions of Turkey during various time periods are published in [8,14,etc.]. These data have been recalculated in accordance with the discharge norms presented in Toble 1. For rivers of the northwestern Black Sea region we used analogous materials for southeastern Bulgaria [6]. An estimate of the intrayear discharge of the Turkish part of the Chorokh River Basin was made according to the Erge section. Tentative values of total discharge of Turkish Rivers into the Black Sea are presented in Table 3. The coefficient of intrayear variability of the discharge was 0.56.

Results of the completed studies let us substantially revise the norm of discharge of Black Sea rivers of Turkey and obtain a good idea of its interyear and intrayear variability.

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