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# A study on Isatis suspension trap efficiency; Advantages and disadvantages

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**Abstract**

Different types of sediment trap have been introduced so far to be used in erosion measuring stations, each with its own advantages and disadvantages in trapping aeolian particles. These traps have different collection and retention efficiency due to aerodynamic conditions. Some characteristics such as isokinetic feature of the trap, collection efficiency, time needed to download sediment, capability of installation in different altitudes and capability to collect sediment from different geographical directions are the criteria used to assess the efficiency of different types of sediment traps. In the present study Isatis Suspension Trap (Isatis SUSTRA) was tested in a wind tunnel and wind erosion measuring station. This is a kind of passive trap and its sediment collecting efficiency varies between 55% to 88% for 5 to 9 m/s velocities respectively in the height of 15cm. Although the efficiency of the trap in low wind velocities is less than 55%, it is remarkable comparing with other traps. Larger mouth of the trap provides it with vaster opportunity to trap sediment. Isatis SUSTRA has the capability to segregate sediments in different geographical directions. This privilege leads to 1) possibility to analyze horizontal distribution in different geographical directions, 2) determining the most sediment producing fraction and easy recognition of the source, 3) estimating moved materials such as dissolved salts or heavy elements in mine range) through separating sediment samples and 4) easy installation in different altitudes and enough capacity to reserve aeolian sediment. Generally speaking, the results from indoor and outdoor tests indicate that Isatis SUSTRA has appropriate capabilities with regard to collecting efficiency, keeping, sediment reserve capacity and easy download in hard conditions.

***Keywords:*** Isatis; Sediment trap; Wind erosion; Yazd

## 1. Introduction

Measuring dust particles is easily possible in controlled lab conditions and wind tunnel but it becomes extremely difficult in outdoor conditions. Erosion measuring can be done in various ways including using natural evidence such as the distance from plant fringe to general surface of the earth, installing index and putting pins in the ground, establishing measuring stations and monitoring the events through sediment traps and using satellite images. Different kinds of sediment trap have been designed so far and they have been introduced to be used in erosion measuring stations. Bagnold sediment trap introduced in 1941 is among the first ones and was mainly used in wind tunnel experiments (Marva and Peterson, 1983). The most important deficiency of this trap was its fixed mouth in the field conditions although its shortcoming was relieved by the wind erosion lab's experts of USA Dept. of Agriculture though making the mouth rotate (Marva and

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Peterson, 1983). Fryrear (1986) introduced BSNE[1] sediment trap. This trap has the capacity of being installed in different altitudes and changes its direction according to wind direction and is capable of trapping saltation and suspended particles. The velocity of aeolian particles reduces after passing the 20×50 mm mouth of the trap and these particles sediment at the bottom of the trap. The space under the 18 mesh screen at the end of the trap prevents the movement of collected sediments. The 60 mesh sieve in the traps wall makes ventilation possible. According to Fryrear (1986) the collection efficiency of the trap is 88%-94% that varies based on wind velocity and particle size. Retention efficiency of BSNE is 95%-98%. This trap has lower efficiency for the particles smaller than 60 micron. It is recommended that this trap be used in coarse grain soils. BSNE sediment trap was used by Karimzadeh and Jalalian (2002) in Sajzi plain located in Isfahan province in order to study the origin of the aeolian particles. In this study, the traps were installed in seven different altitudes and the sediments were collected. Collection efficiency and diametric distribution of the particles in different altitudes were also analyzed. The results from this study have been applied in order to study the origin of Aeolian sediments, genesis and soil formation.

Azimzadeh et al. (2008) used BSNE sediment trap in Iran's farmlands for the first time to measure wind erosion. In this study 12 single events of wind erosion were recorded fallow lands during one year, since April 2006. Through BSNE, control and creeping traps horizontal and vertical distribution of the particles were determined. From the results of this study it can be referred to assessing total amount of losses due to 12 events of 13.5 tones in the fallow lands of Yazd-Ardakan plain.

Stout and Fryrear (1989) introduced an improved sediment trap that enjoyed isokinetik conditions. The results indicate the trap has a high efficiency without choosing-effect for the particles in specific size. The ventilation hatch is designed in such a way that the air in the trap be isokinetic. As Goossens and Offer (2000) put it, Sustra[2] traps were invented by Yansen and Tetzelof in 1991. Just like BSNE, this trap was used to collect aeolian particles. The air and its sediments enter the trap through a 5cm-diameter horizontal pipe and fall to the reservoir of the trap. There is a plastic container at the bottom of the trap located on a sensitive digital balance and their weights would be measured in different time intervals. In this way the aeolian particles remain in the trap except for a trace of suspended particles. Just like BSNE trap, this trap has a rudder that locate the trap's mouth in the wind's direction. The reservoir of the trap is placed in the ground. The usual altitude of SUSTRA trap from the ground level is 23 mm and in order to place it in a lower altitude we need to put the reservoir deeper in the ground (Goossens and Offer, 2000)

The primary design of MWAC[3] was done by Wilson and Cook (1990). This trap consists of a plastic bottle as the reservoir which is connected to the air pipe. In this trap the bottle is installed vertically and the mouth of air entering pipe is located in the wind direction. Due to the pressure difference resulted from entering and exiting pipes' diameter, the sediment that enter the trap remains at its bottom. Kuntze et al. (1990) installed the bottles horizontally and connected all of them to a single rudder. In this case various bottles are installed in different altitudes to determine the vertical aeolian particles flux. Air entering and exiting pipes are made of glass with external diameter of 12.5 mm while the internal diameter of air entering pipe is 7.5 mm and the internal diameter of air exiting pipe is 10.0 mm.

WDFG is another trap that can be provided commercially. The trap has a simple structure, consisting of two parallel and vertical walls and the horizontal 100×180 mm walls have an angle of 0˚ with the horizon while the front wall has an angle of 24.5˚ with the horizon. The trap's mouth is 1.9×10 cm in a rectangular form. WDFG trap ahs a foam rubber filter with 10 pores in an inch. This filter has a fine sticky surface and the particles are kept after they strike against it. The filter has 3cm thickness and is installed in 2 cm distance from the trap's bottom wall (Hall et al., 1993).

The isokinetic sediment trap SARTORIUS is the only active trap that does not have a considerable effect on isovelocity lines because sucking the air according to air velocity. The sucked air remains in a 4 cm filter. The holder of the filter is connected to the sucking part through a flexible plastic pipe and let the air sucking part freely located in the wind's direction. The volume

1- Big Spring No Eight
2- Suspended sediment trap
3- Modified Wilson and Cook

of sucked air is 200-1800 liter/hour (Goossens and Offer, 2000).
The present study aims to assess the efficiency of a new sediment trap called Isatis SUSTRA[1]. This trap has been under various field and lab tests and the present study introduces different features and capabilities of that. The main reason for designing Isatis trap is the importance of measuring transmitted sediments from different directions in order to determine the soil losses resulted from wind erosion. As far as the traps with single reservoir are not able to segregate the directions when the wind direction changes, the advantage of having separate reservoir for each direction leads to higher accuracy in measuring. On the other hand, based on hard conditions of wind erosion field measuring, it is crucial to have a reservoir with enough storage capacity. In this case it would be possible to increase the trap's downloading cycle especially in the regions far from city.

## 2. Materials and methods

### *2.1. General characteristics of Isatis SUSTRA*

Isatis SUSTRA is a trap for saltation and suspended aeolin particles. This trap has two main parts namely upper part (lid) and lower part (reservoir) (figure 1) the lower part is in the shape of a tray and includes eight azimotic sectors (according to eight main and secondary geographical directions) vertical to the surface of the tray in four crossing axes of 45˚, providing the trap with eight reservoirs. The reservoirs are designed in such a way that can store the loess particles that enter the trap from different directions. At the bottom of each sector a layer of 6-10 mesh screen is installed. The drum that covers the trap has a rudder and also a passage for entering air and sediments to the reservoir. The rudder is designed in such a way that puts the trap's mouth in the direction of wind. So the lower part is fixed and the upper part moves. Isatis SUSTRA is made of galvanized sheet and all the welding seams were completely covered and is suitable for the hard conditions of desert.

As you can see in figure 1, one of the capabilities of this trap is the possibility of sampling from different directions and segregating the sediments. The trap is also designed to have enough capacity to trap sediments for a long time. This capacity makes it possible to use the trap in remote areas. The other capacity of Isatis SUSTRA is the possibility of being installed in different altitudes. This property provides the necessary data to draw vertical distribution curve which is followed by horizontal distribution of the erosion.

### *2.2. Isatis SUSTRA dimensions*

The dimensions of this trap meet latest scientific findings according to the following hypothesizes. Hypothesis (1): in designing the trap, the maximum discharge passing the width unit of recorded events in Yazd_Ardakan plain with 2m distance from the surface is 80 kg/m (Azimzaheh et al., 2008). It is obvious that in the events with lower intensity the storage capacity would decrease. Storage capacity can be calculated in different plains in Iran with regard to maximum discharge passing width unit. Hypothesis (2): as far as altitude profile determines the percentage of the materials passing the surface with different altitudes, we assumed that all the transmitted materials from altitude beds of 0-20, 20-40, 40-60, 60-80, 80-100 and +100 (cm) are 35%, 25%, respectively and 10% for the rest. Hypothesis (4): collection efficiency of the trap is less than 1. It can be calculated through wind tunnel test. This is crucial for the reclamation of the amount of trapped loess particles. In table 1 we presented the storage capacities for different

events based on that the trap was designed. In the present study we designed a small and a large models of the Isatis SUSTRA. The small one is half of the large one in all the dimensions so that the wind tunnel wind be done on that. The large one was designed to be used in wind erosion measuring stations. From the side view, the diameter of both the drum and the rudder is 800 mm. the location of rudder is vertical to the trap's mouth so the trap can always be located in the wind direction. The trap's mouth direction is 20×20 mm. when the air enters the trap it strikes to the walls and its sediments will remain. These sediments pass two layers of scalp at the bottom of the reservoir and get trapped. It is obvious that the smaller

1- Called after the name of Yazd province, the fourth historic city of the world (Isatis suspension trap)

Table 1. Reservoir volume and depth calculation in different proposed events

| Max. Reservoir Depth (cm) | Max. Calculated Vol. of one Sector ($cm^3$) | Collection Efficiency | Altitude (cm) | Relative Transmitted | Transport Capacity in Trap Mouth (kg/0.25m) | Max Transport Capacity (kg/m) |
|---|---|---|---|---|---|---|
| 10 | 2240 | 0.60 | 0-20 | 0.35 | 16 | 80 |
| 7 | 1600 | | 20-40 | 25.0 | | |
| 3 | 640 | | 60-40 | 10.0 | | |
| 3 | 640 | | 60-80 | 10.0 | | |
| 3 | 640 | | 80-100 | 10.0 | | |
| 3 | 640 | | 100+ | 10.0 | | |
| 7 | 1680 | 60.0 | 0-20 | 0.35 | 12 | 60 |
| 5 | 1200 | | 20-40 | 25.0 | | |
| 7 | 480 | | 60-40 | 10.0 | | |
| 2 | 480 | | 60-80 | 10.0 | | |
| 2 | 480 | | 80-100 | 10.0 | | |
| 2 | 480 | | 100+ | 10.0 | | |
| 5 | 1120 | 0.60 | 0-20 | 0.35 | 8 | 40 |
| 4 | 800 | | 20-40 | 25.0 | | |
| 2 | 320 | | 60-40 | 10.0 | | |
| 2 | 320 | | 60-80 | 10.0 | | |
| 2 | 320 | | 80-100 | 10.0 | | |
| 2 | 320 | | 100+ | 10.0 | | |
| 3 | 560 | 0.60 | 0-20 | 0.35 | 4 | 20 |
| 2 | 40 | | 20-40 | 25.0 | | |
| 1 | 160 | | 60-40 | 10.0 | | |
| 1 | 160 | | 60-80 | 10.0 | | |
| 1 | 160 | | 80-100 | 10.0 | | |
| 1 | 160 | | 100+ | 10.0 | | |

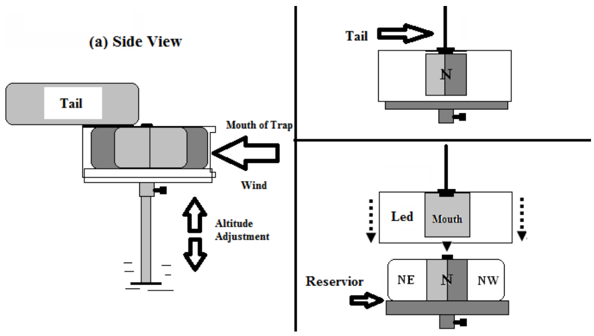


Fig.1: Isatis SUSTRA schematic

mouth changes the efficacy of the trap. It is worth mentioning that larger dimensions of the trap's mouth increase the chance of getting the aeolian particles. In this way the amount of machine error would decrease. Discharge transformation coefficient in this trap is 5 while in BSNE it is 50.

Fig. 2. Wind erosion measurement station in Meybod, Yazd Province

The trap's vanes are in four axes having an angle of 45° to each other separating main and secondary geographical dimension. The vanes' height from the edge of the sediment reservoir is 200 mm and the depth of sediment reservoir can be calculated based on table 2. To the amount referred to table 1, it could be added about 20% as the free depth. The volume of reservoir has two sieves. The front sieve with big pores includes all the organic and mineral components of the sediments and in bottom layer there is a 10 mesh scalp.

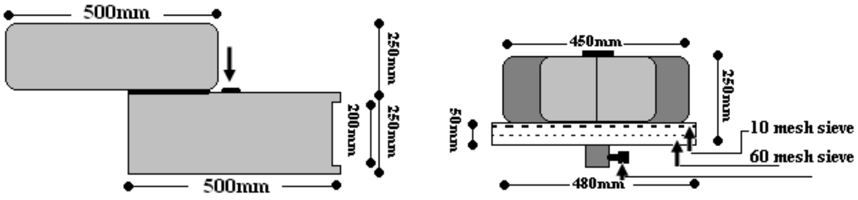

Fig. 3. Isatis SUSTRA Ingredient (Side View)

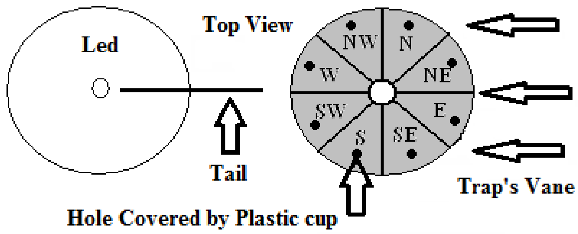

Fig. 4. Top view of Isatis SUSTRA

At the bottom of each part of the trap there is a hole covered by a plastic cap. This hole is designed for easier downloading in the desert. In this case, the sediments have to sweep the sediments at the bottom of the trap to a pocket by means of a brush. The amount of time necessary to download is an important feature of a trap. One of the advantages of Isatis SUSTRA is the short time that it takes for downloading. This trap has the capacity of being installed in different altitudes, from 2 cm to 2 m. the cap part is movable and its direction changes according to wind direction by means of a bearing.

*2.3. Calculating the collection efficiency of Isatis SUSTRA*

The collection efficacy was calculated after five repetitions with the station's soil and in wind tunnel. First the sampler was firmly installed on a base. In front of the sampler was a tray with 290 mm width, 300 mm length and 5 mm height. The height of tray's floor is equal to the average height of sampler's mouth and the distance between tray's edge and sampler's mouth was 50 mm. In each test we used 650 gr of the soil that had passed the 2 mm scalp. The soil was spread all over the tray by means of a brush and the fan of the tunnel worked each time with velocity of 5, 7 and 9 m/s in the height of 15 cm. The tested continued until the soil in the tray ended. Collection efficiency was calculated using the following formula

$$CE = \frac{M_{ISATIS} \cdot WD_{tray}}{M_{tray} \cdot WD_{ISATIS}} \quad (1)$$

Where ($M_{Isatis}$) is the weight of collected soil, ($WD_{Isatis}$) is the width of trap's mouth, ($WD_{tray}$) is the width of the tray and ($M_{tray}$) is the weight of the soil spread on the tray.

*2.4. Isovelocity lines in the periphery of the trap*

Isovelocity lines was done by measuring wind velocity in the vicinity and periphery of the trap. The location of the bearing the lid was considered as the center of coordinate axis. Wind velocity was measured in different distances from the trap according to coordinate axis. Measuring in the conditions of the smaller model of the trap was done against wind tunnel with the fixed velocities of 7.5 m/s and 9 m/s. In the study, we disregarded the resistance created by the wind velocity sensor. The interpolation method for drawing Isovelocity lines is the inverse distance weighted .

*2.5. Installation of Isatis SUSTRA in the desert*

The traps were installed in 4 altitudes in the wind erosion measuring station in the county of Meybod in Yazd province and were tested during the year 2006 (figure 2). In this testing phase, the traps were installed in the SW-NE axis, where most erosional winds are experienced, in 4 altitudes of 0-25, 25-50, 50-75 and 75-100 cm.

## 3. Results

*3.1. Collection efficiency of Isatis SUSTRA*

Collection efficiency of Isatis SUSTRA was calculated in three wind velocities and in order to do that we designed another trap which was smaller is all dimensions. The results are presented in figure 5. Collection efficiency of the trap with wind velocity of 5 m/s is 55%-70%, with wind velocity of 7 m/s is 63%-82% and with the wind velocity of 9 m/s 78%-88%. The wind velocity was measured at the height of 15 cm in wind tunnel and it is possible to measure it in different heights.

*3.2. Analyzing Isovelocity lines in the periphery of the trap*

As you can see in figure 6 Isatis SUSTRA affects the draft lines. This effect has the minimum decrease in the mouth of the trap and the maximum decrease in the left and right sides. The minimum velocity was 2.5 m/s occurred in the bottom of the trap. The wind velocity in the trap's mouth was 4.2 m/s.

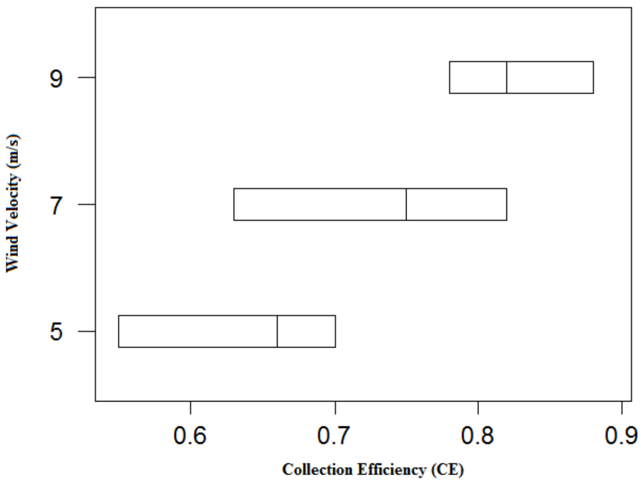


Fig. 5. Range of collection efficiency in different wind velocity at height 15cm above surface

This can justify the collection efficiency of 70% at the velocity of 5 m/s. Figure 6 indicates the velocity of 5 m/s and the changes of isovelocity lines for higher velocities (7 & 9 m/s) are not presented.

*3.3. Diametric distribution of loess particles in Isatis SUSTRA*

One of the unique capacities of Isatis SUSTRA is to be able to measure aeolian sediments transferred from different geographical directions. Through this trap it would be possible to compare physical and chemical properties of the sediments transferred from different geographical directions. This can be helpful in the study of particle's origin as well as measuring windy and plain regions of the domain. The trap had been installed for one year in the field conditions (station 1, Meybod) and the collected sediment samples were analyzed.

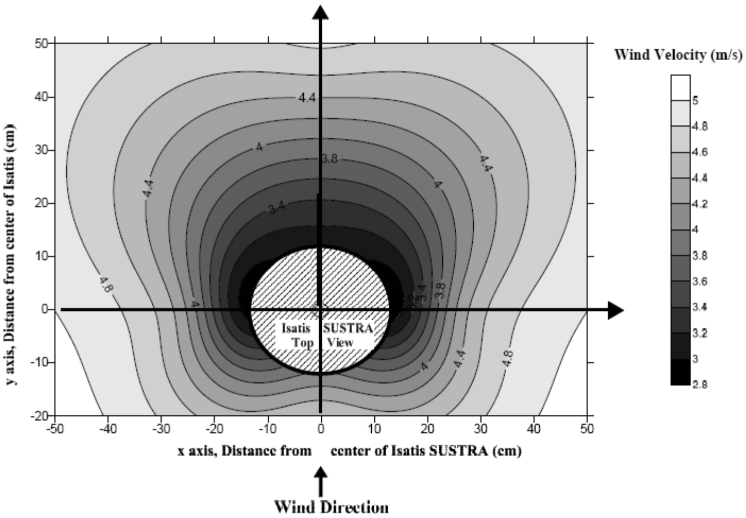


Fig. 6. Top view of isovelocity lines in the periphery of the Isatis SUSTRA. Origin of coordinate system match to center of dust sampler

Aeolian particles have different diametric distributions in different geographical directions. The difference in gradation is shown in Figure 7. As indicated in this figure, although all directions have almost homogenous distribution but it is more homogenous in NW direction. In order to have a better understanding of the differences among collected sediments we used the indices of geometric average of particle's diameter and geometric standard deviation.

Figure 8 & 9 show that geometric standard deviation of the aeolian particles changes between 2 to 2.5 in different geographical directions that indicates by itself the homogeneity of sediment particles. The geometric average of particle's diameter is maximum in S and SE that proves the wind erosivity from these directions, trapped bigger particles. Drawing Geometric Mean Diameter rose is another privilege of the trap.

3.4. The relative amount of collected sediment in the Isatis SUSTRA

The relationship between displacement of aeolian particles in different geographical directions and the relative displaced amount is an almost recent issue that has been presented under the notion of Sand Rose (Ekhtesasi et al., 2005) Isatis SUSTRA makes it possible to practically measure aeolian particles displacement in the field. The results from measurement are close to the calculation of Sand Rose and indicate the final sand carrying direction changes from SW-S to NE-N. The angle of sand movement with regard to geographical N was about 77˚ clockwise (Ekhtesasi et al., 2005), shown in Figure 10.

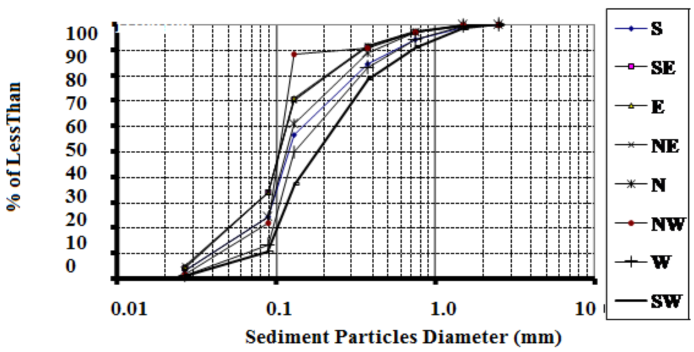


Fig. 7. Sediment particles diameter distribution in different geographical directions

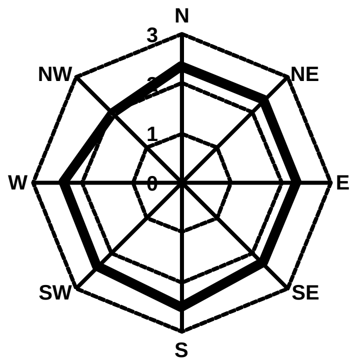


Fig. 8. Standard Deviation of Sediment Particles in Different geographical Direction

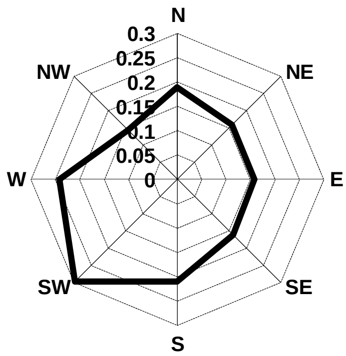


Fig. 9. Geometric Diameter of Sediment Particles in Different geographical Direction

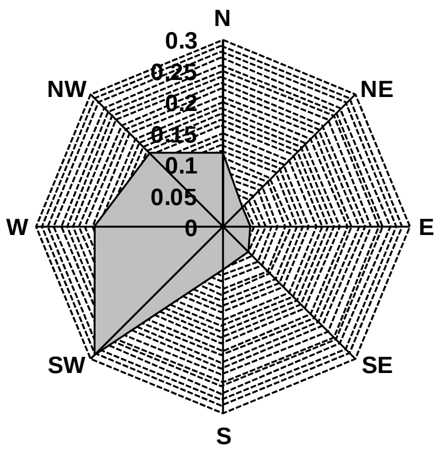


Fig. 10. The relative amount of collected sediment in the Isatis SUSTRA

## 4. Discussion and Conclusion

Different sediment traps have so far been introduced to measure aeolian particles each with its own advantages and disadvantages. Sediment traps are usually passive and collect aeolian deposit without having an energy source. In this section we try to compare shortcomings and capacities of Isatis SUSTRA with other traps. The areas that make the differences between Isatis SUSTRA and other traps are the following:
Being isokinetic means that the trap has a minor effect on Isovelocity lines. Not all the present traps are isokinetic. The only isokinetic trap is SARTORIUS due to sucking air by the same velocity with the wind at the periphery of the trap and small mouth of the trap. Analyzing Isovelocity lines at the vicinity of the trap suggests that the trap affects the Isovelocity lines in such a way that in the rear and some parts in the periphery of the trap the velocity decreases by 50% while the wind velocity near the mouth of the trap is 85% of the original wind velocity. This is considered as one of the disadvantages of the trap. Reduction of the velocity at the mouth of the Isatis traps prevents some sediments from entering the trap.

The 55%-70% collection efficiency of the trap in the velocity of 5 m/s indicates this point. This reduction leads to reduction of sediment collection efficiency. In this condition the particles fall before getting to the trap’s mouth. With the increase of wind velocity we experienced less velocity reduction around the mouth of the trap. Collection efficiency at the velocity of 5 m/s in MWAC, BSNE, WDFG and SUSTRA traps comparing with SARTORIUS were 0.9, 0.41, 0.22 and 0.17 (Goossens and Offer, 2000) so it is possible to have a relative comparison of Isatis trap with other traps. It means that, the collection efficiency of MWAC, BSNE, WDFG and SUSTRA traps are equal to 90, 41, 22 and 17 in percentage, respectively. Isatis SUSTRA collection efficiency was measured at about 55-70% in velocity 5 m/s. it is considerable in compare to above mentioned samplers.

Isatis SUSTRA can trap the sediments without consuming energy, in the other words it is a passive trap. So in this regard it looks like MWAC, BSNE, WDFG, and SUSRTA and is different from SARTORIUS. The other capacity of Isatis trap is the capability to be installed in different altitudes, the points that this trap has in common with BSNE, MWAC, WDFG and SURTORIUS.

Isatis trap can be designed with different storage capacities to collect sediment particles from different geographical directions and store them long enough for the stormy months that stations are not available.

Downloading the trap in a short time through the hole at the bottom of the every 8 sectors is easily possible by means of a brush. In additions, this trap has the unique capability of segregating the sediments entering from different directions. So it is possible to measure the balance sheet of nutritious elements, salts, different combinations and probably pollutions from different directions. Drawing Sand Rose curves for each of the materials or measurable combinations in sediment samples makes it possible to analyze the balance sheet and displacement of different materials in windy arenas.

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