Investigation of Chemical Properties of Eroded Particles at Four Heights with Surface Soil

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ABSTRACT: *The chemical analysis of dust particles is essential to assess the potential impacts of dust on climate, environment, soil, and health. The objective of this study is to compare the different chemical compositions of dust particles that are collected at different heights above the soil surface and the eroded soils of the around Lake Urmia. To trap the dust particles, the BSNE samplers were used. 14 poles were installed inside 3 ha. area and 4 samplers were installed on each pole at 0.15, 0.5, 1, and 2 m heights above the soil surface. Chemical properties such as %T.N.V, %OC, EC_e, pH, and SAR of collected particles were determined. The results of variance analysis and mean comparison illustrated that there was no significant difference between the eroded soil and the particles sampled from 15 cm height among all the investigated chemical parameters. It proves that the source of the moving particles at > 0.15 m is different from the eroded soil. By elevating height above the soil surface increased, the %T.N.V, EC_e, and pH decreased but the SAR and %OC increased. There was a strong negative and significant correlation between the monthly rainfall and the EC_e, %T.N.V, and SAR, except for the %OC. The correlation between the speed of the strongest wind and the EC_e, %OC, and SAR was positive and remarkable ($P \leq 0.01$). The pH was the only parameter that was independent of all meteorological parameters in this research. Furthermore, the SAR was the most sensitive factor to the meteorological parameters.*

KEYWORDS: *Lake Urmia; Rainfall; Sampling time; Soil surface; Wind erosion; Wind speed.*

INTRODUCTION

Approximately 430 million ha of drylands, which comprise 40 percent of the earth's surface are susceptible to wind erosion [1]. Wind erosion is a serious problem in several regions of Iran and it is about 1.3×10^9 t/ha or 7.8 t/ha/y. In fact, more than 75 percent of Iran is affected by wind erosion [2]. The unfavorable conditions of geology and climate, along with inappropriate human activities have provided conditions for wind erosion.

Lake Urmia which is the largest inland lake in Iran and located in north western of the country, is one of these regions. Climate factors such as rainfall reduction, and global warming (evaporation increasing) have a significant impact on this damage. In addition, human factors such as over-consumption of water, especially for agricultural and industrial uses, building structures such as dams on the rivers leading to the Lake, building a bridge for the

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highway, and digging numerous illegal wells have accelerated the problem. The mentioned factors created a drier area with 4600 square kilometers [3-5]. *Lak et al.* [7] and *Dehghan et al*. [4] reported in their studies that human factors are more involved in the drying of the lake than climatic factors. According to official reports, more than 80% of this lake was dried during the last 20 years (1995 to 2015) [8]. Unfortunately, this trend has continued and this area is a serious hazard for local people (more than 7 million people). It should be noted this damage to the lake increased the Albedo coefficient and it will lead to different types of diseases [3].

On the other hand, this area is highly exposed to wind erosion and susceptible to generating dust particles with a diameter of less than 0.1 mm. Many harmful effects of wind erosion are created by these particles (<0.1-mm) generated in erosion events. These destructive effects consist of soil fertility reduction, visibility reduction that causes airport closures and road accidents, food and drinking water contamination, respiratory problems, and economic losses [9]. If the dust transportation continues and if they travel some distance and settle on the ground surfaces, the salinity of these particles may increase the salinity of agricultural lands in the region.

Few studies have been conducted on the chemical properties of dust particles. *Wang et al*. [10] studied the properties of wind-eroded dust from different landscapes of an arid inland river basin in north-western China. They concluded that SiO_2, AL_2O_3, and Fe_2O_3 were the main matter in components of the aeolian dust uplifted in the Heihe River basin. In addition, there were some differences in elemental contents between the middle and lower reaches. In lower reaches, there were more amounts of Mg, Na, Cl, and S and less amount of Si and Al rather than in the middle reaches due to the high salinity of lake sediments. *Wang et al.* [10] examined the dust fluxes and conditions under which they occurred. They analyzed the elements (Na, Mg, Al, Si, S, Cl, K, Ca, Ti, Fe) of the aeolian dust, but they did not consider parameters that affect soil acidity or sodium content. *Zobeck* and *Fryrear* [11] concluded that the quantity of soil carried by wind decreases with height above the soil surface, but the concentration of Na, K, Ca, Mg, cation exchange capacity and organic matter increased with height. Although the total amount of eroded soil increased with storm intensity, the relation between storm intensity and nutrient content was not well defined. Most studies on the dust's chemical properties focus on mineralogy and the amount of heavy elements (such as Fe, Cu, Zn, Pb, Ni, Co, Mn, Ba, Sr, Cr, etc.) [12-15], but considering that most of the lands around this Lake are farms and gardens, so the need to study the chemical parameters that affect agriculture, gardening, quality and quantity of crops (such as pH, EC, SAR, %T.N.V, %OC, etc) was felt more than ever.

Even though many types of research have been designed to transform and provide guidance to water level restoration of Lake Urmia [3, 16-18], there is no information about the chemical properties of suspended particles caused by wind erosion in the drylands area of Lake Urmia. Government officials especially Urmia Lake Restoration Program are just paying attention to restore the water level to this lake. On the other hand, due to changes in factors affecting wind erosion such as soil erodibility, elevation, wind speed and direction, rainfall, type of vegetation, etc. at different sampling times, wind erosion should be examined at different time periods [6-7].

In order to provide suggestions and solutions for dealing with wind erosion, we need to know the chemical properties of suspended particles with different heights above the soil surface at different sampling times and we need to compare them with the eroded soil in the study area. To support this goal, we need a special tool to accurately trap the suspended particles. Using the samplers to study the suspended particles obtained from wind erosion has started since 1957 [19] and it has been changed a lot to increase the efficiency of samplers. The last and most advanced sampler for suspended particles gathering from height 0.05 m to 6 m is BSNE (Big Spring Number Eight) sampler that was made and used by Donald Fryrear in Big Spring-Texas for the first time in 1986. The average efficiency of BSNE has been reported 89% [20]. Several types of research have compared this sampler with other field samplers and concluded that this sampler is the most efficient for field measurements because its efficiency does not change with the wind speed and it is able to orientate into erosive wind [21-25].

The purpose of this study was to investigate the chemical properties of suspended particles collected by BSNE sampler at different heights above the soil surface in different sampling times and then to compare it with the primarily dried soils around Lake Urmia on continuous sampling collection from February 2017 until November 2017.

Table 1: The average 11 years of meteorological information of the studied area (from 2000 to 2011).

Months	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.
Mean wind velocity (m/s)	1.89	5.17	2.7	2.44	5.03	5.11	3.96	1.54	1.81	1.52
A speed of the strongest wind (m/s)	30	45	25	30	38	28	45	80	40	30
The total amount of rainfall (mm)	20.95	3.9	53.41	27.29	1.86	2.41	2.19	27.06	12	20.55
Air temperature	2.35	7.70	12.05	16.87	22.75	26.44	26.1	21.13	14.68	6.51

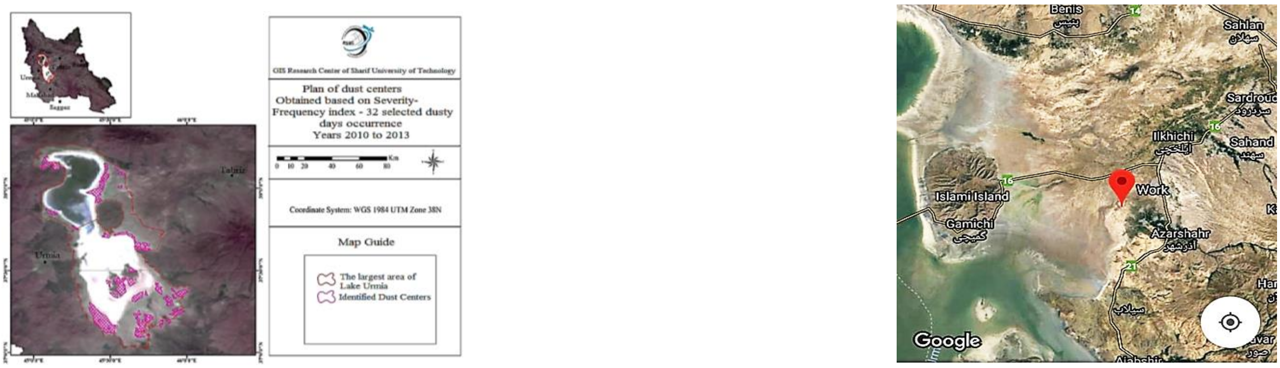

Fig. 1: Right) Location of the studied area. Left) Plan of dust centers around Lake Urmia (obtained based on Severity-Frequency index – 32 selected dusty days occurrence -Years 2010 to 2013) [3].

In addition, the effect of meteorological parameters such as rainfall, wind speed, and air temperature on the chemical properties of suspended particles were examined in this work.

Experimental Section

Location of study

Lake Urmia is located in northwestern of Iran. The study area is limited to the southeastern zone of Lake Urmia. This area is one of the dust centers around the lake that has been created by recent droughts (Fig. 1). This region was a suitable place to study wind erosion due to the insignificant earth's slope gradient, the thin exposed plant cover, the high wind speed and the low mean amount of rainfall [25]. The average 11 years of meteorological information (2000 to 2011) of the area obtained from Tabriz weather station [26] has been shown in Table 1.

The geographical location of the studied region's center is 45° 51′ 0.771″ eastern Longitude and 37° 47′ 0.675″ northern Latitude with a semi-arid and cold climate. This zone is located at a 30 km distance from Tabriz city, the capital of East-Azerbaijan province. The soil of the studied area has 28% sand, 40% silt, and 32% clay (soil texture was clay loam). The bulk density of soil was 1.34 g/cm (Table 2).

BSNE sampler

To trap and collect the suspended particles and study the chemical properties, an accurate instrument is required.

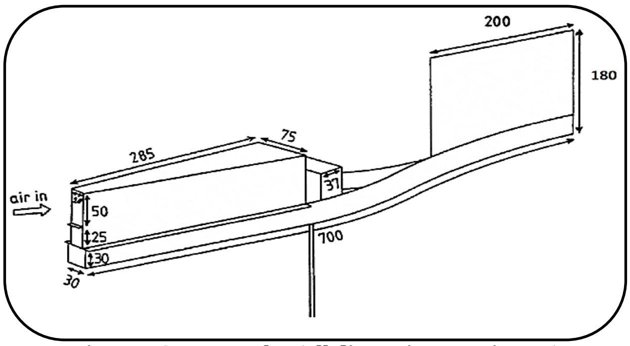

Fig. 2: BSNE sampler (all dimensions are in mm)

The standard BSNE sampler designed and tested by Donald Fryrear at Big Spring, Texas in 1986 with a vertical opening of 20 mm wide and 50 mm height has been shown as a compatible device. *Stout* and *Fryrear* [27] and *Fryrear et al.* [20] reduced the height of the opening to 10 mm for a sampling of 40 mm of the soil surface and to increase the efficiency of sample trapping. We used the modified BSNE sampler with the following specifications; it has been made of stainless steel (28-gauge galvanized metal) with a vertical opening 20 mm wide and 50 mm height and with an 18 mesh stainless screen in the opening of the sampler for dust entering and the 120 mesh stainless steel screen on the top of sampler allowing the air to exit while the airborne material can remain in the sampler tray (Fig. 2). Four samplers were installed on the same mounting pole (a 12.5 mm steel pipe with an outside diameter of 18 mm)

Table 2: Results of chemical and physical analysis of the initial soil

Depth (cm)	Sand %	Silt %	Clay %	Soil texture	ρ_b (gr/cm)	ECe (dS/m)	pH	T.N.V%	OC%	SAR
0-15	28	40	32	C-L	1.34	143.1	7.88	16.25	0.45	80.5

Fig. 3: Made and installed the Samplers

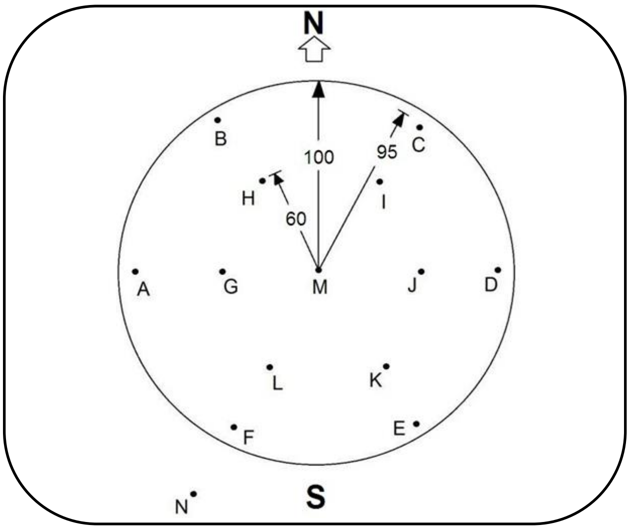

Fig. 4: The installation pattern of 14 poles

at 0.15, 0.5, 1, and 2 m heights above the soil surface [20]. A 180×200 mm sheet provided as a sampler tail accompanied by a rubber retainer in the lower of each sampler allowed it to rotate and orient according to wind direction (Figures 2 and 3). In addition, 14 poles were installed in a circular pattern (Fig. 4) inside the 3.2-ha area. This pattern permitted field erosion data collection regardless of the wind direction and provided a range of field lengths with a minimum number of sample locations [20].

Samples gathering and analytical methods

Totally, 56 samplers were installed in the above-mentioned pattern. After 30 days of installation, the tray of each sampler was evacuated and the collected particles were dried at 105°C and they were transported to the laboratory for chemical testing. This gathering was continued in 10 interval monthly periods (from February 2017 until November 2017). The chemical properties, such as total natural value (%T.N.V), the electrical conductivity of saturated extract (EC_e), pH and sodium absorption ratio (SAR) were measured on dust samples from different heights above the soil surface according to the standard methods [28]. Organic carbon (%OC) was measured using chromic acid oxidation [29].

The effect of sampling time (February 2017 until November 2017) and sampling height (0, 0.15, 0.5, 1 and 2 m) of dust particles on measured chemical properties were analyzed. The data of primary soil (zero height) at different times were also measured. Factorial experiment on the basis of completely randomized design with 3 replicate was performed. Comparison of means by Duncan multiple range test at 1% probability level was carried out. Before data analysis, the normality test of variables was applied. Data analysis was done using SPSS-16 software and the graphs and tables were drawn by Excel software. The meteorological data were obtained from Tabriz weather station.

RESULTS AND DISCUSSION

The meteorological information during the research period

In the studied area, there was no significant difference between the slope gradient, soil texture, and plant cover. Therefore, these indicators were ignored. Instead, the atmospheric parameters such as the rainfall amount, wind speed and air temperature which were fluctuating in the research period were taken into consideration. These factors are important for aeolian dust studies as mentioned by Wang et al. [10]. The amount of rainfall is one of the main indicators in wind erosion research especially in dust emission or dust flux. This parameter indirectly affects wind erosion. In fact, rainfall effects on the soil surface attributed to soil aggregates and their adhesion along with soil moisture, will reduce the rising up of the soil particles [9, 10, 20, 23, 30]. According to meteorological data of

Table 3: Meteorological information of studied area during the research period (February 2017- November 2017).

Date	Minimum surface temperature (°C)	Air temperature (°C)			Mean wind velocity (m/s)	A speed of strongest wind (m/s)	Total of rainfall (mm)
		Min	Max	Mean			
Feb.	-9	-16	6.7	-3.2	4.3	12	20.95
Mar.	-1.2	-3.2	19.2	7.9	8.7	15	1.5
Apr.	0.1	-3.8	20.4	9.1	4.4	19	26.6
May	5.1	2.4	28.6	16.2	6.8	16	26.1
Jun.	9.21	10	32.2	20.5	7.5	19	1.1
Jul.	16.1	15.6	38.4	26.2	5.6	16	3.3
Aug.	18.5	17	39.4	28.6	6.1	13	1.8
Sep.	12.6	11	37.4	24.5	7.1	17	1.7
Oct.	3.7	1.8	28.8	16	7.7	18	1.1
Nov.	-0.4	-4.2	20.8	8.6	5.4	10	26.4

Table 4: Mean squares of sampling time and height above the soil surface effects on chemical properties of collected particles by BSNE sampler

Source	df	mean squares				
		%T.N.V	%OC	EC_e	pH	SAR
sampling time	9	1.346^{**}	0.029^{**}	434.104^{**}	1.060^{**}	16087.57^{**}
a height of soil surface	4	13.139^{**}	1.836^{**}	887.365^{**}	1.222^{**}	2526.871^{**}
height above the soil surface × sampling time	36	0.105^{ns}	0.008^{**}	5.772^{**}	0.007^{ns}	120.505^{**}
Error	100	0.104	0.001	0.08	0.008	11.446
CV%		4.03	43.03	25.98	4.18	41.65

ns, * and ** are insignificant, significant at P≤0.05 and P≤0.01

the studied area during the research period (February through November 2017), the highest rainfall was 26.6 mm in April, and the lowest was 1.1 mm in June and October (Table 3). Wind characteristics such as wind velocity and wind direction are important in wind erosion research studies ([10, 22, 23, 24, 31, 32]). It should be noted that one of the capabilities of the BSNE samplers was its ability to orientate into erosive winds and rotate itself in the direction of the dominant wind. Therefore, the wind direction did not influence the collection of dust particles. Meteorological information of the studied zone during the research period (February 2017- November 2017) is listed in Table 3. The range of mean wind velocity varied from 4.3 m/s (February) to 8.7 m/s (March). The maximum speed of the strongest wind was 19 m/s in April and June. The data of the highest and lowest amount of rainfall and the mean wind velocity in the research period corresponds to the average 11 years of meteorological data gathering are shown in (Table 1). Air moisture effects on the plant cover, and as mentioned before, the area was characterized as degraded grassland.

The effects of sampling time and height above the soil surface

The effects of sampling time during the research period (February 2017 until November 2017) and height of the soil surface (0, 0.15, 0.5, 1, and 2 m), on the chemical properties of (%T.N.V, %OC, EC_e, pH, and SAR), were analyzed. The results of variance analysis (main and corresponding effects) (Table 4) showed that the corresponding effect of sampling time and height above the soil surface on %OC, EC_e, and SAR was significant (P≤0.01). The main effect of sampling time and the main effect of height above the soil surface on pH and %T.N.V were also significant (P≤0.01).

The relationships between the chemical properties of collected particles and the meteorological parameters

To evaluate the relationships between the chemical properties of collected suspended particles and the meteorological parameters during the research period, the correlation coefficients between chemical properties and some main atmospheric parameters such as total rainfall (R),

Table 5: Correlation coefficients between monthly chemical properties of collected suspended particles and main meteorological parameters during the research period

	EC_e	pH	%T.N.V	%OC	SAR	MW	SW	R	AT
EC_e	1	0.341^{ns}	0.186^{ns}	0.479^{ns}	0.634^{*}	0.258^{ns}	0.611^{*}	-0.625^{*}	0.285^{ns}
pH		1	-0.425^{ns}	0.515^{ns}	0.449^{ns}	0.297^{ns}	0.489^{ns}	0.065^{ns}	0.437^{ns}
%T.N.V			1	-0.208^{ns}	0.030^{ns}	0.340^{ns}	-0.205^{ns}	-0.639^{*}	0.161^{ns}
%OC				1	0.886^{**}	0.614^{*}	0.813^{**}	-0.419^{ns}	0.78^{**}
SAR					1	0.696^{*}	0.847^{**}	-0.619^{*}	0.662^{*}
MW						1	0.608^{*}	-0.618^{*}	0.321^{ns}
SW							1	-0.388^{ns}	0.332^{ns}
R								1	0.6^{ns}
AT									1

ns, * and ** are insignificant, significant at $P \leq 0.05$ and $P \leq 0.01$

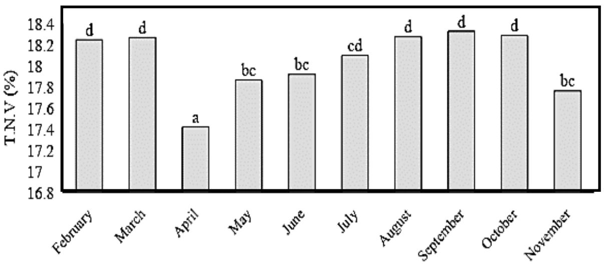

Fig. 5: Mean comparison of sampling time effect on %T.N.V of collected particles

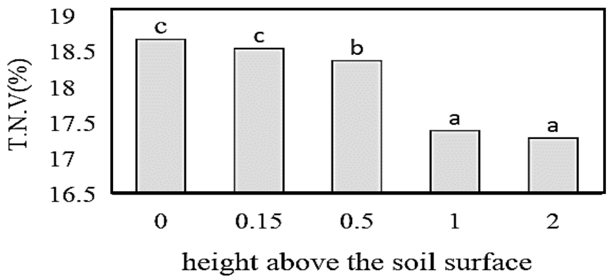

Fig. 6: Mean comparison of the height above the soil surface effect on %T.N.V of collected particles

speed of the Strongest Wind (SW), monthly Mean Wind velocity (MW) and monthly mean Air Temperature (AT) were calculated by statistical software (Table 5). Results showed that there was a significant and negative correlation ($P \leq 0.05$) between the total rainfall (R) and the chemical properties such as EC_e, %T.N.V, and SAR. There was a significant and positive correlation between the speed of the strongest wind (SW) and the monthly mean of EC_e, %OC, and SAR. Furthermore, the monthly Mean Wind velocity (MW) correlated with the monthly mean of %OC and SAR ($P \leq 0.05$). There was a significant correlation between the Air Temperature (AT) and the monthly mean of %OC and SAR. In order to better express these relationships, the graphs were drawn (Figures 7, 11, 13 and 15). There was no significant correlation between the pH of collected particles and the meteorological parameters.

Total natural value (% T.N.V)

To calculate the lime content of soils, calcium carbonate must be measured. Too much lime in soil is harmful to agricultural products, it causes an increase in pH, so it prevents the absorption of some nutrients by the plant. The mean comparison results of the main effect of sampling time (Fig. 5) showed that in April and November, the %T.N.V of collected particles was minimum. Actually, the rainfall amount in Apr. and Nov. was higher than the other months (Table 3). Therefore, it can be concluded that, when the rainfall amount is high, the %T.N.V of collected particles will be low.

On the other hand, the mean comparison results of the effect of the height above the soil surface on %T.N.V of collected particles (Fig. 6) showed that the %T.N.V. at heights 0, 0.15 and 0.5 m were more than the %T.N.V at heights of 1 and 2 m. Therefore, the particles that move at low heights will increase the amount of lime in the nearby soils, because they will settle on the ground sooner, and due to the high lime content of the studied soils (Table 2), this can cause an increase in Ph. The high pH generated by high amounts of calcium carbonate in the soil; will reduce the plants' access to nutrients, especially micronutrients, phosphorus and potassium, is reduced [33].

Fig. 7 shows the relationship between the monthly mean of the %T.N.V of collected particles by BSNE sampler (grey bars) and the meteorological parameters

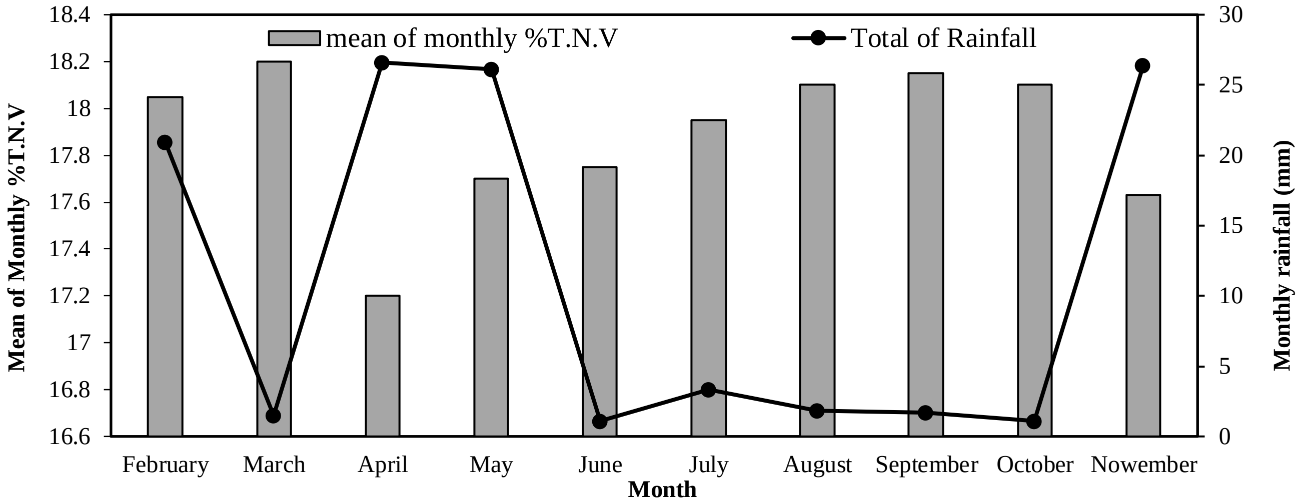

Fig. 7: Variation of the monthly mean of %T.N.V (grey bars) and its relationship with the main meteorological parameters at the studied site

during the research period. The monthly mean of the %T.N.V only correlated with the total of rainfall negatively, and not correlated with other meteorological parameters (table 5). It means when the amount of rainfall is low, the monthly mean of %T.N.V is high, that can be attributed to the effect of rainfall in salts leaching and the reduction of %T.N.V.

pH

As shown in Table 4, the main effects of the sampling time and the height above the soil surface on the mean pH of collected particles were significant ($P \leq 0.01$). The mean comparison of the sampling time on the pH of collected particles (Fig. 8) showed that the pH in Sep., Oct. and Nov. were less than in the other months. According to meteorological information (Table 4), the rainfall amount in these months (Sep., Oct., and Nov.) was more than in the other months. In fact, rainfall leaches the alkaline elements such as calcium (Ca), magnesium (Mg) and potassium (K) and it doesn't leach the acidic elements such as hydrogen (H), aluminum (Al), and manganese (Mn). As a result, soil acidity or soil pH decreases [34, 35]. Since the pH of the soil in the area (Table 2) is relatively high (pH=7.88), we concluded that rainfall can improve the pH, but it doesn't occur after a rainy day. It requires many years of rainfall in the region. As seen in the correlation results (Table 5) there was no significant correlation between the pH of collected particles and the studied meteorological parameters.

On the other hand, the type of soil texture also has effect on the pH changes. The pH of sandy soils changes more rapidly than clay soils because the soil elements are not strongly bonded together in sandy soils and water passes through them more rapidly and leaches the elements. In clay soils with poor drainage, less water passes through the soil particles and as a result, the soil elements are less exposed to leaching. In studied soils with clay-loam texture (Table 2), we did not expect the soil pH to change during the study period (one year), but the results showed that during the months with high rainfall (Sep., Oct., and Nov.), the pH changes in the collected particles were significant.

The mean comparison result of the main effect of the height above the soil surface on the pH of collected particles (Fig. 9) showed that when the height above the soil surface increases, the pH will decrease. Similar to the %OC result, when the height above the soil surface increased, the %OC would increase. Increasing inorganic carbon content causes a decrease in pH, because of hydrogen cations in organic materials. The results of some studies showed that when the height above the soil surface increases, the amount of finer particles will increase [36] and thereby, pH will increase too due to the cations inter-connect to finer particles. Here, we achieved the opposite results. In other words, by increasing in the height above the soil surface, the pH decreased. Similar to the phenomenon explained in the %T.N.V result, when the height increased, the amounts of lime would decrease, and lime decreasing led to the pH reduction. Finally, we can

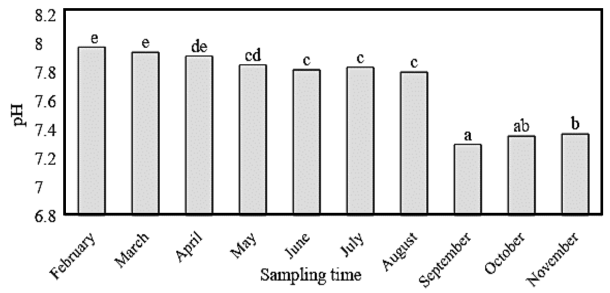

Fig. 8: ***Mean comparison of sampling time effect on pH of collected particles***

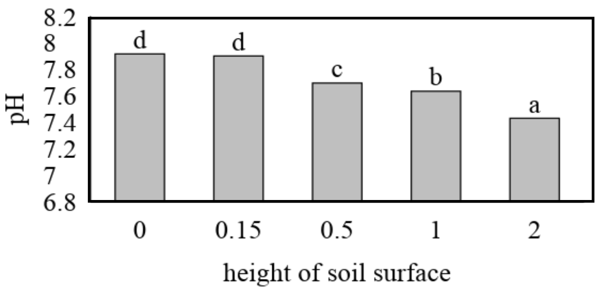

Fig. 9: ***Mean comparison of height above the soil surface effect on pH of collected particles***

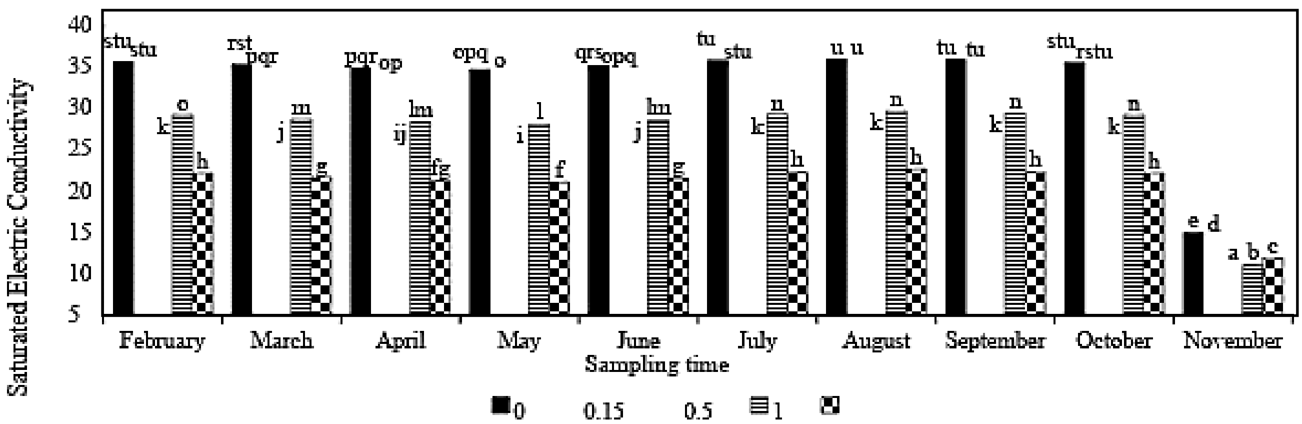

Fig. 10: Mean comparison of the corresponding effect of sampling time and height above the soil surface on ECe of collected particles

conclude that the effect of %T.N.V. on the pH reduction is more than the effect of hydrogen cations.

The electrical conductivity of saturated extract (EC_e)

Soil Electrical Conductivity (EC) is a measure of the amount of salts in soil (salinity of soil). It is an important indicator of soil health. Inherent factors affecting EC include soil minerals, climate, and soil texture which cannot be changed. Salts originate from disintegration (weathering) of minerals and rocks. In areas with high amounts of rainfall, soluble salts from minerals and rocks are flushed below the root zone, eventually into deep groundwater systems or into streams that transport salts to the ocean. Conversely, in arid areas or in areas where less rainfall occurs or saline irrigation water is used, soluble salts are more likely to accumulate and remain near the soil surface, resulting in high EC [37]. *Che Othaman et al.* [38] showed that the soil EC is directly proportional to the nutrient concentration and inversely proportional to the depth of the soil. Besides, the soil EC values reflect the soil salinity (salt concentration) where, the higher the EC value, the higher the salt concentration in the soil and vice versa.

For the investigated area, the soil EC was very high (Table 2, EC= 143.1 dS/m). Because the study area is located near Lake Urmia, and the water of Lake Urmia has decreased significantly in recent years. This has increased the EC of the lake water because the salinity of the lake water is directly related to the reduction of water level [39]. Consequently, the particles have risen to the air and have settled in surrounding lands. On the other hand, the amount of sodium in these particles was very high, which made the high SAR results (Table 2, SAR = 80.5).

It is clear from Table 4, the corresponding effect of the sampling time and the height above the soil surface on EC_e, %OC, and SAR were significant. Therefore, the main effect of the height above the soil surface and the sampling time will not be discussed. The mean comparison result of the corresponding effect on EC_e (Fig. 10) showed that when the height above the soil surface increases, the EC_e of collected particles will reduce. Also, it can be analyzed that when the height above the soil surface increased, the %T.N.V would decrease. Certainly, when the %T.N.V decreases, the salts will decrease. Consequently, EC_e will decrease, because it is related to salts. Thus, the particles

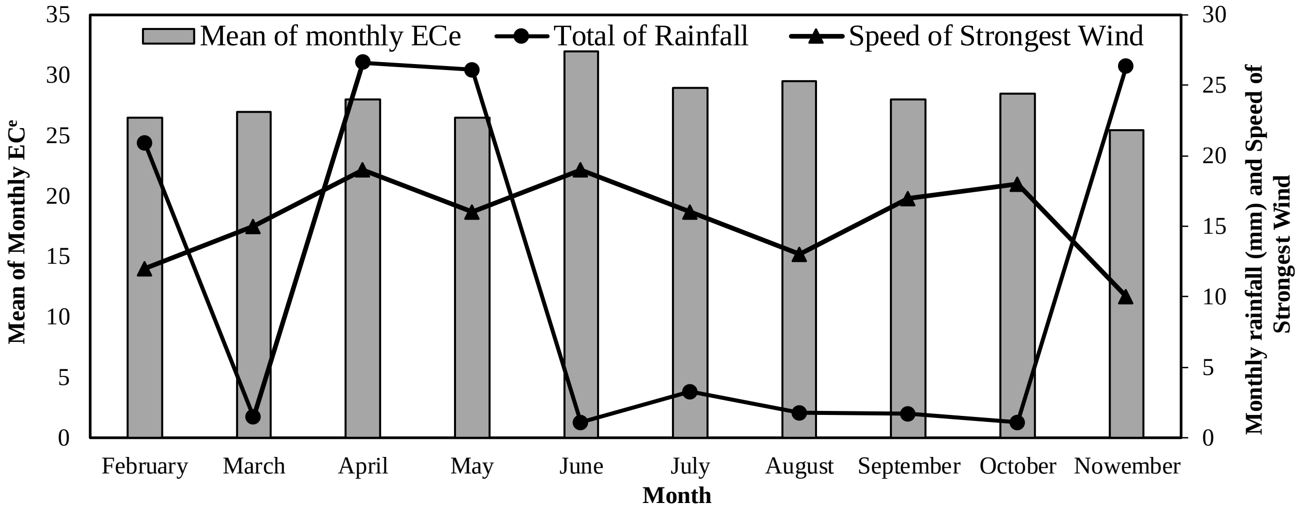

***Fig. 11:** Variation of monthly mean of ECe (grey bars) and its relationship with the main meteorological parameters at the studied site*

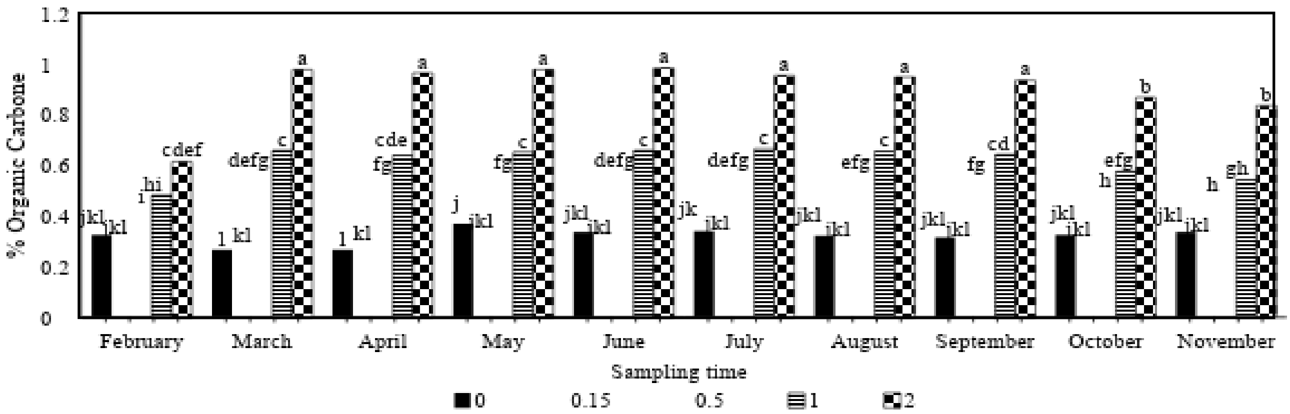

***Fig. 12:** Mean comparison of the corresponding effect of sampling time and height above the soil surface on %OC of collected particles*

that were transported in lower heights had higher EC_e, and a greater impact on the salinity increasing of soils in the studied area. The lowest EC_e was in November. This is because of the high amount of rainfall in that month (Table 4) (total rainfall in Nov. was 26.4 mm).

Fig. 11 shows the relationship between the monthly mean of EC_e of collected particles by BSNE sampler and the meteorological parameters during the research period at the study site. The monthly mean of the EC_e was correlated with the total rainfall negatively and with the speed of the strongest wind positively (Table 5). It means when the total rainfall increased, the EC_e of collected particles decreased. In fact, the salt particles of soil were leached by rain and this has reduced EC_e. On the other hand, when the speed of the strongest wind increases, the EC_e of collected particles increases. This can be attributed to the fact that, with increases of wind speed, the evaporation rate also increases. This will have a positive effect on the increase of soil particle's salts and EC_e.

Organic Carbon (%OC)

Many factors affect the amount of soil organic carbon. These factors can be listed as soil depth, particle size, erosion, vegetation, microorganisms, temperature, humidity, soil ventilation, available nitrogen, land use change and etc. [40, 41]. Even the depth of soil sampling can change the amount of organic carbon. The amount of soil organic carbon at lower soil depths (0-15 cm) was higher than the amount of organic carbon at greater depths (15-30 cm) [42]. The mean comparison results of the corresponding effect of the sampling time and the height above the soil surface on organic carbon (%OC) content of the collected particles (Fig. 12) showed that when the height above the soil surface increases, the %OC of

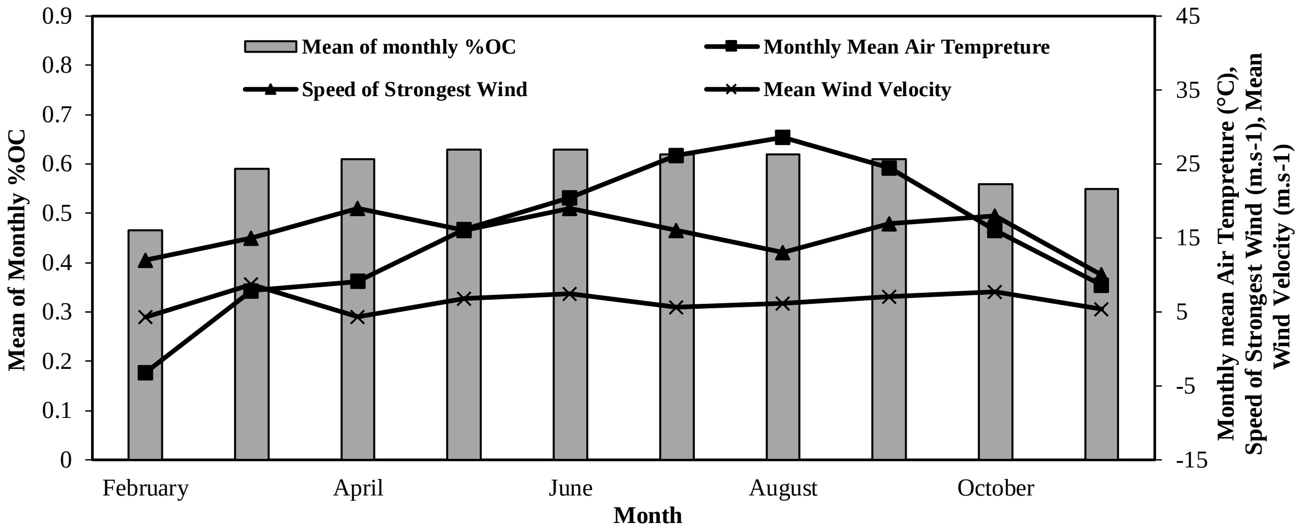

Fig. 13: Variation of monthly mean of %OC (grey bars) and its relationship with the main meteorological parameters at the studied site

collected particles will increase. In other words, the finer particles moving on high elevation, have more %OC than the coarser particles moving on a lower elevation. Because the amount of soil organic carbon is directly related to the particle size. The finer particles have higher %OC because of more adsorption capacity [42, 43]. Therefore, when finer particles reach to the air, they cause more fertility reduction left soils in the site. *Zobeck* and *Fryrear* [11] concluded that when the height above the soil surface increases, %OM (organic matter) will increase. The less %OC was observed at 0 and 0.15 m heights in all months. A decrease in %OC over time has reported by other studies [44].

Fig. 13 shows that the monthly mean of the %OC was positively correlated with the speed of the strongest wind, mean wind velocity and monthly mean air temperature, and not correlated with a total of rainfall (table 5). This means that the total rainfall did not influence the %OC of collected particles. But when the wind speed and air temperature increased, the %OC of collected particles increased, too. Mansori et al. [42] reported there was no significant relationship between soil organic carbon content and climatic parameters. They concluded that the range of temperature and rainfall changes in this region is not to the extent that they have a significant impact on biomass production.

Sodium Absorption Ratio (SAR)

Sodium absorption ratio (SAR) is a parameter used in the management of sodium-affected soils. It allows assessment of the state of flocculation or of dispersion of clay aggregates in a soil. It is directly related to the amount of exchangeable sodium cations and inversely related to the amount of exchangeable calcium and magnesium cations in the soil. This index indicates the possibility of dispersion in clay. Sodium and potassium cations facilitate the dispersion of clay particles, while Ca and Mg cause them to contract. The mean comparison results of the corresponding effect of the sampling time and the height above the soil surface on SAR of the collected particles (Fig. 14) showed that the higher SAR was found in the period of March until October. In this period when the height above the soil surface increases, the SAR of collected particles will increase. These field results are in accordance with the *Zobeck* and *Fryrear* [11] findings. They concluded that when the height above the soil surface increased, the concentration of Na, K, Ca and Mg increased. The Ca, Na and Mg are the principal elements for calculating SAR. The lowest SAR value was in the months of November and February. In these months when the height above the soil surface increases, SAR of collected particles will not change. According to meteorological information (Table 4), these months (November and February) had more rainfall and less wind velocity than other months. In a study that investigated the effect of instantaneous and slow-release salt stress on beta-carotene production in Dunaliella Salina cells, concluded that a rapid increase in salinity (especially NaCl) reduces biomass, but if this increase occurs sequentially and slowly, the organism can adapt to the conditions [45].

Fig. 15 shows that the monthly mean of the SAR was correlated with all of the studied meteorological parameters.

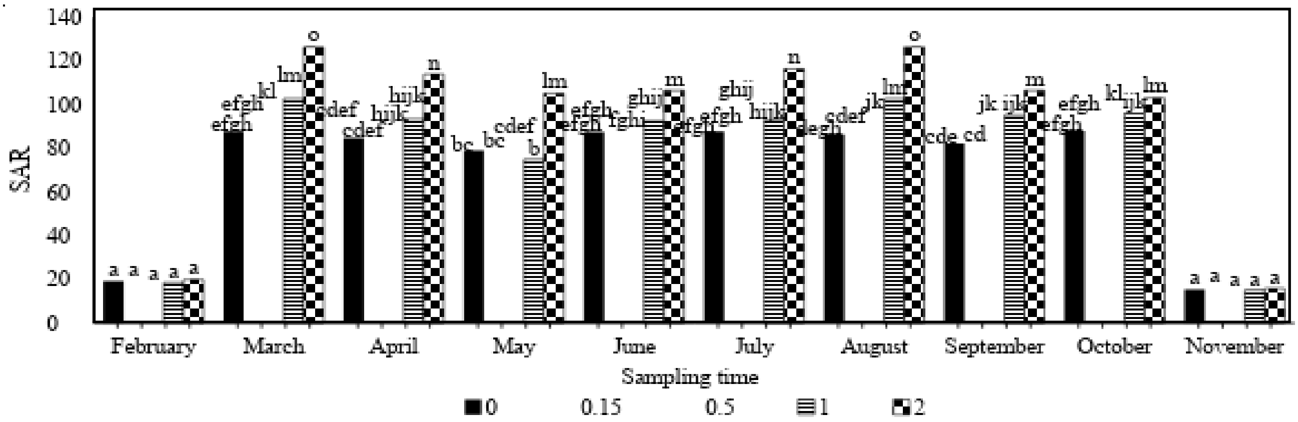

Fig. 14: Mean comparison of the corresponding effect of sampling time and height above the soil surface on SAR of collected particles

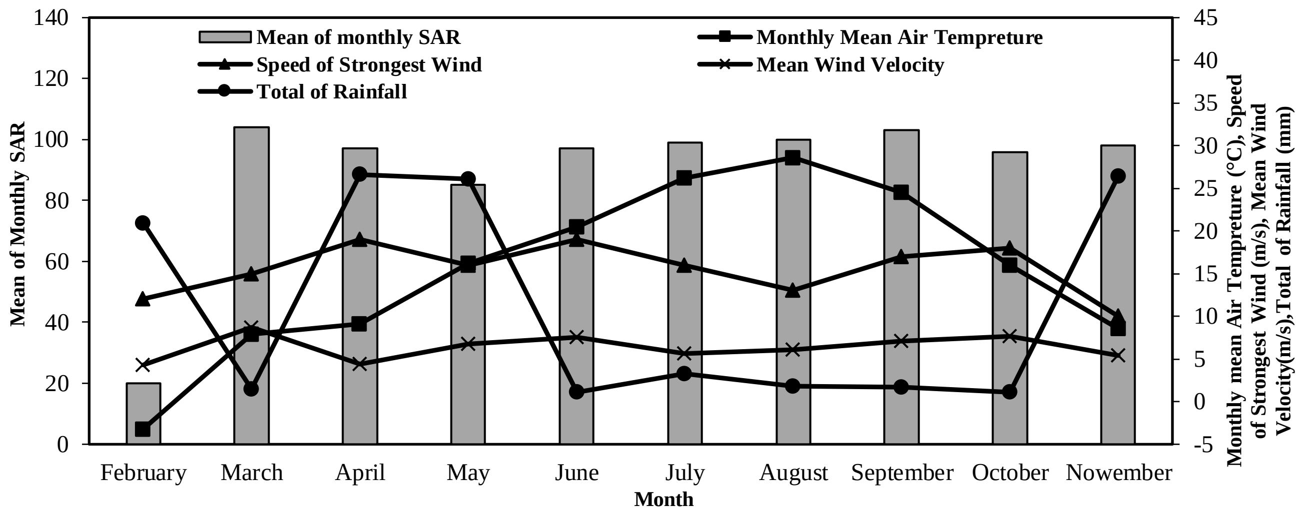

Fig. 15: Variation of the monthly mean of SAR and its relationship with the main meteorological parameters at the studied site

It can be concluded that the SAR of collected particles is the most sensitive to changes in meteorological parameters in comparison to other studied chemical parameters because all correlation coefficients were significant (Table 5). When the amount of rainfall is higher, the monthly mean of SAR is less. This is normal because of salts leached by increasing rainfall. The monthly mean of the SAR was positively correlated with the speed of the strongest wind, mean wind velocity, and air temperature. It means when the wind speed and air temperature increase, the SAR of collected particles will increase too.

The comparison of dust particles collected from different heights above the soil surface with the eroded soil of the area

To compare the chemical properties of dust particles collected from different heights (0.15, 0.5, 1, and 2 m) above the soil surface with the eroded soil of the studied area, we collected samples of the soil in the studied area at all times, and the dust particles of all poles samples that were trapped. Then the chemical properties of these samples were determined. The results of variance analysis and mean comparison showed that in all chemical properties (%T.N.V, %OC, EC_e, pH, and SAR), there was no significant difference between the eroded soil of the studied area and the particles collected from 0.15 m height above the soil surface. By checking Figs 5, 6, 8, 9, 10, 12, and 14, one can see the bars that are related to heights of 0 and 0.15 m have the same letters. But at other heights above the soil surface (0.5, 1, and 2 m), the letters of the bars are different. This indicates that there was a significant difference between the primary soils and the particles collected from different heights by BSNE samplers.

This result suggests that the dust particles moving at greater than 15 cm height above the soil surface are different from the eroded soil of the studied area. Probably the source of these particles is the flat land and large salt mines around Lake Urmia that have been dried recently. The other conclusion that can be obtained is that the dust particles after rising can travel long distances. This issue can be studied accurately by marking the particles by the isotope elements. This result is very useful in the prevention management plans to prevent the suspended particles from damaging farmlands, and residential and industrial buildings around Urmia Lake.

CONCLUSIONS

The terminal lake beds around Lake Urmia are the most important source of aeolian dust deposits in northwestern Iran. During this research period (from February 2017 to November 2017), the chemical properties of suspended particles collected by BSNE sampler were measured at various heights above the soil surface at different times.

The results illustrated that there was no significant difference among all chemical parameter measurements between the primary soil of the studied area and the particles collected from 15 cm height above the soil surface. In other heights (50, 100 and 200 cm), there was a considerable difference between the eroded soil and the collected particles. That means the source of dust particles which are moving greater than 0.15 m in height is different from the eroded soils of the study area. When these particles settle on the surrounding soils, they can cause significant changes in soils and reduce their fertility and consequently, reduce the quality and quantity of crops. This finding should be studied more widely with higher precision and accuracy. Furthermore, the results proved that the content of chemical properties such as %T.N.V, EC_e, and pH decreased by elevating the height above the soil surface but the SAR and %OC increased.

In addition to the fact that rainfall has a positive effect on increasing the amount of plant cover, also it reduces rising the suspended particles. In this study, rainfall reduced the values of EC_e, %T.N.V, and SAR of collected particles which is also in favor of the amount of plant cover. When the suspended particles settle on the ground, they do not increase the soil salts. By increasing the speed of the strongest wind, the EC_e, %OC, and SAR of collected particles increased. The pH was the only parameter that had no correlation with the studied meteorological parameters. In contrast, the SAR was the most sensitive parameter among the studied chemical parameters.

More chemical aspects needed to be studied, such as CEC, elements including S, K, Al, Fe, Mn, and Si for the purpose of health considerations. This is crucial because the area is designated as one of the locations that are susceptible to hazards of dust pollution. Eventually, we recommended more accurate and wider studies of hazardous dust pollutants. Future investigations should include various landscapes with different meteorological parameters and more effective parameters on the wind erosion (such as soil texture, plant cover, earth slope gradient etc.), with different sources of aeolian dust around the Lake Urmia area.

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