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G.T. Issanova[1,2,3], J. Abuduwaili[2], A. G. Kuanyshbekova[4]

[1]Research Center of Ecology and Environment of Central Asia(Almaty), 050060, Kazakhstan;
[2]Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences,State Key Laboratory of Desert and Oasis Ecology, 818 South Beijing Road, Urumqi, 830011, Xinjiang, China;
[3]Al-Farabi Kazakh National University, Faculty of Geography and Environmental Sciences, Almaty, 050040, Kazakhstan;
[4]Kazakh State Women Pedagogical University, Faculty of Natural Sciences, Almaty, 050000, Kazakhstan
E-mail: gul_nur.777@mail.ru, agamprit@gmail.com, jilil@ms.xjb.ac.cn

DEFLATION PROCESSES AS DUST STORMS IN THE SANDY DESERTS OF THE SOUTHERN BALKASH REGION

Abstract. Study of deflationprocesses as dust storms are important in arid environments such as deserts. The deserts of Kazakhstan mostly cover lowlands and extend from the eastern coast of the Caspian Sea to the piedmonts of the Tien-Shan Mountain. Deserts are one of the major sources of dust storm activities. On the basis of generalization and analyses of the numerous cartographic materials, meteorological observations data were identified seats of the powerful sources of dust storms within Kazakhstan, including the Southern Balkash sandy deserts. The Taukum, Moiynkum deserts, Ile river deltas and valleys, and southern coast of Lake Balkhash are most prone to dust storms. The most frequent storms were observed in the Ile river valley (Bakanas meteorological station).In general, duststorm outbreaks are common in the spring, summer and autumn seasons: April through August andApril through September and October.

Dust storms have a great negative impact on soil conditions and they are particularly dangerous for theenvironment.Thus, our study deflation processes as dust storms in the southern Balkhash sandy deserts has great importance towards aiding in the prediction andmonitoring of dust and sand storms and movement patterns.

Keywords: Deflation processes, dust storms, deserts, desertification, Kazakhstan.

Introduction. Destruction of soil surfaces as a result of wind impact is mostcommonly referred to as deflation process. This process includesremoval, transportation, and re-deposition of the soil mass.

The deflation processes are very common in Kazakhstan and it has differing soil and climatic conditions, topography,and geology[1-4].Deflation processes in deserts and dust deposits occur dueto physical–geographical and climatic conditions of the region[2, 5]. Theprocess is especially intensive in areas of Aral, Caspian Seas; man-madeAralkum and southern Balkhash deserts as well as Karakum and Kyzylkum deserts in Central Asia are the mainsource areas of deflation process as dust storms, whichaffect the entire region [6-7]. Central Asian and Kazakhstan deserts are characterized by strong winds, scarcity of vegetation cover, continental and Mediterranean climate with long dry summers, lack of soil moisture, relatively low air moisture, and frequent repletion of soil and atmospheric droughts [8]. Deserts are dry fragile areas with little or no vegetation. Therefore, winds can remove sand-, silt-, and clay-sized particles from the surface and transport them during dust and sand storms over great distances [9]. The main persistent sources of dust storms of Central Asia and Kazakhstan are located in the large "dust belt" that extends from west to east over the southern deserts, north of Caspian Sea deserts, Aral Sea region (Kyzylkum, Aralkum deserts), and Southern Balkash deserts. The highfrequency of dust storms occurs mainly in the sandy deserts, and other types of deserts where sensitive ecosystems have suffered substantially from human impact [8, 10-11].

The vastexpanse of deserts across Central Asia experience duststorms of different frequencies, intensities, and durations. Dueto the great variety and abundance of loose material availablefor transportation, the frequency of dust events in Kazakhstan variesover a wide range of 5–146 days of dust

storms per year[7, 12-13]. Almost all major sources of dust storms are located over topographical lows or on landsadjacent to strong topographical highs, where the fluvial action isevident by the presence of ephemeral rivers and streams, alluvial fans, playas, and saline lakes [14]. The long-term and seasonal variability of dust storms is affected by various parameters including climate, geomorphology, and human activities [15-17].

Dust and Sand storms are both a symptom and cause ofdesertification. Desertification due to wind erosion (deflation process) hastouched the semi-desert and desert landscapes of Central Asiaand Kazakhstan [18-19]. Theproblem of desertification in Central Asia is more serious;75 % of the territory in Kazakhstan, 60 % of Uzbekistan, and66 % of the territory in Turkmenistan are prone to anthropogenicdesertification[20]. Processes of land/soil degradation and desertification are especially intensive in areas of Aral, Caspian seas, and southern Balkhash deserts [21]. Unsustainable land practices and irrational use of natural (water and land) resources and environment pollution lead to land degradation and desertification in almost every Kazakhstan region, including Southern Balkash region. Water resources of the rivers flow to Balkashlake are mainly used for irrigation, and also for water supply and electric energy production. Reduction and regulation of Ili and Karatal rivers flow led to the drying of many lakes, including salty lakes in deltas of these rivers [4, 22-23]. As a consequence, the new sources of soil deflation and sources of dust storms have appeared in the Southern Balkhash deserts that lead to high concentration of salts and sands in the atmospheric flows. These salts and dustsprovoke deterioration of pastures, reduction of biodiversity, salinization, and desertification of soils.

From this review, it is clear investigations of soil deflation as dust storms and desertification process are importantand required.

Study area. The research was conducted in the southern Balkashsandy deserts. Specific features of general lithological–edaphic conditions in the formation of Central Asian and Kazakhstan deserts are classified into six groups as follows: sandysandy-gravel and gravel, crushed stone-gypsum, loess, clay, and solonchak [19]. The southern Balkash deserts belong to sandy deserts. The sandy deserts are located in southeast Kazakhstan, within vast (by size of about 70,000 km^2) shallow southern Balkhash Depression. This depression is bordered by Shu-Ili Mountains in the west, by Balkhash Lake in the north, and by Arganty, Arharly, Saikan mountains, and northeastern spurs of Zhetysu (Dzhungar) Alatau in the east [22, 24]. Taukum and Moiynkum deserts are stretched along the left bank of Ili river; Saryesikatyrau, Bestas, Irizhar, and Zhamankum deserts are located between Ili and Karatal rivers. Zhalkum sands are located between Karatal and Aksu rivers (Fig. 1). Erosion processes are most intensive in piedmont areas composed mainly of poorly cemented sandstones, loess loams, and similar ground subject to easy scouring and weathering. After the demise of the ancient river system, the alluvial plains were gradually subject to deflation and Aeolian dissection. Therefore, in Central Asia, most widespread are sandy deserts that were largely formed in areas of development of ancient or modern alluvial or lacustrine–marine loose deposits [19]. The Balkhash Depression is formed in the Neogene period. The Paleogene rocky deposits are found mainly in the periphery [25]. The climate of the southern Balkashregionis continental, arid, characterized by large daily and annual variations of air temperature, and high levels of solar radiation. Mean air temperature during the coldest month (January) is −16 °C in the northern part and −5 °C in the southern part of the plain territory. Mean air temperature during the hottest month (July) is about 20–25 °C. Distribution of precipitation over the region is very variable: about 150 mm falls on the north, northwest (coast of Balkhash Lake), and 200–300 mm in the southeast. Precipitations during the warm time of the year on the plain are almost completely spent through evaporation. The biggest monthly amount of precipitations falls during spring months (April–May) and the smallest during February and August–September [26].

Materials and methods. Dust storm observations were made at meteorological stations located in particular areas of interest in Kazakhstan.A long-term observation data from meteorological stations (Taldykorgan, Matay, Kapshagai, Bakanas, Kyzylorda, Aral Sea and Zhusaly) and numerous cartographic materials [12, 27] were used in this study for the detection of strong dust storm sources within Kazakhstan and their causes.

For the analyses about dust storms and to show the dynamics of dust storms, the long-term observations data of dust storms in the deserts of the Southern Balkash region from four meteorological stations (Taldykorgan, Matay, Kapshagai, Bakanas) for the period between 1971 and 2010 were used. As

well as the seasonal frequency of dust storms in the desert zone of Kazakhstan have been analyzed according to an average number of days with dust storms in different months for the period of 1966–2003 from seven weather stations (Taldykorgan, Matay, Kapshagai, Bakanas, Kyzylorda, Aral Sea and Zhusaly). These data were provided by the Dust Storm Climatology for Kazakhstan databases. This database comprises the archive data collections contained in the Reference Books of Kazakhstan Climate (2003). This database contains the monthly 39-years average number of days with dust storm for each weather station (30 weather stations) as well as their frequencies.

Arc Map software was used as the main tool to analyze the regional distribution of dust-storm events as well as for sketching the map of dust-storm frequency. Using this map, we may identify the sources of dust, sand, and salt storms, and estimate their area.

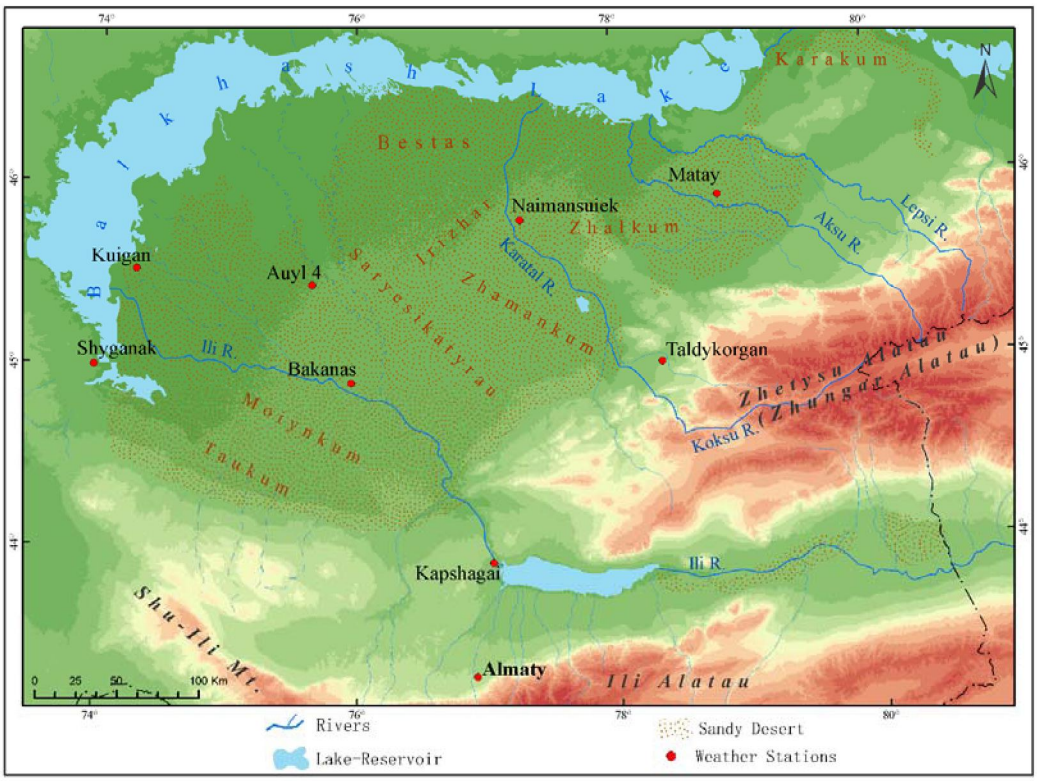

Figure 1– Sandy deserts of the Southern Balkash region

Results and discussion. A dust storm starts within Kazakhstan with a wind speed >6 m/s. The dust storm is considered "strong" when the wind speed reaches 10–14 m/s with visibility between 500 and 1000 m. Usually such wind lasts from 3 to 12 h. "Very strong" dust storms last ≥12 h with wind speeds >15 m/s and decreased visibility ≤50 m [12, 28].

Dust storms appear under the conditions of some critical thresholds of wind speed, topography and soil structure when unrelated particles are <250 μm, high soil dryness, and scarcity of vegetation cover, these thresholds vary from region to region.Large areas of strong and very strong dust storms (lasting >4 days) cover mostly the western Kazakhstan and Atyrau oblasts, part of the Aktobe and Karaganda oblasts, the northern half of the right bank of the Ertis River in thePavlodar oblast, the Ili River valley, Sam sands, Kyzylkum sands in the territory of the Syrdarya River ancient delta, and two sources in the Shu River valley (Fig.2). These areas are used for agricultural or industrial production. In addition, such factors as high wind speed (exceeding 8–10 m/s), light-textured soils (soil particle size <250 μm), dry soils, and sandy deserts with sparse vegetation promote the formation of strong dust storms [29].Due to their variable frequency, dust storms are further divided into four groups covering areas with the following frequencies: category 1 = >4 days (19%), category 2 = 3.1–4 days (5%), category3 = 1–1.3 days over (53%), and category 4 = <1 day (23%).

Meteorological features (temperature and dryness) of the Southern Balkhash deserts and its landscape with sparse vegetation are prone to dust and sand storms because winds blow the soil particles from the ground surface very easily [30]. Dust and sand storms are common events and often happen simultaneously with hot dry winds in the region. The number of days with deflation processes as dust and sand storms in the Southern Balkhash deserts reaches 30–40 days (Taukum Desert) in the Ili River deltas and valley and on the southern coast of Balkhash Lake and decreases to 10–20 days in the Saryesikatyrau Desert and the foothills of Zhetysu (Zhungar) Alatau.The duststorm dynamics in the region are shown on Fig.3. According to long-term meteorological data, we found areas that experience dust storms more frequently. There are large numbers of dust and sand storms in the Bakanasweather station because the takyr-like soils contain many silty–sand sediment and clay particles and development of agricultural activities [22].The takyr-like soils are distributed in most areas of Bakanas and the Akdala ancient dry delta plains along the left bank of Karatal River and the northeast outskirts of Zhusandala. The takyr-like soils have a mostly fine structure [31].

The grain size (>100 μm) of the sands in most areas of this region belongs to the categoryof easily deflated soils [22]. Consequently, in this region the natural landscape has a major role in the origin of dust and sand storms.

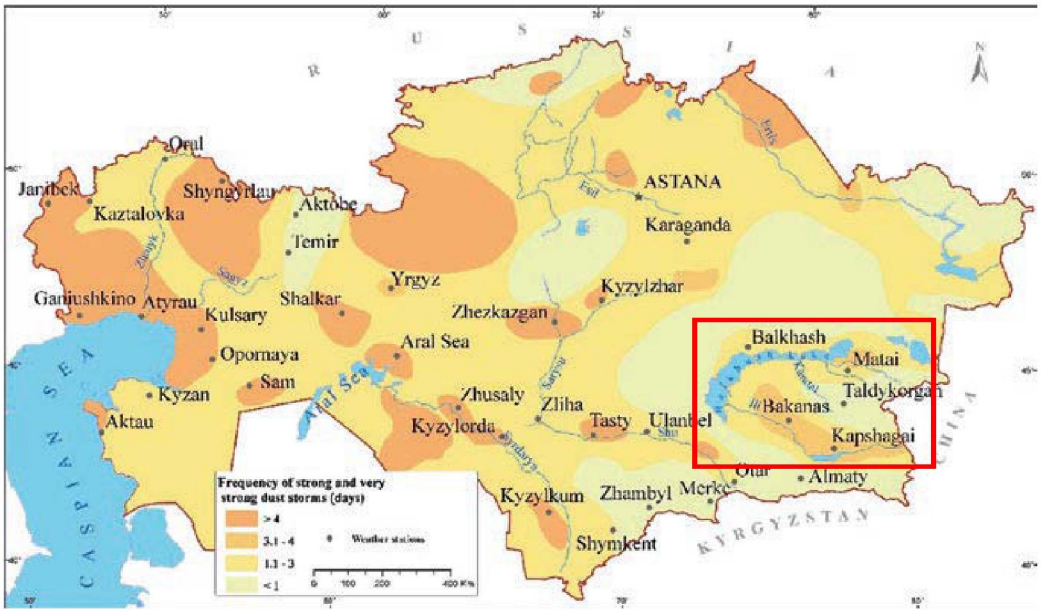

Figure2 –Distribution of strong and very strong dust storms within Kazakhstan

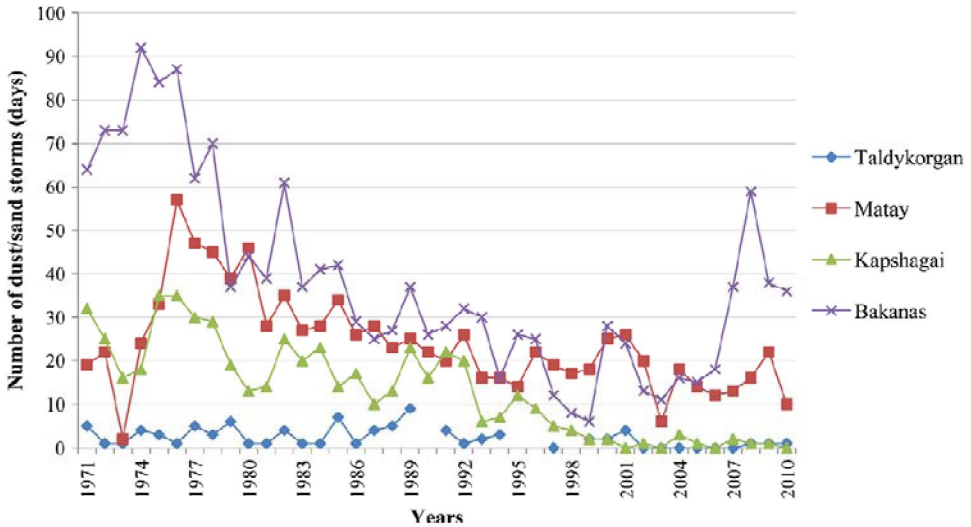

Figure 3 –Long-term dynamics of dust storms in the sandy deserts of the Southern Balkash region for the period 1971–2010

However, the sandy deserts of the southern Balkash region undergo intensive human activity. The Balkash Lake is a narrow and shallow large terminal lake in southeastern Kazakhstan. In the 1970s, the creation of the Kapshagai water reservoir and the intensive use of water from the Ili, Karatal, and Lepsi rivers (for irrigation, electric energy production) led to the decreased in water level in Balkash Lake. Since 1970, it has been rapidly desiccated because of construction of a dam on the Ili River and water diversion for irrigation from the major tributary and most other streams draining into the lake. As a result, a considerable part of the land in the coastal area of the Balkash Lake undergoes soil salinization and degradation processes. In addition, the salinity of the Balkhash lake has rapidly increased. Respectively, reducing and regulating the flow level of the Ili and Karatal rivers led to the drying of many lakes, including salty lakes, in the deltas of these rivers [4, 22-23]. As a consequence, new sources of soil deflation and sources of dust and sand storms have appeared in the southern Balkhash deserts, which haslead to high concentration salt in the atmospheric flows.These salts provoke the deterioration of pastures, reduction of biodiversity, salinization,and desertification of soils.

Seasonal dynamics. Kazakhstan is a large region of variable geographical and climatic features; therefore, dust- and sand-storm activities vary on annual and inter-annual scales. In general, dust- and sand-storm outbreaks are common in the spring and summer seasons. We found two peaks among the average number of days with dust storms in different months for the period 1966–2003: April through June and August through September (Fig. 4). Due to the drastic increase in temperatures and high wind speeds in the spring, desert surfaces suffer from rapid evaporation of precipitation,which together with strong winds favors the development of dust and sand events. The Kyzylkum, Pre-Aral Karakum, and Southern Balkash deserts are the main regions of Kazakhstan where dust and sand storms are common, especially during the periods April through October and April through August, respectively (according to the Aral Sea and Bakanas weather stations) (Figs.3-4). This is due to the dryness of the surface of sandy and clayey deserts during the summer and autumn seasons along with synoptic processes, which bring strong winds and extremely active dust storms.

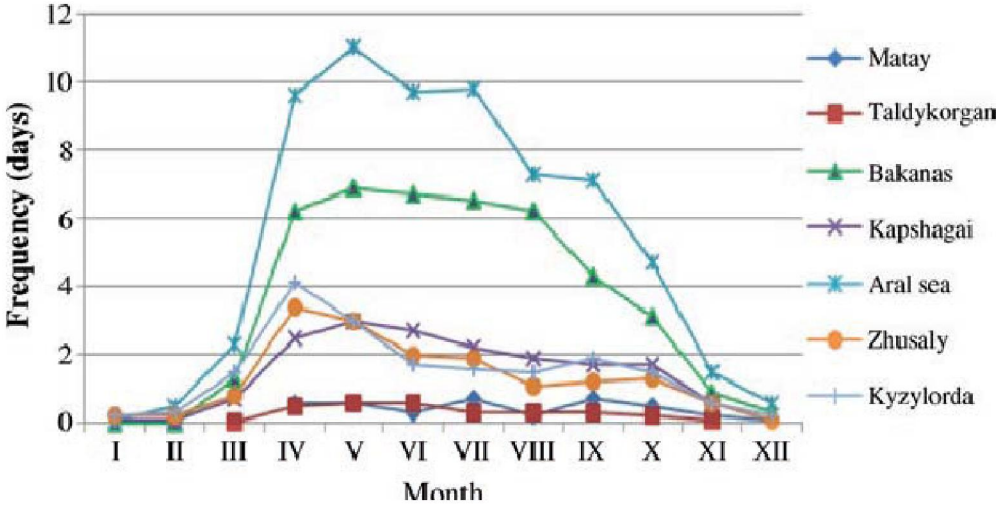

Figure4 – Monthly average frequency of storms for the period 1966–2003 inthe southerndesert zone of Kazakhstan

Almost 80% of the annual duststorm outbreaks in the southern desert zone of Kazakhstan are registered during April through September with highest values in April through July (Fig.4). In addition, the seasonal distribution, amount, and type of atmospheric precipitation significantly influence the seasonality and frequency of dust storms.

Conclusion. The deflation process as dust storms is typical for the sandy deserts in the southern Balkashregion with sparse vegetation cover and availabilityofeasywind-blown sand particles on the surface. According to the variable geographical and climatic features of the Southern Balkash deserts, storm activities vary on annual and inter-annual scales. They are common in the spring, summer and autumn seasons.

The sandy deserts of the region are most affected by the deflation processes as storms. The Taukum, Moiynkum deserts, Ili river deltas and valleys, and southerncoast of the lake are most prone to dust storms. Thisarea is the main source of aerosols, which move with windflow and have a greateffect on the climate and environmentalsituation in the south-eastern Kazakhstan. These aerosols canseriously pollute the air and water and lead to the soil salinizationand vegetation/soil degradation.

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Г.Т. Исанова[1,2,3], Д. Абудувайли[2], А.Г. Куанышбекова[4]

[1] Орталық Азия экология және қоршаған орта ғылыми-зерттеу орталығы (Алматы),
Қазақстан, Алматы қ.әл-Фараби даңғ, 75 в;
[2]Шыңжаң экология және география институты, Қытай ғылым академиясы,
Шөл және оазистер экологиясы мемлекеттік зертханасы, ҚХР, Үрімші қ-сы, 830011, Бейжиннанлу көш, 818;
[3] әл-Фараби атынд.Қазақ Ұлттық университеті, География және табиғатты пайдалану факультеті,
Қазақстан, Алматы қ. әл-Фараби даңғ, 71;
[4] Қазақ мемлекеттік қыздар педагогикалық университеті, Жаратылыстануфакультеті,
Алматы, Қазақстан, 050000, Әйтеке би көш, 99

ОҢТҮСТІК БАЛҚАШ ҚҰМДЫ ШӨЛДЕРІНІҢ ШАҢДЫ ДАУЫЛДАРТҮРІНДЕГІ ДЕФЛЯЦИЯЛЫҚ ПРОЦЕССТЕРІ

Аннотация. Шөл сияқты құрғақ орталарда шаңдыдауылдартүріндегі дефляциялық процесстерді зерттеу маңызды. Қазақстанның шөлдері негізінен ойпаң жерлерді қамтып, Каспий теңізінің шығыс жағалауынан бастап,Тянь-Шанның тауалды аймақтарына дейін созылып жатыр. Олар шаңды дауылдардыңнегізгі көздерінің бірі болып табылады. Көптеген картографиялық материалдарды және метеорологиялық бақылаулар мәліметтерін талдау және жалпылау негізінде Қазақстан территориясындағы, соның ішінде Оңтүстік Балқаш құмды шөлдеріндегі белсендішаңды дауылдардыңкөздері анықталды. Тауқұм, Мойынқұмқұмды шөлдері, Іле өзені аңғары мен атырауы және Балқаш көлінің оңтүстік жағалауы шаңды дауылдарға бейім. Ең жиі дауыл Іле өзені аңғарында байқалды (Бақанас метеостанциясы). Шаңды дауылдар негізінен, көктемгі, жазғы және күзгі кезеңдердеболады: сәуірден бастап тамызға дейін және сәуірден бастап қыркүйек, қазанға дейін.

Шаңды дауылдар топырақ жағдайларына теріс әсер етеді және олар қоршаған орта үшін өте қауіпті. Сонымен, шаңдыдауылдар түріндегі дефляциялық процесстердізерттеу-шаңдыдауылдарды және олардың қозғалыс заңдылықтарын болжау мен бақылау кезінде үлкен маңызға ие.

Түйін сөздер: дефляциялық процесстер, шаңды дауылдар, шөлдер, Қазақстан.

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Г.Т. Исанова[1,2,3], Д. Абудувайли[2], А.Г.Куанышбекова[4]

[1]Научно-исследовательский центр экологии и окружающей среды Центральной Азии (Алматы),
Алматы, Казахстан, 050060,пр.аль-Фараби, 75 в;
[2] Синьцзянский институт экологии и географии АН КНР.Государственная Ключевая Лаборатория Экология пустынь и Оазисов. Китай, г. Урумчи, 830011, ул. Бейжиннанлу, 818;
[3]Казахский национальный университет им. аль-Фараби. Факультет географии и природопользования.
Казахстан, 050060, г. Алматы, пр.аль-Фараби, 71;
[4] Казахский государственный женский педагогический университет, Факультетестествознания,
Алматы, Казахстан, 050000, ул. Айтекеби, 99

ДЕФЛЯЦИОННЫЕ ПРОЦЕССЫ В ВИДЕ ПЫЛЬНЫХ БУРЬ В ПЕСЧАНЫХ ПУСТЫНЯХ ЮЖНОГО ПРИБАЛКАШЬЯ

Аннотация. Изучение дефляционных процессовв виде пыльных бурьимеет важность в аридных средах, таких как пустыни. Пустыни Казахстана в основном покрывают низменности и простираются от восточного побережья Каспийского моря до предгорий Тянь-Шаня. Они являются одним из основных источников пыльных бурь. На основе обобщения и анализа многочисленных картографических материалов и данных метеорологических наблюдений были определены источники активных пыльных бурь в Казахстане, в том числе в песчаных пустынях Южного Прибалкашья. Песчаные пустыни Таукум, Мойынкум, дельты и долины реки Иле и южное побережье озера Балкаш наиболее подвержены пыльным бурям. Наиболее частые бури наблюдались в долине реки Иле (метеостанция Баканас). Бури в основном возникают в весенний, летний и осенний периоды: с апреля по август и с апреля по сентябрь и октябрь.

Пыльные бури оказывают большое негативное воздействие на почвенные условия, и они особенно опасны для окружающей среды. Таким образом, наше исследование дефляционных процессовв виде пыльных имеет большое значение в прогнозировании и мониторинге пыльных и песчаных бурь и закономерности их движения.

Ключевые слова:дефляционные процессы, пыльные бури, пустыни, Казахстан.

Information about the authors:

Issanova Gulnura Tolegenovna is a PhD in Natural Sciences (Physical Geography), scientific secretary at the Research Center for Ecology and Environment of Central Asia (Almaty) and senior researcher at the U.U. Uspanov Kazakh Research Institute of Soil Science and Agrochemistry, gul_nur.777@mail.ru;

Jilili Abuduwaili is a Doctor in Geography, Professor, Deputy Director at the Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, an Executive Director at the Research Center for Ecology and Environment of Central Asia (Almaty), and a foreign academician of the Academy of Agriculture of Kazakhstan, jilil@ms.xjb.ac.cn;

Kuanyshbekova Aysara Galymbekyzyzy is a 4th-year student of the Kazakh State Women Training Universityin Geography, kua.ais.gal@mail.ru.