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**CHARACTERISTICS OF FOGS IN THE KAZAKHSTAN SECTOR OF THE
CASPIAN SEA**

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In the research work, a statistical analysis of the fogs' repeatability in the Kazakhstan sector of the Caspian Sea, continuous duration, wind speed and direction, relative humidity was carried out. Operational data of observations from the following stations were used: isl. Kulaly, Fort-Shevchenko, Aktau and Tushchibek. The research period was from 1970 till 2020. Statistical analysis made it possible to identify the highest frequency of occurrence by seasons, half-years, to estimate the continuous duration of fogs depending on the time of the year and the location of the observation point. The maximum duration of the phenomenon and the accompanying meteorological conditions are also noted. A comparative analysis of the Fort-Shevchenko and Aktau stations was carried out. This made it possible to highlight excellent areas of wind direction with the appearance of fogs. This is a consequence of different baro-circulation conditions for the formation of the phenomenon. In the conclusion of the work, that the highest frequency of fogs on the eastern coast of the Caspian Sea is observed in the transitional seasons of the year, with the exception of Aktau station, which is located much farther south of the other stations. The longest continuous duration of fogs at the stations of Fort-Shevchenko, isl. Kulaly and Tushchibek are recorded in winter, up to 6...8 days. At Aktau station up to 6...8 days in the warm half of the year. Duration more than 60 hours on isl. Kulaly is celebrated during the cold season; the maximum duration in Aktau and Tushchibek in recent decades is significantly less than at other stations; a comparative analysis revealed that in Aktau the highest frequency of occurrence is in the western and eastern sectors, and in Fort Shevchenko in the northern.

Key words: Caspian Sea, fog, fog duration, fog repeatability

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INTRODUCTION

Fogs are dangerous phenomena that can impede the movement of any type of transport. A lot of scientific works are devoted to studies of fog formation, their forecasting and analysis. At the end of the last century, the research of fog formation processes in Kazakhstan was mainly carried out at the Kazakh Scientific Research Hydrometeorological Institute, the Alma-Ata Geophysical Observatory. There are well-known

works by E.M. Moshkovich, L.A. Chubukov in the 1940 years (Moshkovich E.M., 1943). In the 1950s, T.A. Duletova was engaged in the synoptic-aerological conditions of fogs in Kazakhstan. The study used observational data from stations located at the country's airports. The work also carried out a thorough analysis of aerological conditions. All types of fogs are considered, as well as phenomena that could precede them or follow after them, such as rain, drizzle, haze (Duletova T.A., 1957). In the modern period, the studies of fogs in Kazakhstan are carried out by

G.O. Orakova, G.T. Musralinova and other scientists (Orakova G.O. et al., 2016). V.P. Pastukh, L.E. Anapolskaya studied the annual course of fogs, V.V. Smirnova, V.P. Shevchenko studied the fogs of the northern seas of Russia, where there is also a stable ice cover as in the Caspian Sea (Pastukh V.P., 1960, Smirnov V.V. et al., 2003). Fogs are observed from satellite data, for example, using the EOS MODIS model Chinese scientists determine the location of fogs over the China Sea (Hao Zhengzhou et al., 2009). The features of using a two-dimensional model of the atmospheric boundary layer for estimating the parameters of coastal fog for Siberian water bodies based on reanalysis and the output data of a regional climate model are also considered (Nadezhina E.D. et al., 2010). Of course, the main conditions for the formation of fogs their features are given in many sources devoted to hazardous phenomena, marine research (Bukharitsin P.I. et al., 2014, Hydrometeorology and hydrochemistry of the seas, 1992, Matveev Y.L., 2005, Smirnov V.V. et al., 2003). Fog studies were carried out both on land and in the sea area of various regions (Dorman C.E. et al., 2020, Gultepe I. et al., 2015, Koračin D. et al., 2014). Limited visibility during fogs is a serious hazard to shipping, fishing and coastal services. Deterioration of visibility up to 2 km or less does not allow to fully carry out loading and unloading operations in ports, poses a danger to navigation and shipping.

During fog, the mooring of ships to bases, transport refrigerators and tankers stops, which leads to downtime of ships and lifting equipment, the cessation of work in ports and oil transshipment points (Bukharitsin P.I. et al., 2014). Driving with limited visibility is prohibited. During the cold period of the year in the Caspian region, the frequency of fog is quite high, especially long-term fog. Radiative and advective fogs can form depending on synoptic conditions. Radiation fogs, as a rule, form during the night and morning hours, lasting up to 6 hours. They appear in the crumbling spur of the Siberian anticyclone. Radiation fogs practically do not form during the warm season. Advective fogs are longer and are formed in warm sectors of cyclones. They also appear mainly in the cold half-year (Hydrometeorology and hydrochemistry of the seas, 1992, Matveev Y.L., 2005, Uteshev A.S., 1959). Researches of fogs in the Caspian Sea are relevant in the modern period there are not many works in this direction due to the limited source material and its access.

DATA AND METHODS OF RESEARCH

For the research work were used data of observations from 4 meteorological stations located in the North and Middle Caspian of the period 1970...2020 (Aktau, Tushchibek Stations) and 1986...2020 (Fort-Shevchenko, Kulaly Island Stations). Their locations are shown in Figure 1.



Fig. 1. Map of the location of observation stations

The stations were selected in the sea area, on the coast and on the continent, which

made it possible to consider how the orography and local features affect the distribution of the

phenomenon. As data, we used information about the recording of the phenomenon, the time of the beginning and end of the phenomenon. Conducted statistical analysis. Over the entire period, the frequency of fogs was calculated by months, seasons and half-years. The duration of the events was also calculated.

Frequency of days with fog

The number of days with fog depends on many factors: on synoptic conditions, surface, time of year and day, proximity of the sea and settlements, etc. The greatest frequency of fogs in the East Coast - in the spring, early summer and autumn. Longer fogs up to 8 days

are observed in winter, with the exception of Aktau, where the duration of the phenomenon is maximum in the warm season, namely in late spring and early summer (Fig. 2). This fact is associated with the presence of abnormally cold waters during this period, which increase the possibility of steam condensation in the drive layer. During the year, the movement of warm water can cause fog formation from the central part of the sea (Hydrometeorology and hydrochemistry of the seas, 1992). Fogs last up to 2 days in spring and autumn. There are very few fogs from July to September.

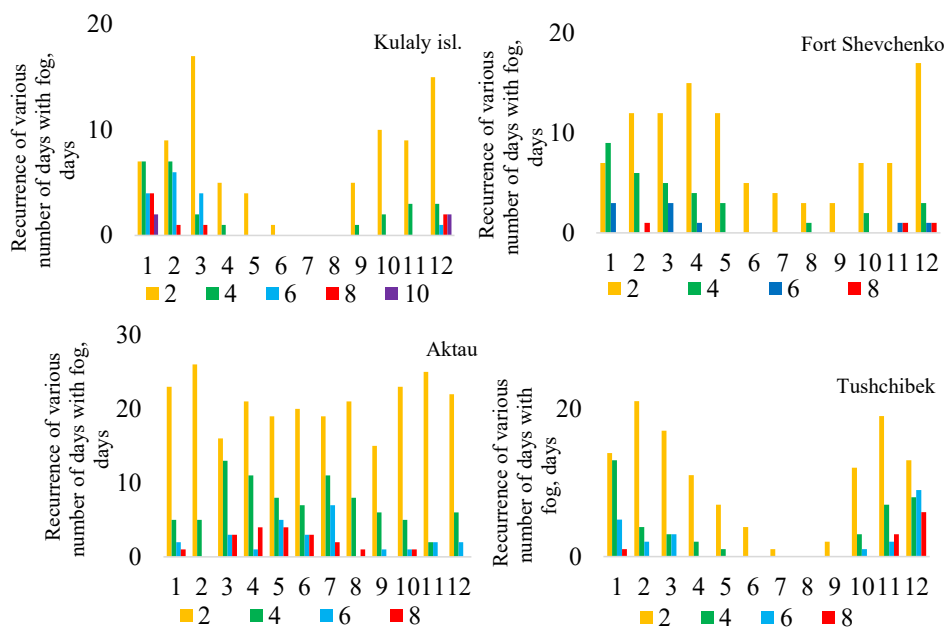


Fig. 2. Frequency of occurrence of various number of days with fog

The distribution of the number of days with fogs by seasons and semesters is also different. For the entire period the total number of days with fogs at the stations was calculated (Table 1). It follows from the table that the

largest number of foggy days are observed in winter and autumn. However, in Aktau, the maximum is observed in spring (334 days for the entire period from 1970 to 2020).

Table 1

The number of days with fogs for the entire period

Station	Winter	Spring	Summer	Autumn	Cold season (Oct-March)	Warm season (Apr-Sep)	All period
Kulaly isl.	253	79	1	59	361	31	392
Fort-Shevchenko	146	118	16	42	234	88	322
Aktau	179	334	290	156	392	567	959
Tushchibek	328	93	6	132	517	42	559

Rare fogs characterize the summer period, except for Aktau. Kulaly Island station recorded such fog 1 time in 35 years, at Fort-Shevchenko – 16 times, and at Tushchibek station for 51 years only 6 times. If we consider the total number of fogs, then the highest frequency of their occurrence is observed in Aktau (959 cases) which is several

times higher than the indicators at other stations. The duration of the fogs. It is not only the frequency of fog recurrence that is important, but also their continuous duration. Table 2 presents information on the continuous duration of the phenomenon by hours in percentage terms for all months for the stations.

Table 2

Duration of fogs in percent per hour

Station	Month	Duration of fogs in hours													
		0...4	4...8	8...12	12...16	16...20	20...24	24...28	28...32	32...36	36...40	40...44	44...48	48...60	>60
Kulaly isl.	1	41	3	3		3	6	3	9	13	3	3		9	3
	2	38	13	6		13	3	9	3	6	3		6		
	3	47	16		6	6	6	3	3	3	3		3	3	
	4	91		3	3									3	
	5	97			3										
	6	97	3												
	7	10													
	8	0													
	9	91		3	6										
	10	75	6	13	3										
	11	65	10	10	3	10		3							
	Fort-Shevchenko	12	44	16	6	6	9		3					3	3
1		51	6	11	6		3	11	3		6	3			
2		59	12	3	12		3	6	3					3	
3		56	12	6	3	3	6	3	6		3			3	
4		69	9	11		3	3			6					
5		71	17		6	3			3						
6		97		3											
7		94	6												
8		94		6											
9		94	3		3										
10		83	6	3	3	6									
11		91	3							3	3				
Aktau	12	54	14	17	3	3	3				6				
	1	65	14	10	2		2	4			4				
	2	75	4	12	8				2	2					
	3	48	16	12	6	8	4	2	2		2				
	4	39	29	10	8	6	2					2	2		2
	5	53	10	10		6	8	2	4			2	4	2	
	6	49	18	18	2	4	2			2	4	2			
	7	47	20	12	2	6	4	4	2	2					2
	8	67	14	10	2	4		2		2					
	9	76	4	8	4	2	2	2		2					
	10	61	20	10	2			4		2			2		
	11	69	14	6	4	2	2	2	2						
Tushchibek	12	69	10	10	8			4							
	1	42	14	8	2	8	20				2	2			2
	2	64	12	6	6	4	2	4				2			
	3	74	10	6	4	2			2						2
	4	86	8	4			2								
	5	92	6	2											
	6	10													
	7	10													
	8	0													
	9	98	2												
	10	90	6			2	2								
	11	55	16	10	6	6				2	2			4	
12	45	16	6	6	8	6	2	4	2		4		2		

Naturally, duration up to 4 hours is more often observed at all stations. More than 60 hours on the Kulaly Island are observed in the cold season, 3 and 9% of the total number of recorded observations. The duration of fogs is 60 hours in January and March at Tushchibek and Aktau stations – 2%. More than 30 hours the duration of fogs is not more than 13%, mainly from 3 to 6%. From 10 to 20 hours averages 8...10%.

According to this table you can also notice a higher percentage in the autumn-winter period of the season.

It was also interesting to look at the maximum values of the duration of the phenomenon for the entire observation period and the accompanying values of relative humidity, wind speed and direction. Thus, the maximum at the Fort-Shevchenko station was in February 2002, the duration of the fog was 56 hours. The humidity was 98-100%, the wind speed was on average up to 3 m/s, mainly in the western and southern sectors.

On the Kulaly Island Station the maximum duration was in January 2001, it was 78 hours with a humidity of 97-100% the wind of the northern sector at a speed of 0-3 m/s.

At Aktau station, there were more prolonged fogs in 1970...1980 period – 64 hours (1984, July), in the 21st century the duration does not exceed 50 hours, a maximum of 46 hours in 2010 in May. Also at Tushchibek station the maximum was in 1971 – 71 hours. And in recent years no more than 20 hours.

During researching, it was noticed that there are some differences in the frequency of fog in Aktau compared to other stations. Undoubtedly, the main reason is the location of the station (Gusak Zh.K. et al., 1976). The sea currents are also influenced by the distribution of the wind, respectively, the baric-circulation field, and the proximity of the settlement. Even in light winds, smoke from two adjacent chimneys of different heights can be carried in different directions. The fog zone over 200 m is usually not transferred as a whole. The upper and lower layers can be transported in different directions at different rates (Koshelenko I.V., 1977). For a visual comparative analysis, the distribution schemes of the amount of fogs depending on the wind direction and speed at Fort-Shevchenko and Aktau stations are presented for the period from 2010 till 2020. (fig. 3). Wind speeds are

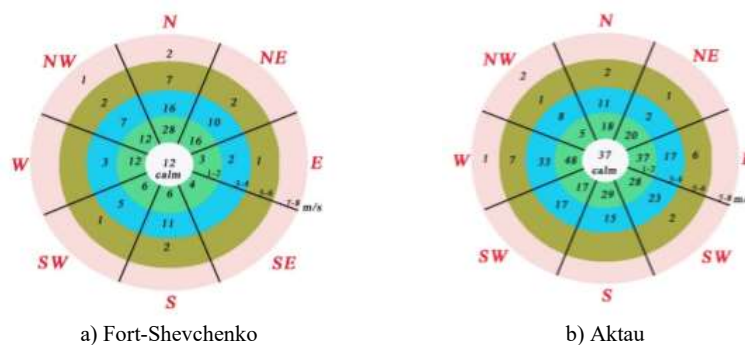


Fig. 2. Distribution of the number of fogs depending on wind direction and speed at Fort- Shevchenko and Aktau stations for the period from 2010 till 2020

Naturally, the recurrence of fogs at low wind speeds of 1...2 m/s is the highest. The highest frequency of fogs in Fort-Shevchenko was noted in the northern sector – 28 cases at wind speed of 1...2 m/s and even 2 cases at wind speed of 7 m/s. In the Aktau, the highest frequency of occurrence is in the western and eastern sectors, 48 and 37 cases. Number of fogs in the Aktau is higher than in the Fort-Shevchenko station for the same period.

As a result, prolonged fogs for more than a day can be observed in the cold season, and in Aktau in summer, which can lead to a long-term deterioration of visibility. This, in turn, is reflected in the work of shipping, fishing, etc.

Ships slow down and sometimes stop sailing altogether. When visibility is less than 1 km, restrictions are introduced for small ships and for ships engaged in fishing.

CONCLUSION

In the conclusion of the study, the following conclusions can be drawn:

- the highest frequency of fogs on the eastern coast of the Caspian Sea is observed in spring and autumn, with the exception of Aktau station, which is located to the south. There, the maximum frequency of fog is observed in the spring-summer period;
- the longest duration of fogs at the stations of Fort Shevchenko, Kulaly Island and Tushchibek are recorded in winter, up to 6-8 days, sometimes up to 10 days. At Aktau station up to 6-8 days in the warm half of the year;
- the duration of the fogs is more than 60 hours on the Kulaly Island Station is observed in the cold season, 3...9%. At Tushchibek and Aktau stations, fogs for more than 60 hours are observed in January and March, 2%. More than 30 hours, the percentage of duration does not exceed 13%, mainly from 3 to 6%. 10 to 20 hours on average 8-10%;
- the maximum duration in Aktau and Tushchibek in recent decades is less than at the stations of Fort-Shevchenko and Kulaly Island;
- in the Aktau, the highest frequency of occurrence is in the western and eastern sectors, 48 and 37 cases. Number of fogs in the Aktau is higher than in the Fort-Shevchenko station for the same period.

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КАСПИЙ ТЕҢІЗІНІҢ ҚАЗАҚСТАНДЫҚ СЕКТОРЫНДАҒЫ ТҰМАНДАРДЫҢ СИПАТТАМАСЫ

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Ғылыми-зерттеу жұмысында Каспий теңізінің қазақстандық секторында тұманның қайталануы, үздіксіз ұзақтығы, желдің жылдамдығы мен бағыты, ылғалдылыққа статистикалық талдауы жүргізілді. Зерттеу үшін Құлалы арал, Форт-Шевченко, Ақтау және Тұщыбек станциялардың жедел деректері пайдаланылды. Зерттеу мерзімі 1970-2020 жж. Жыл мезгілдері бойынша тұманның ең көп қайталануы анықталды. Жыл мезгіліне және бақылау нүктесінің орналасуына байланысты үздіксіз ұзақтығы есептелген. Феноменнің максималды ұзақтығы мен ілеспе метеорологиялық жағдайлар да белгіленеді. Форт-Шевченко және Ақтау станцияларына салыстырмалы талдау жүргізілді, бұл тұманның пайда болуымен жел бағытының секторларын анықтауға мүмкіндік берді, бұл құбылыстың пайда болуының барикалық-циркуляциялық жағдайын көрсетеді. Жұмыстың қорытында Каспий теңізінің шығыс жағалауында тұманның ең жоғары жиілігі бір-бірінен оңтүстікте орналасқан Ақтау станциясын қоспағанда, жылдың өтпелі кезеңінде байқалады; Құлалы мен Тұщыбек станцияларда 6...8 күнге дейін қыста болады; Ақтау станциясында жылдың жылы жартысында 6...8 күнге дейін; ұзақтығы 60 сағаттан асады; Құлалы суық мезгілде болады; соңғы онжылдықтардағы Ақтау мен Түшібектің максималды ұзақтығы басқа станцияларға қарағанда айтарлықтай аз; Ақтауда ең жоғары тұманның жиілігі батыс және шығыс секторларында жел болса анықталады, ал Форт-Шевченко станциясында – солтүстік секторда.

Түйін сөздер: Каспий теңізі, тұман, тұманның ұзақтығы, тұманның қайталануы

ХАРАКТЕРИСТИКА ТУМАНОВ В КАЗАХСТАНСКОМ СЕКТОРЕ КАСПИЙСКОГО МОРЯ

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В исследовательской работе проведен статистический анализ повторяемости туманов казахстанского сектора Каспийского моря, непрерывной продолжительности, скорости и направления ветра, относительной влажности. Для исследования привлечены срочные данные станций: о. Кулалы, Форт-Шевченко, Ақтау и Тущыбек.

Период исследования с 1970 по 2020 гг. Статистический анализ позволил выявить наибольшую повторяемость по сезонам, полугодиям, оценить непрерывную продолжительность туманов в зависимости от времени года и расположения пункта наблюдения. Также отмечены максимально длительные продолжительности явления, сопутствующие при этом метеорологические условия. Проведен сравнительный анализ станций Форт-Шевченко и Актау, который позволил выявить отличные сектора ветрового направления при появлении туманов, что говорит о различных барико-циркуляционных условий формирования явления. В заключении работы сделаны выводы, что наибольшая повторяемость туманов на восточном побережье Каспийского моря отмечается в переходные сезоны года, за исключением станции Актау, которая расположена гораздо южнее относительно остальных станций; наибольшая непрерывная продолжительность туманов на станциях Форт-Шевченко, о. Кулалы и Тущибек регистрируется зимой, до 6...8 дней. На станции Актау до 6...8 дней в теплое полугодие; продолжительность более 60 часов на о. Кулалы отмечается в холодное время года; максимальная продолжительность в Актау и Тущибек в последние десятилетия значительно меньше, чем на других станциях; при сравнительном анализе выявлено, что в Актау наибольшая повторяемость в западном и восточном секторах, а в Форт-Шевченко в северном.