Investigation of Salt and Dust Transfer Processes Using Passive Dust Traps in Uzbekistan

L.Y. SHARDAKOVA*1, Y.I. KOVALEVSKAYA 1), N.G. VERESCHAGINA 1) and L.G. ORLOVSKY 2)

Abstract: The article discusses some experimental results obtained in the framework of the international project CALTER to study the eolian erosion in Uzbekistan in the period 2006-2010. Network monitoring has been organized for research, which included sampling points of dry atmospheric fall-out (DAF), located in different physical and geographical zones and characterized by different types of soil and wind load. As an indicator of the intensity of eolian erosion process, the flux density of dry atmospheric deposition has been selected (monthly, seasonal, annual and perennial), the particulate composition of the surface layer of soil and dry atmospheric fall-out at points of monitoring had been investigated. The influence of some meteorological parameters on the quantitative characteristics of DAF has been investigated. The obtained values of the flux density of dry deposition are comparable to characteristics traditionally used to determine the intensity of wind erosion. The proposed method is cheap and easy to use, allows covering large areas, and exploring the features of salt and dust transfer processes.

Key Words: Dry atmospheric fall-out, Eolian erosion, Soil, Total flux density.

1. Introduction

Natural geographic and climatic features of Uzbekistan and limited water resources determine the fragility of arid systems and induce processes of their degradation. The eolian erosion is one of these processes, which leads to a decrease in soil fertility and crop yield losses.

In general, 48.7% of all lands in Uzbekistan are exposed to wind erosion. Soils of the most part of the flat territory of the country, including Ustyurt, Southern Aral Sea region, Kyzylkum are characterized by average exposure to deflation (Atlas of Uzbek SSR, 1982).

Wind erosion on irrigated land is distributed in Fergana, Zerafshan valley and Karshi steppe. Significant areas being prone to wind erosion are located in Tashkent region (138.6 thousand hectares), Samarkand region (121.9 thousand hectares), Kashkadarya region (159.7 thousand hectares).

For quantitative and qualitative assessment of deflation and deposition of dust two groups of methods have been used: (i) methods based on registration of changes on the soil surface level (the so-called “method of stud”); (ii) use of dust catchers of different design to estimate the amount of dust deposition of the atmospheric boundary layer.

The most frequently used method in the world is of the second group (www.soil-science.ru). One such method is the method of passive sampling of dust on artificial underlayer, the so-called method of selection of dry atmospheric fall-out.

Dry atmospheric fall-out (DAF) is the coarse fraction of particular matter, which falls out from the atmosphere by gravity on the underlying surface (soil, ground vegetation, surface of water bodies, snow cover, constructions and etc.).

We used this method in the framework of an international project FP6 "Long-term research program on monitoring of eolian soil erosion in Central Asia".

Methodological basis for DAF monitoring in Uzbekistan were developed by NIGMI in the 1980s (Tolkacheva, 2000), as well as in publications (Tolkacheva et al., 2002, 2006), but for evaluation of the intensity of wind erosion, we used DAF characteristics for the first time.

2. Materials and Methods

The quantitative characteristics show that the process of wind erosion is characterized by the intensity of blowing top layers of the soil, expressed in t/ha per year, or the power of the lost layer of the soil per time unit (mm/year). According to classification proposed by Zaslavsky M. N. (Golitsyn et al., 1983), the intensity of wind erosion is classified by the following gradations:

- small - up to 0.5 t/ha per year (up to 0.05 mm/year);
- weak - 0.5-1.0 t/ha (0.05-0.1 mm/year);
- average - 1.5 t/ha (0.1-0.5 mm/year);
- strong - 5-10 t/ha;
- very strong - more than 10 t/ha.

As the dust catcher in our research in 2006-2010 we used medical gauze (with the size of 0.06 m²) with a polyethylene underlayer placed in a box with a wall height of 40 cm, located

---

* Corresponding Author: nigmi@albatros.uz, uzcalter@mail.ru
1) Department of Environmental Pollution Investigation and Forecast, Hydrometeorological Research Institute (NIGMI) at the Republic of Uzbekistan Cabinet of Ministers the Centre of Hydrometeorological Service (UZHYDROMET)
2) Department of Solar Energy and Environmental Physics, Jacob Blaustein Institute for Desert Research, Ben Gurion University of the Negev

(Received, January 30th, 2014; Accepted, March 4th, 2015)
Dust catchers were installed at the sites of 10 meteostations of Uzhydromet. Stations selected for monitoring of DAF are located in the latitudinal direction, in the areas with different physical and geographical conditions, different levels of anthropogenic load and with different types of soils (Fig. 1).

Three sampling points have been established in the South Aral Sea region: MS Jaslyk (Ust-yurt); MS Muynak (the area of old drying of the Aral Sea, exposed to dust- and soil transfer from the sea area and the area with fresh drying); MS Takhiatash (area of irrigated land).

The fourth point - MS Buzaubay - was located in the center of Kyzylkum, the fifth - MS Nurata - in the foothills of Nurata mountain range. Other monitoring stations were placed in areas that experience anthropogenic stress along with natural factors: AMSC Bukhara, AMSC Termez, MS Tashkent, Fergana AHM. Background environment monitoring station in the Central Asian region - “Chatkal reserve” (branches of West Tien Shan, Tashkent Region) was chosen as a background sampling point.

Each sample of dust (DAF) was collected during calendar month, the dust weight increment on the underlayer of each sample was determined in a laboratory. The disperse composition was determined in total samples of DAF, if the amount of selected dust was enough.

Samples of the surface layer of soil (from a depth of 0-10 cm) were collected once a year in spring-summer around the sampling point of DAF. Mechanical and particulate composition was determined in collected soil samples. More than 400 samples of DAF and 30 samples of soil were selected and analyzed during the period of the study.

Based on the obtained results, DAF database was developed, and total flux density of DAF and flux density of water-soluble components were calculated: sulfates, chlorides, bicarbonates, sodium, potassium, calcium and magnesium. Calculation of the total flux density \( P_{\text{total}} \) was made according to the formula:

\[
P_{\text{total}} = \sum_{n=1}^{12} P_n \cdot \frac{10m}{S},
\]

where \( P_n \) (kg/ha/months) is DAF total flux density on the gauze per month, \( m \) (g) is DAF weight increment on gauze per sampling period, \( S \) (m\(^2\)) is area of gauze, 10 is ratio of recalculation g/m\(^2\) in kg/ha.

3. Results and Discussion

To assess the deflation stability of the soil, estimates of the mechanical and grain-size composition were made. The mechanical composition of soil samples was determined in laboratory of University of Marburg (Groll et al., 2009).

The results of the study (Fig. 2) showed that highly unstable soils by mechanical composition are in Buzaubay and Muynak, where the share of the sand fraction accounts to 85 and 92%, respectively.

The results of experimental study of grain-size composition of the surface layer of soil taken from the monitoring stations, conducted using the sieving method (DIN 66165) are shown in Figure 3.

The results of the data suggest that for the majority of the samples taken from the monitoring points of DAB on the territory of Uzbekistan, the fraction "average sand" of particles with size 0.2-0.5 mm is prevailing in the disperse composition (according to the classification of Kachinsky (1958)).

In the disperse composition of well-structured soils (Tashkent, Fergana, Chatkal reserve and Takhiatash) fraction which corresponds to a large particle aggregates is prevailing. The samples of dry atmospheric fall-out at these points showed...
minimum dust weight increment on the underlayer during the entire observation period. Exposure of these soils to eolian erosion is insignificant.

In parallel with the study of soils, DAF disperse composition was analyzed for the monitoring points, where there was a sufficient amount of dust obtained by combining the separate monthly samples. DAF disperse composition was determined in the range of particle size from 1 to 0.05 mm using sedimentation analysis.

It was revealed that at all monitoring points the greatest contribution to the mass of dry deposition has been made by fractions with the particle size of 0.5-0.2, 0.2-0.1 and 0.1-0.05 mm (Fig. 4). These results are consistent with the reference data (Golitsyn, 1999).

At Buzaubay and Muynak stations, the largest sand fraction with a particle size of 0.5-1 mm dominated in the composition of DAF, the most sizeable weight increment (up to 25 g per month on the underlayer with area of 0.06 m²) was observed.

As an indicator of the intensity of wind erosion at the monitoring points, we used the calculated average annual value of DAF total flux density (Fig. 5).

Comparison of the results obtained from the mapping information on exposure to soil erosion showed their good correspondence excluding MS Buzaubay, for which intensity level of wind erosion obtained experimentally proved to be above than at existing maps of soils erosion.

Analysis of seasonal values of the total flux density (Table 1) showed that for the majority of sampling points of DAF, maximum values observed in spring; minimum values - in winter. In Takhiatash and Termez the maximum values of the total flux density observed in summer, and in Nurata and Fergana - in autumn.

Analysis of annual values of the flux density showed that the significant difference between the maximum and minimum values $\Delta P_{\text{total}} = P_{\text{max}} - P_{\text{min}}$ for the investigated period is observed at Jaslyk, Muynak and Buzaubay stations (Table 2). At the other stations $P_{\text{total}}$ does not exceed 0.5 t/year.

Comparative analysis of data range obtained by the quantitative characteristics of DAF and meteorological parameters concomitant to sampling showed that the changes in the values of DAF flux density relate to different meteorological conditions during a year. Each year of observations was characterized by different amount of days with precipitation, the type of moistening of the underlying surface, the number of days with strong winds, frequency of wind direction, the number of days with dust storms and drift snow, air and soil temperature, relative humidity.
Table 2. Annual values of DAF total flux density (P_{total}) at the monitoring points.

<table>
<thead>
<tr>
<th>monitoring point</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>ΔP_{total}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaslyk</td>
<td>1271</td>
<td>913.8</td>
<td>650.7</td>
<td>-</td>
<td>620</td>
</tr>
<tr>
<td>Maryuk</td>
<td>1351</td>
<td>3659</td>
<td>335.0</td>
<td>-</td>
<td>324</td>
</tr>
<tr>
<td>Tashkentah</td>
<td>469.5</td>
<td>491.5</td>
<td>169.9</td>
<td>-</td>
<td>322</td>
</tr>
<tr>
<td>Buzaubay</td>
<td>8606</td>
<td>7101</td>
<td>12361</td>
<td>11664</td>
<td>5260</td>
</tr>
<tr>
<td>Bukhara</td>
<td>982.7</td>
<td>1305</td>
<td>871.7</td>
<td>1032</td>
<td>433</td>
</tr>
<tr>
<td>Nurata</td>
<td>338.9</td>
<td>193.6</td>
<td>96.81</td>
<td>-</td>
<td>242</td>
</tr>
<tr>
<td>Termez</td>
<td>738.6</td>
<td>520.3</td>
<td>292.5</td>
<td>649.5</td>
<td>446</td>
</tr>
<tr>
<td>Tashkent</td>
<td>569.9</td>
<td>809.6</td>
<td>460.40</td>
<td>406.7</td>
<td>403</td>
</tr>
<tr>
<td>Fergana</td>
<td>118.23</td>
<td>147.98</td>
<td>102.79</td>
<td>71.96</td>
<td>76</td>
</tr>
<tr>
<td>Marxak</td>
<td>56.75</td>
<td>102.28</td>
<td>94.71</td>
<td>113.98</td>
<td>57</td>
</tr>
</tbody>
</table>

Note: (-) no observations were made.

The correlation of the listed meteorological parameters and DAF flux density was investigated. However, direct dependencies were not revealed.

The highest values of the correlation ratio were obtained between monthly weight increment of DAF and repeatability of separate grades of wind speed (0-1, 2-3, 4-5, 6-7, 8-9, 10-11 m/s) during a month. For example, the correlation ratio between recurrence of the wind speed 18-24 m/s and dust weight increment is equal to 0.64 for MS Jaslyk, where dispersed fraction of the dust particles having a size of 0.1-0.2 mm predominates in the composition of DAF. The predominant disperse fraction of the soil surface layer has the same particle size. Consequently, to lift into the air, the large mass of particles from surface of Ustyurt plateau, where the MS Jaslyk is located, the wind of very high-speed is required. At the same time, for sandy soils of MS Buzaubay, it is enough to have wind strength of 10-11 m/s (ratio of correlation is 0.54) to lift into the air a big amount of particles with the predominant sizes of 0.1-0.5 mm.

4. Conclusions

The following conclusions can be made from these experimental studies:

1. Quantitative characteristics of dry atmospheric fall-out obtained from the monitoring stations may serve as sensitive indicators of the intensity of wind erosion.

2. The developed and testing in NIGMI method of dry atmospheric fall-out monitoring is cheap and easy to use. It allows to cover large areas for research. It can be an alternative to the practiced methods of experimental evaluation of wind erosion, as it allows to obtain comparable to conventional characteristics for the quantitative estimates of soil removal in ton/year.

3. DAF and the surface layer of soil in sampling points have similar disperse composition. The predominant disperse fractions in the composition of DAF are the particles of size of 0.2-0.5, 0.1-0.2 and 0.05-0.1 mm.

4. Quantitative characteristics of DAF are variable in time and depend on the weather conditions. The most evident dependence was found between definite wind speed at sampling points and obtained dust weight increment on the underlayer.

References


