A laboratory desert dust generator using vibration on a soil sample: mineralogical and compositional study

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Abstract

A laboratory study was carried out using a vibrating system (SyGAVib) to produce particles from four soils collected in the central Tunisian region around Sfax. The aim of this device is to mimic dust emission by natural wind erosion. Using compositional analysis, the dust produced was compared to: dust generated in a wind tunnel by the same soils, fine sieved and original bulk soils, and naturally occurring aerosol samples collected in the same area. The relative quartz content strongly decreases from bulk to fine soils, and again from fine soils to both wind tunnel and vibration generated aerosols. Compositional data analysis (CoDA) clearly shows: a silica dilution effect in bulk soils, and that if silica is removed from the composition, the elemental compositions of fine soils and generated aerosols are similar but differ from bulk soils. Both aerosol generation methods produce material with chemical compositions that are also close to those measured in field-sampled aerosols, and the fine soil composition is much closer to that of field and laboratory aerosols than to the parent soil. Aerosols generated from soils in the laboratory, either using a vibrating system or a wind tunnel, can be used as surrogates of the particles collected directly in the field.

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Key Points:

- aerosol generation
- compositional analyses

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Abstract

A laboratory study was carried out using a vibrating system (SyGAVib) to produce particles from four soils collected in the central Tunisian region around Sfax. The aim of this device is to mimic dust emission by natural wind erosion. Using compositional analysis, the dust produced was compared to: *(i)* dust generated in a wind tunnel by the same soils, *(ii)* fine sieved and *(iii)* original bulk soils, and *(iv)* naturally occurring aerosol samples collected in the same area. The relative quartz content strongly decreases from bulk to fine soils, and again from fine soils to both wind tunnel and vibration generated aerosols. Compositional data analysis (CoDA) clearly shows: *(i)* a silica dilution effect in bulk soils, and *(ii)* that if silica is removed from the composition, the elemental compositions of fine soils and generated aerosols are similar but differ from bulk soils. Both aerosol generation methods produce material with chemical compositions that are also close to those measured in field-sampled aerosols, and the fine soil composition is much closer to that of field and laboratory aerosols than to the parent soil. Aerosols generated from soils in the laboratory, either using a vibrating system or a wind tunnel, can be used as surrogates of the particles collected directly in the field.

Plain Language Summary

A laboratory study was carried out using a vibrating system (SyGAVib) to produce particles from four soils collected in the central Tunisian region around Sfax. The aim of this device is to mimic dust emission by natural wind erosion. The chemical composition of the dust produced was compared to another dust generator (a wind tunnel), fine sieved soil, original bulk soils, and finally naturally occurring dust found in the same area. Both dust generators produce similar samples which look very different from bulk soils.

1 Introduction

Mineral dust is extensively studied because its emission due to wind erosion in arid and semi-arid regions of the Globe accounts for approximately 30 to 50% of the total aerosol injections in the troposphere (Andreae, 1995). Mineral dust emission by wind erosion can be driven by direct aerodynamic resuspension (Kjelgaard et al., 2004), saltation bombardment and aggregate disintegration (Gomes et al., 1990). Only the finest particles can remain in suspension in the atmosphere and be transported over thousands of kilometres from their emission areas (Arimoto, 2001). Consequently, the chemical composition of transported soil-derived dust is related to the fine fraction of soil particles and the use of the bulk source soil chemical composition as a surrogate for the dust chemical composition may result in systematic biases.

Natural dust emission from a given source is strongly dependent on local meteorological conditions and is difficult or even impossible to isolate from advection coming from elsewhere. Artificial dust production in the field or laboratory is an alternative way to study the source of the soil dust. Gillette (1978) investigated dust emission by wind erosion using a straight-line wind tunnel laid on the ground and Alfaro & Gomes (1995) brought soil into a wind tunnel mounted in their laboratory. Although the wind tunnel directly simulates the natural wind erosion process under controlled wind conditions, it is difficult to use due to the large amount of soil that needs to be brought back to the laboratory. To work at a laboratory bench scale, Lafon et al. (2014) generated desert dust by shaking soil samples in an Erlenmeyer flask, Engelbrecht et al. (2016) blown fine soil in a closed cabinet, Salam et al. (2006) generated aerosol by vibrating soil samples using a loudspeaker to study the ice nucleation efficiency and Mendez et al. (2013) used a rotating drum. For further details regarding previous experiments see the extensive review on aerosol generation published by Gill et al. (2006). Note that some authors simply used fine sieved soils as dust analogues (Guieu et al., 2014).

Table 1. Soil characteristics using the WRB classification derived from dry sieving with a stainless steel system. El Attaya and El Hsar are located on Kerkennah Island. The finest fraction contains aggregated silt and clay particles.

Soil name	El Attaya	El Hsar	Cherarda	Ghraïba
Location (WG84)	34°44'N 11°18'E	34°42'N 11°09'E	35°22'N 10°10'E	34°24'N 10°18'E
Nature	oolitic limestone	continental silt	limestone bed	alluvium and wind sand
Soil Fraction				
Coarse and medium sand (> 200 µm)	30.0%	44.2%	35.9%	69.1%
Fine and ultra-fine sand (between 63 and 200 µm)	61.5%	48.2%	59.9%	29.0%
Silt and clays (< 63 µm)	8.5%	7.6%	4.2%	1.9%

Here, a new soil-derived dust generator has been developed. It is based on controlled vibration waves and requires a very small amount of bulk soil. The aim of this paper is to chemically compare the material produced by this new device with aerosols generated by the wind tunnel, fine mesh sieved soil and original bulk soil. Chemical changes are evaluated using compositional analyses, a set of statistical tools especially designed for handling chemical compositions in a clear and concise manner (Pasquet et al., 2016; Monna et al., 2017).

2 Experimental, Materials and Methods

2.1 soil sampling

In order to generate aerosols in the laboratory, four different surface bulk soil samples of approximately 10 kg each were collected in the Sfax region, Tunisia (see Table 1 for the sampling locations and physical properties). They were first coarse sieved (2 mm). Approximately 100 g of all collected soils were dry sieved with a stainless steel system to determine their texture (Table 1, supporting information Table S1). A fraction smaller than 56 µm was also sieved on a nylon mesh for further comparison with generated aerosols.

2.2 Aerosol generation

Approximately 0.3 g of soil was placed into an open-top ≈20 mL polyethylene cup that was fixed on top of a loudspeaker (Figure 1). Vibrations from the loudspeaker (sine-wave frequency = 100 Hz) levitated the soil particles, while collisions broke up the largest aggregates, favouring the emission of fine particles. The dust generation cup was placed at the bottom centre of an upright stainless steel cylinder measuring 125 mm in diameter. Two air inlets were positioned at the bottom of the tube; a third air inlet directed toward the top centre of the soil container created a local turbulence, which improved the extraction of the particles. An external pump and an optical particle counter, with flow rates of 5.5 $\mathrm{L\,min^{-1}}$ and 2.8 $\mathrm{L\,min^{-1}}$ respectively, were connected to the top of the cylinder to maintain a constant upwards air flow within the system. The total ascending flow rate was approximately 8 $\mathrm{L\,min^{-1}}$, providing a vertical air velocity of ≈1.1 $\mathrm{cm\,s^{-1}}$. According to Stoke's steady state equations, and assuming spherical particles with a density of 2.2 $\mathrm{g\,cm^{-3}}$, only particles smaller than ≈10 µm were carried up to the top of the cylinder. Particles were collected during 40 min on a polycarbonate membrane filter (32 mm

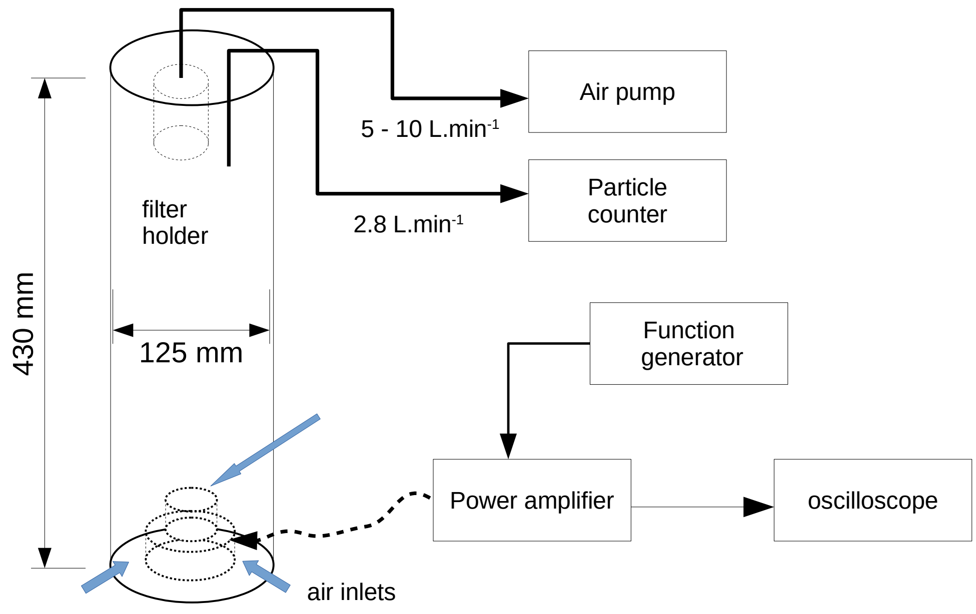


Figure 1. Diagram of the SyGAVib system

in diameter, and with a pore size of 0.4 µm). The whole system was placed in a vertical laminar flow hood to prevent any external contamination.

The laboratory wind tunnel generator is extensively described in Alfaro & Gomes (1995) and Alfaro et al. (1997). In practice, approximately two kilograms of soil were placed at the bottom of the wind tunnel (30x30x400 cm^3), and an air flow of approximately 5 $m\,s^{-1}$ was applied to generate aerosols for several minutes (2 to 15 depending on the generated dust concentration), This simulated wind speed induces a friction velocity large enough to produce saltation and simulates wind erosion with a process occurring under natural conditions. The generated aerosol was pumped at mid-height (10 cm) through a 30 µm cut-off diameter decanter, as described in Alfaro (2008), and deposited on similar polycarbonate filter membrane as that used for the SyGAVib experiments.

For each soil origin, aerosol generation was replicated 5–6 times by the wind tunnel device and 3–5 times by the SyGAVib device. At least one replicate was loaded to the maximum dust amount for mineralogical determinations by X–Ray diffraction (XRD), while the other filters were adequately loaded for further elemental analysis using X–Ray fluorescence spectrometry (XRF).

2.3 Soil and aerosol analyses

Chemical analyses were performed on the bulk soil and fine soil (BS and FS respectively) using energy dispersive X–ray Fluorescence spectrometry (EDXRF, Epsilon, PANalytical). Aerosol filters obtained with the wind tunnel (WT) and the SyGAVib (Syg) system were analysed directly on the membrane filter in thin layer conditions for aerosols (Losno et al., 1987). Soil samples were first finely ground in a tungsten carbide ball mill and 5 g of the fine powder was transformed into a pressed pellet with an addition of 0.9 g of wax for the EDXRF analyses. Soil pellets were then analysed as infinite thickness layers using the Ominan® software, which deconvolves spectra from the background and from the line overlaps, and empirically corrects matrix effects. A detection limit of a few $\mu g\,g^{-1}$ is obtained for most elements. The initial calibration was established using 13 certified reference materials from SARM (Nancy): Anorthosite AN–G, Basalt BE–N, Basalt BR, Bauxite BX–N, Diorite DR–N, Disthene (Kyanite) DT–N, Granite AC–E, Granite GA, Granite GS–N, Granite MA–N, Phlogopite Mica–Mg, Potash Feldspar FK–N, and Serpentine UB–N.

Structural analyses were performed by XRD using an EMPYREAN (PANalytical) diffractometer equipped with a copper anode and a multichannel PIXCEL® detector. Crystalline mineral identification and quantification were obtained for the bulk and fine soils, as well as generated aerosols (by both the wind tunnel and SyGAVib devices) using the Highscore Plus 3.0 software and ICSD database (Inorganic Crystal Structure Database). The MAUD program (Material Analysis Using Diffraction) is a general diffraction program mainly based on the Rietveld method (Lutterotti et al., 1999) and is specifically used for the quantitative phase analysis in this work.

The aerosol size distribution was obtained using a MetOne 237B 6 channels (0.3, 0.5, 0.7, 1 and 5 µm) laser particle counter.

2.4 Statistical compositional analysis

Data processing was performed using the free R software (R Core Team, 2018), specifically with the "compositions" package (K. van den Boogaart et al., 2014) which provides a set of functions especially designed to process compositional data.

3 Results and discussion

3.1 Structure and crystalline mineralogy

Sand exceeds 91% of the total mass for all soils (Table 1); as a result, the soil samples are classed as sandy according to the common soil classification (Baize, 2000). Soil from Ghraiba is the sandiest (98%) and the least silty, whereas that from Kerkennah is the siltiest, with ≈8% of silt and clay. Different types of aggregates are generally observed in dry soils from arid and semi-arid regions. These aggregates are either almost exclusively composed of very small individual particles (Alfaro et al., 1997), or of a 'core' (most often a quartz grain) to which some small clay plates, or assemblages of plates, adhere (Rajot et al., 2003; Engelbrecht et al., 2009, 2016).

Figure 2 shows an example of the four diffractograms obtained for the Ghraiba soils and derived child samples. A strong decrease in the relative intensity of the quartz diffraction peaks is observed from bulk soil to generated aerosols, with a simultaneous increase in the peaks for clay and calcite, which are the major mineral crystalline phases. This quartz depletion from soil to dust was already observed by Caquineau (2002) on transported airborne Saharan dust samples collected at Cape Verde, Barbados and Miami, and also by Engelbrecht et al. (2009) for resuspended aerosols from the middle east. Sieving the bulk soil also decreases the relative quartz content, but to a lesser extent. Regardless of which device was used (SyGAVib or wind tunnel), the diffractograms for the generated aerosol samples are similar in terms of their pattern as well as their semi-quantitative results (Figure 3), indicating a comparable mineralogical composition.

3.2 Aerosol size distribution

The size distribution, expressed as the number of particles, of the material produced by the SyGAVib device is consistent all throughout the experiments; this is apparently not the case with the wind tunnel experiments as the first replicate is notably enriched in the finest particles (0.3–0.5 µm channel in Figure 4). Given that this finest fraction only accounts for less than 1% of the total aerosol mass, this should have little influence on the overall composition of the collected aerosol, at least on the major and minor el-

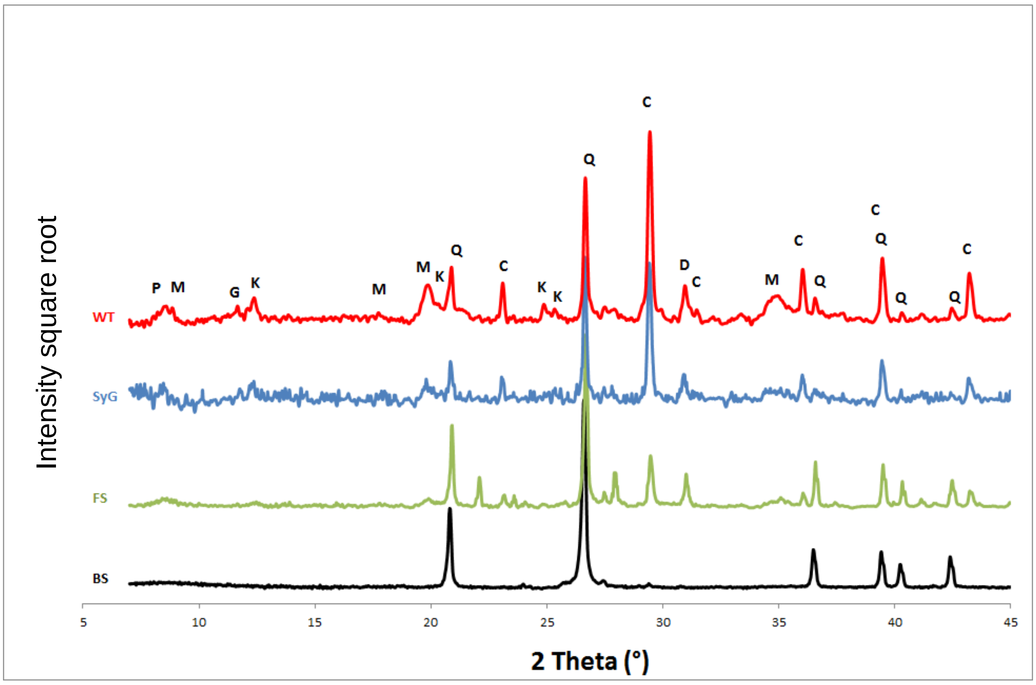


Figure 2. Diffractograms of the aerosols generated by the SyGAVib system and the wind tunnel from the Ghraiba soil. Each diffractogram intensity was rescaled to obtain the same average height on a square root scale. Q: quartz, D: dolomite, C: calcite, M: muscovite, K: kaolinite, P: palygorskite, G: gypsum. The diffractograms and semi-quantitative mineralogical composition of the other soils are provided in the supporting information (Figure S1 and Table S2).

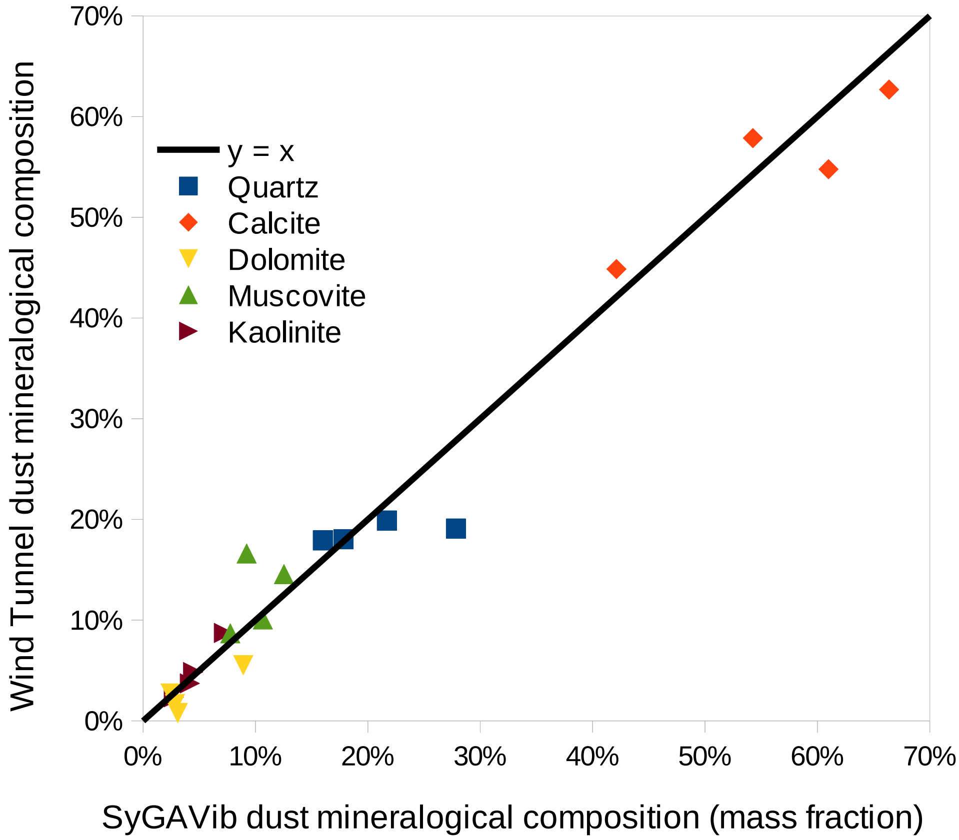


Figure 3. Comparison of the semi–quantitative analyses of the major minerals in wind tunnel experiments (WT, y axis) versus Sygavib experiments (Syg, x axis) for the four parent soils aerosol samples. The line y = x have been drawn.

Table 2. Chemical composition of soils and aerosols expressed as oxides. The abbreviations Syg, WT, FS and BS stand for SyGAVib, wind tunnel, Fine Soil and Bulk Soil, respectively. The Syg and WT aerosol samples correspond to the average of the replicates.

	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2OO	Na_2O	TiO_2	SrO	MnO	SO_3
Attaya_BS	13%	78%	2.7%	1.4%	1.2%	1.1%	0.7%	0.29%	0.08%	0.014%	0.35%
Attaya_FS	28%	45%	9.3%	5.0%	3.7%	2.3%	1.5%	0.90%	0.14%	0.052%	2.1%
Attaya_Syg	34%	32%	8.8%	5.1%	3.7%	2.9%	2.0%	0.68%	0.19%	0.063%	7.5%
Attaya_WT	36%	29%	8.1%	5.7%	3.2%	2.9%	1.9%	0.73%	0.20%	0.070%	7.9%
Cherrarda_BS	3.0%	89%	4.0%	1.4%	0.7%	1.1%	0.06%	0.24%	0.009%	0.009%	0.04%
Cherrarda_FS	18%	59%	11%	5.1%	2.3%	2.3%	0.22%	0.96%	0.045%	0.048%	0.18%
Cherrarda_Syg	31%	43%	13%	6.0%	2.7%	2.5%	0.18%	0.83%	0.050%	0.072%	0.35%
Cherrarda_WT	33%	39%	12%	7.6%	3.0%	3.0%	0.16%	0.96%	0.068%	0.091%	0.48%
Ghraiba_BS	0.7%	96%	1.9%	0.4%	0.41%	0.5%	0.05%	0.11%	0.004%	0.0039%	0.15%
Ghraiba_FS	18%	60%	8.8%	4.5%	3.0%	2.2%	0.39%	1.15%	0.053%	0.045%	0.71%
Ghraiba_Syg	22%	49%	14%	5.1%	3.4%	2.7%	0.36%	0.91%	0.063%	0.079%	1.7%
Ghraiba_WT	18%	47%	15%	6.1%	4.3%	2.9%	0.37%	0.91%	0.061%	0.091%	3.1%
Hsar_BS	9.5%	84%	2.9%	1.5%	0.84%	0.7%	0.07%	0.19%	0.037%	0.008%	<0.1%
Hsar_FS	31%	49%	8.9%	4.6%	3.0%	2.0%	0.25%	0.89%	0.079%	0.035%	0.29%
Hsar_Syg	42%	36%	9.9%	4.2%	3.6%	2.2%	0.23%	0.58%	0.11%	0.053%	0.67%
Hsar_WT	46%	31%	8.4%	6.0%	3.0%	2.7%	0.28%	0.75%	0.14%	0.071%	0.76%

ements or phases. Both aerosol generation methods present a maximum number of particles within the 2–5 µm fraction, but particles tend to be larger when they are produced by the wind tunnel compared with SyGAVib (Figure 4).

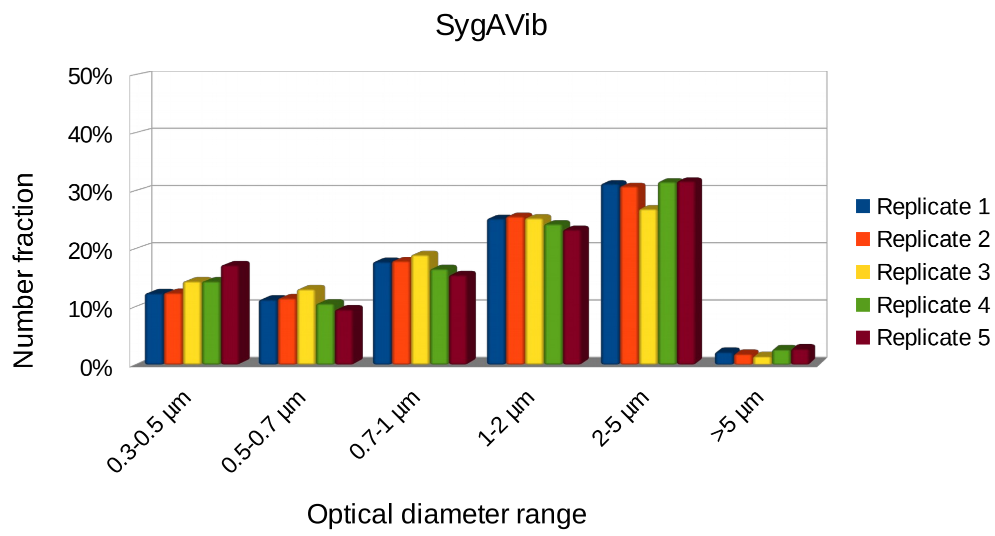
3.3 Chemical composition

The elemental compositions expressed as oxides: SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, TiO_2, SrO, MnO and SO_3, were measured and averaged for all sample types (Table 2, and the measurement dispersion is reported in Table S3 in the supporting information).

The elemental ratios of the generated aerosols and fine soils over their corresponding bulk soils were calculated for each soil sample (see Figure 5 for the Cherrarda samples, and Figure S2 in the supporting information for the other soils). SiO_2 appears to be systematically depleted in all treatments that include sieving and generated aerosols, while all the other elements are enriched (their ratios are much higher than one), as already pointed out in previous studies (Acosta et al., 2009; Schütz & Rahn, 1982). This is particularly obvious in the Ghraiba samples, which exhibited the highest silica content. This behaviour can easily be explained by a more or less pronounced diluting effect of SiO_2.

This is fully coherent with the larger amount of quartz crystals already identified via XRD analysis in bulk soils, and with the mineralogical changes observed after aerosol generation. As additional proof, when the elemental composition ratios were calculated without SiO_2 (considering the sum of all remaining elements as being equal to 100%), all elemental composition ratios tended toward unity (Figure 6). Although the influence of SiO_2 is clear enough to be interpreted in a straightforward manner, it is more difficult to evaluate the extent to which the elemental composition has been modified by sieving or by aerosol generation, and to compare the results obtained between them after treatment.

It is possible to explore the structuration inside a compositional dataset using a compositional biplot. This representation expresses the relative variation of a multivariate dataset by projection onto a plane (J. Aitchison & Greenacre, 2002). Similarly to the classic biplot of Gabriel (1971), it allows samples and variables to be depicted together. It is worth mentioning, however, that centred log-ratio (clr) transformed data



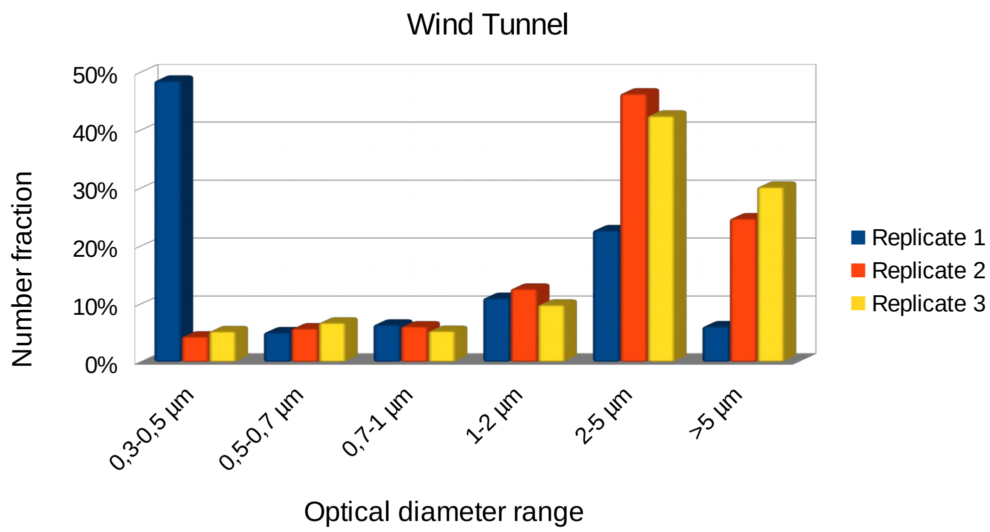


Figure 4. Size distributions (in terms of particles number) of the replicates of the dust generated by the SyGAVib system (n=5, 40 min each) and wind tunnel (n=3, 3 min each) averaged for the total duration of each replicate for the Cherarda soil SyGAVib,and WT experiments).

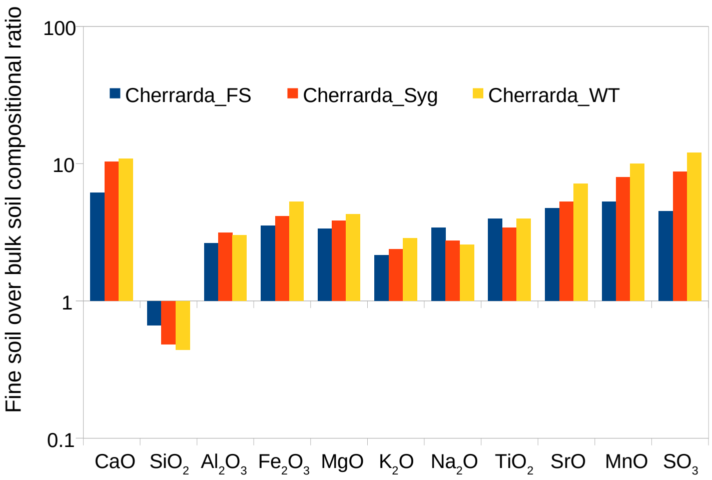


Figure 5. Compositional ratios of the generated aerosols and fine soil fraction over the bulk soil, with a logarithmic scale.

are used as inputs instead of raw concentrations. The rays formed by variables cannot be interpreted directly. Only links between two arrow heads (i.e., the projection of the variables) are meaningful, and approximate the standard deviations of the log-ratios of these variables. The angle cosines between the links estimate the correlations between two log-ratios (for more details see J. Aitchison & Greenacre 2002; K. G. van den Boogaart & Tolosana-Delgado 2013). A compositional biplot can therefore be used to examine elementary ratios (actually pairwise log-ratios) in the individuals, and not their level of concentrations, as observed in Gabriel's biplot. Consequently, the absolute concentration values disappear during this statistical analysis which means that all the elemental ratios remain instead. A conventional biplot representation cannot be used here because spurious correlations due to the interdependence of the components are expected in any compositional dataset (Chayes, 1960).

The compositional biplot clearly displays the distance between two samples which is used as a reliable proxy of compositional similarity in terms of the elemental log-ratios (for further more details and the additional properties of the compositional biplots, see J. Aitchison & Greenacre (2002); J. M. Aitchison (2005); K. G. van den Boogaart & Tolosana-Delgado (2013)). Given that values of zero or those below the detection limit cannot be handled in a compositional biplot, SO_3 which is too low to be measured in Hsar BS, is removed from the compositional data set. This is not an issue for compositional analyses because compositional biplots are also suitable for all sub-compositions (J. M. Aitchison, 2005).

Figure 7 is a biplot presenting the results of the compositional data analyses on all parent and child samples with a very large dispersion of the log-ratios; in the diagram, it can be observed that BS, FS, Syg and WT are well spread out along the SiO_2 axis (demarcated by a red arrow). The second main split involves log-ratios including sodium. It discriminates between the origins of the sample parent soils, but not the nature of the sample (BS, FS, WT or Syg). This type of graph presents clearer and more concise compositional variations than the bar graphs shown in Figures 5 and 6, where the dilution effect of silica can be seen but not the role of sodium. As mentioned above, the physical distance between two points is equivalent to a compositional distance. By removing the influence of silica dilution and sodium soil discrimination, the bulk soil chemical composition remains clearly different from that of fine sieved soils, or generated aerosols,

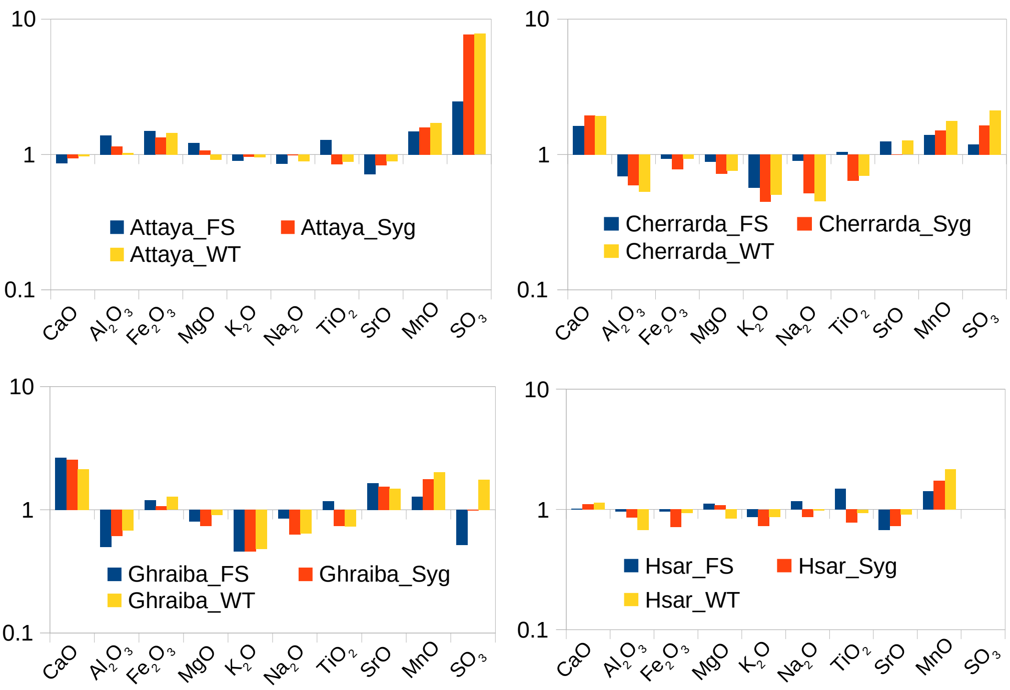


Figure 6. Compositional ratios of aerosol and fine soil over bulk soil excluding the silica contribution with a logarithmic scale.

with no clear specific contribution of one given element (Figure 8). For each parent soil, the SyGAVib, wind tunnel and fine soil generation methods are found relatively close together on the biplot diagram and thereby show similar compositions. However there were slightly more similarities between the two generated aerosols. The cut-off diameter, ranging from 56 µm for fine soil to 10 µm for aerosol generations, does not have a strong effect on the chemical composition of the resulting material, when calculated without silica or sodium. Excluding the silica and sodium contribution, the fine sieved soil fraction is therefore a good surrogate for generated aerosols for working with internal elemental ratios.

3.4 Comparisons with field sampled aerosols

Natural airborne aerosols have been collected and measured on Kerkennah Island, close to the bulk soil sampling locations, over a one year period in 2010 and 2011. Sampling was performed on a mast two meters above the roof of a three levels building in a free area using the same filtration system and the same filters (Trabelsi et al., 2016). The Na_2O, MgO and K_2O contents of these aerosols were much higher than those of the soils and derived aerosols measured in the present study, due to a large contribution of sea salt aerosols, especially in winter. To assess the soil contribution to aerosols, these three elements were not considered, and samples collected in winter were removed. A new compositional biplot including bulk and fine soils, laboratory-generated aerosols, and field-sampled aerosols was produced using CaO, SiO_2, Al_2O_3 and Fe_2O_3 (Figure 9). Field sampled aerosols were similar to both SyGAVib and wind tunnel aerosols, and quite different from bulk soils, due to the variation in the silica content, while fine soils were more similar to the aerosol samples than to the parent soils. In this case, aerosols generated

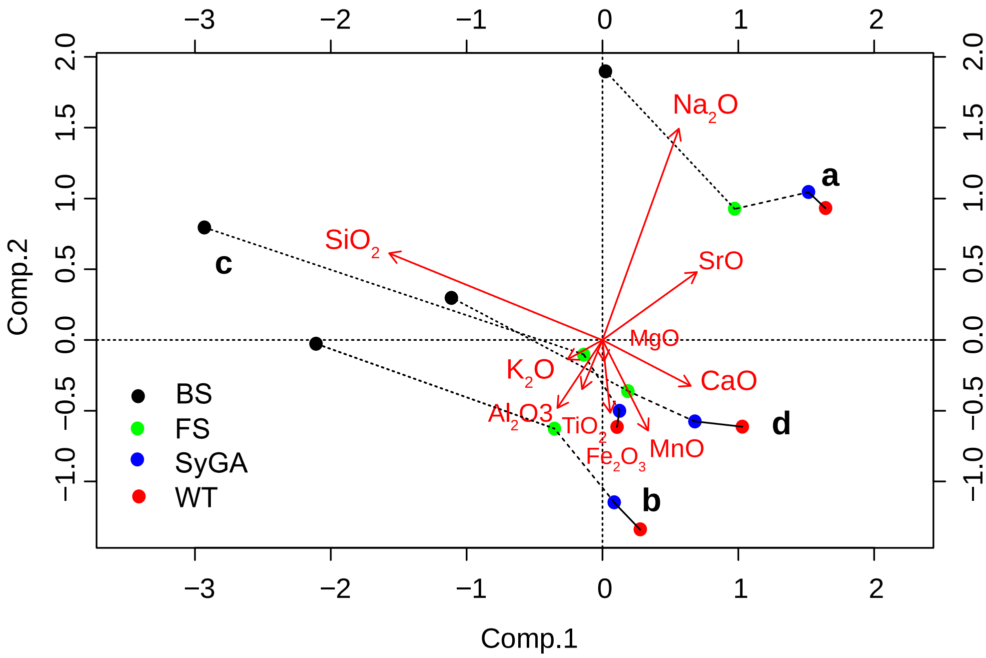


Figure 7. Biplot including bulk and fine soils, and generated aerosol. Together Component 1 and Component 2 account for 86% of the total variance (56% and 30%, respectively). **a**: Attaya, **b**: Cherrarda, **c**: Ghraiba, **d**: Hsar.The solid line links the wind tunnel and SyGAVib generated aerosol from the same soil type, the dashed line links the SyGAVib and fine soils of the same soil type.

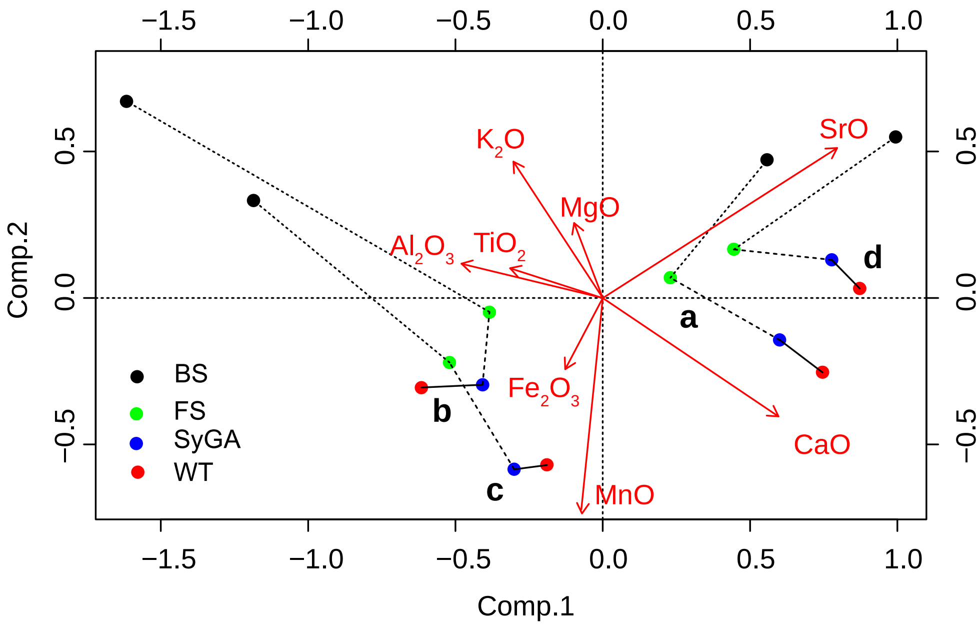


Figure 8. Biplot including bulk and fine soils, and generated aerosol excluding the silica and sodium contribution. The solid line links the wind tunnel and SyGAVib generated aerosol from the same soil type, the dashed line links the SyGAVib and fine soils of the same soil type. Together Component 1 and Component 2 account for 86% of the total variance (70% and 16%, respectively). **a**: Attaya, **b**: Cherrarda, **c**: Ghraiba, **d**: Hsar.

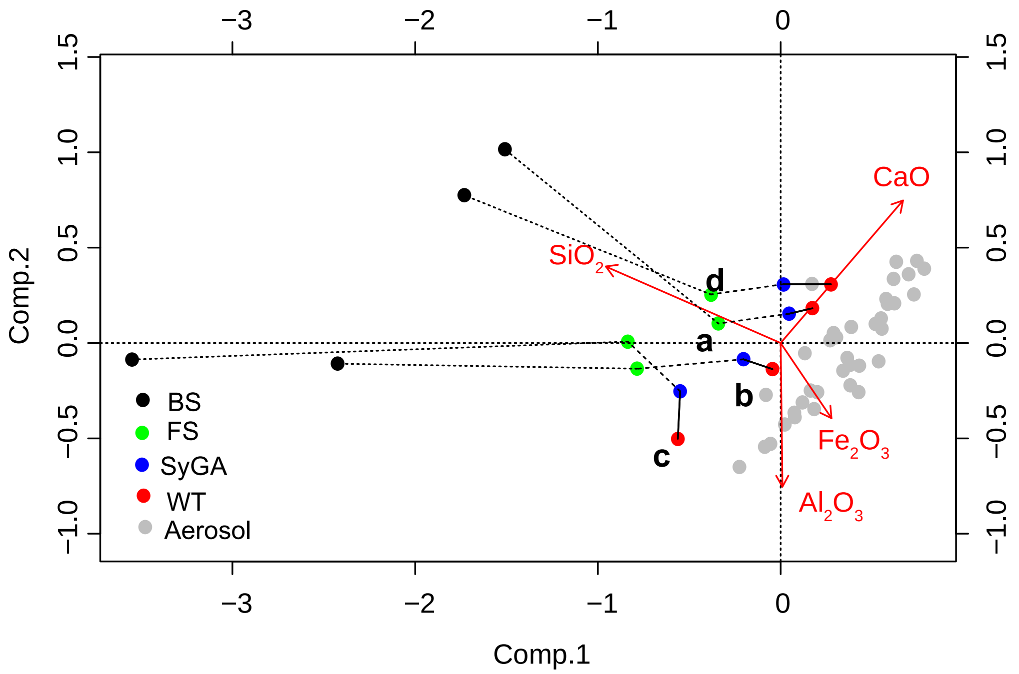


Figure 9. Compositional Principal Component Analysis biplot of the soil, laboratory generated aerosols and field aerosols except in winter. Component 1 and Component 2 account for 98% of the variance, with 84% for Component 1. **a**: Attaya, **b**: Cherrarda, **c**: Ghraiba, **d**: Hsar. Lines have the same meaning as in the Figures 7 and 8. Aerosol data are from Trabelsi et al. (2016).

by both the SyGAVib and wind tunnel device are approaching close to the airborne crustal aerosols collected in the field.

4 Conclusions

Using the new aerosol generation system by vibration (SyGAVib), it was possible to extract a fine soil fraction ($<$ 10 µm) with a chemical and mineralogical composition similar to wind-generated aerosols for a given soil. This vibration system, which is much smaller than a wind tunnel, can be installed on a laboratory bench at a low cost. This method does not require large amounts of parent soil ($\approx$ 0.5 g), it gives a high collection yield, insures a clean sample without ambient air contamination and it is easy to use. Fine sieved soil can also be used as an analogue of aerosol if silica is not to be taken into account.

Acknowledgments

The full data set used to write this paper can be found in supplementary readings and also in the AERIS database (https://doi.org/10.6096/DV/CGVYXC). We thank Sara Mullin correcting the English content and G. Brissebrat for the AERIS database. We are grateful to the anonymous reviewers whose judicious comments have improved the manuscript.

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Journal of geophysical Research (Atmosphere)

Supporting Information for

A laboratory desert dust generator from stock soil using vibration. A mineralogical and compositional study

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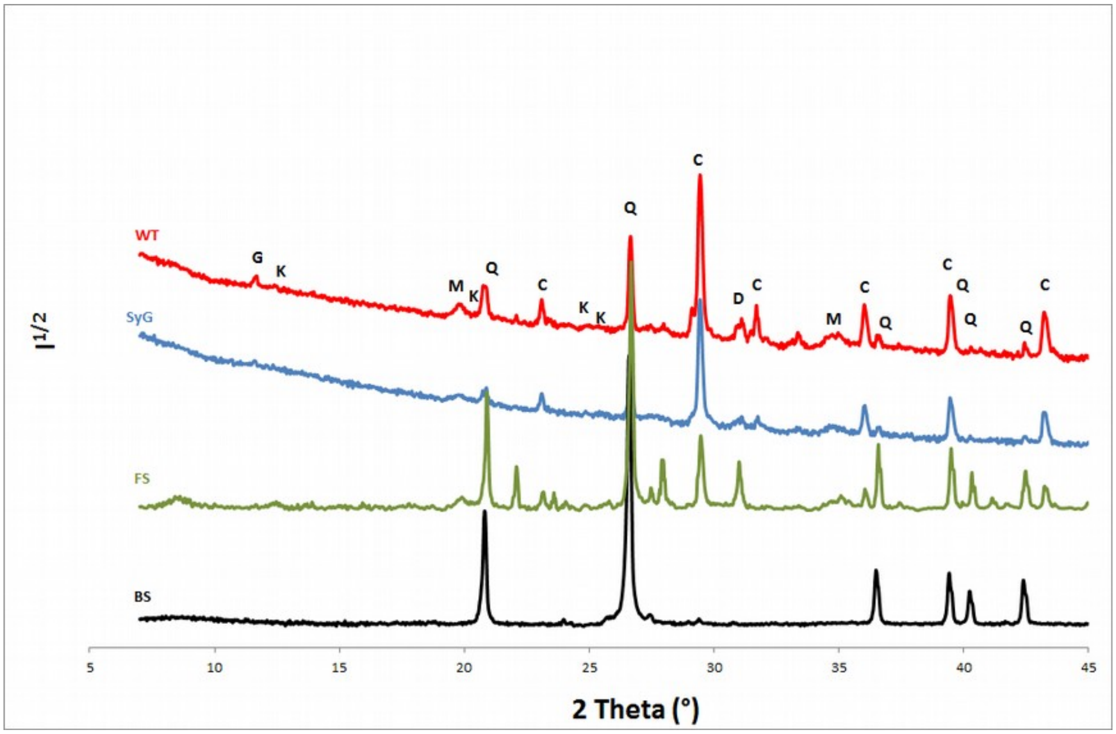
Contents of this file

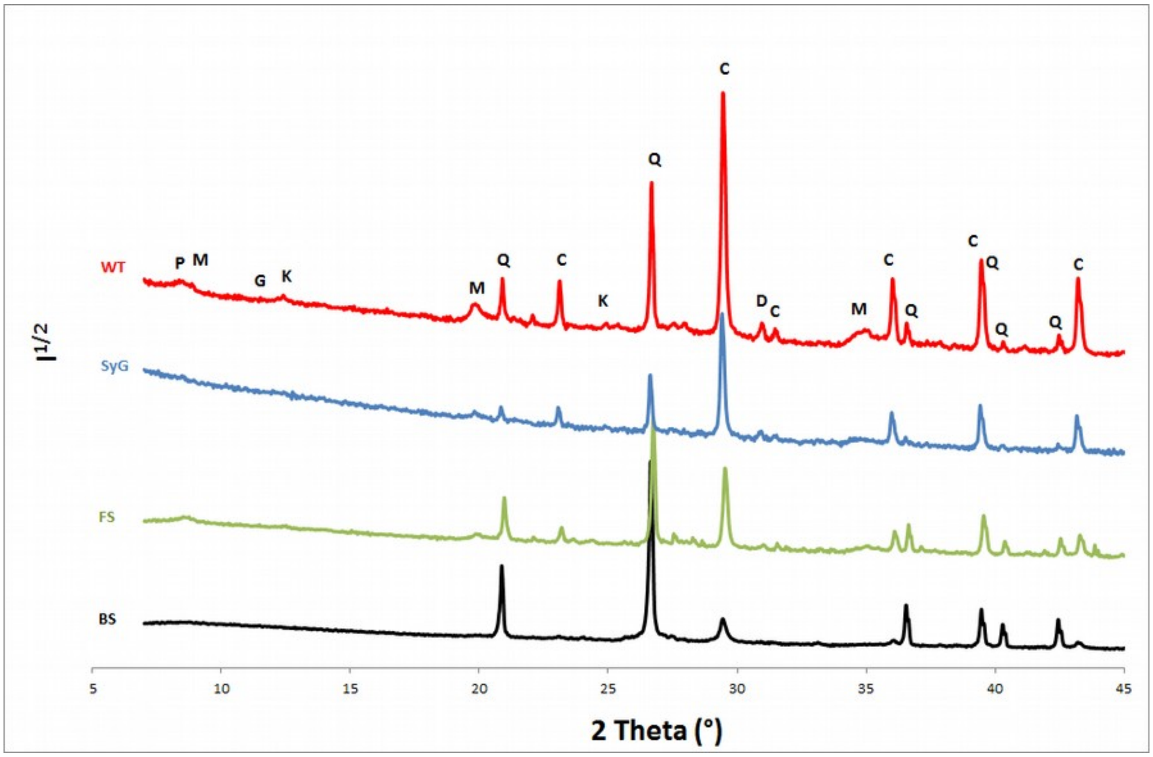
Figures S1 and S2
Tables S1, S2 and S3

Introduction

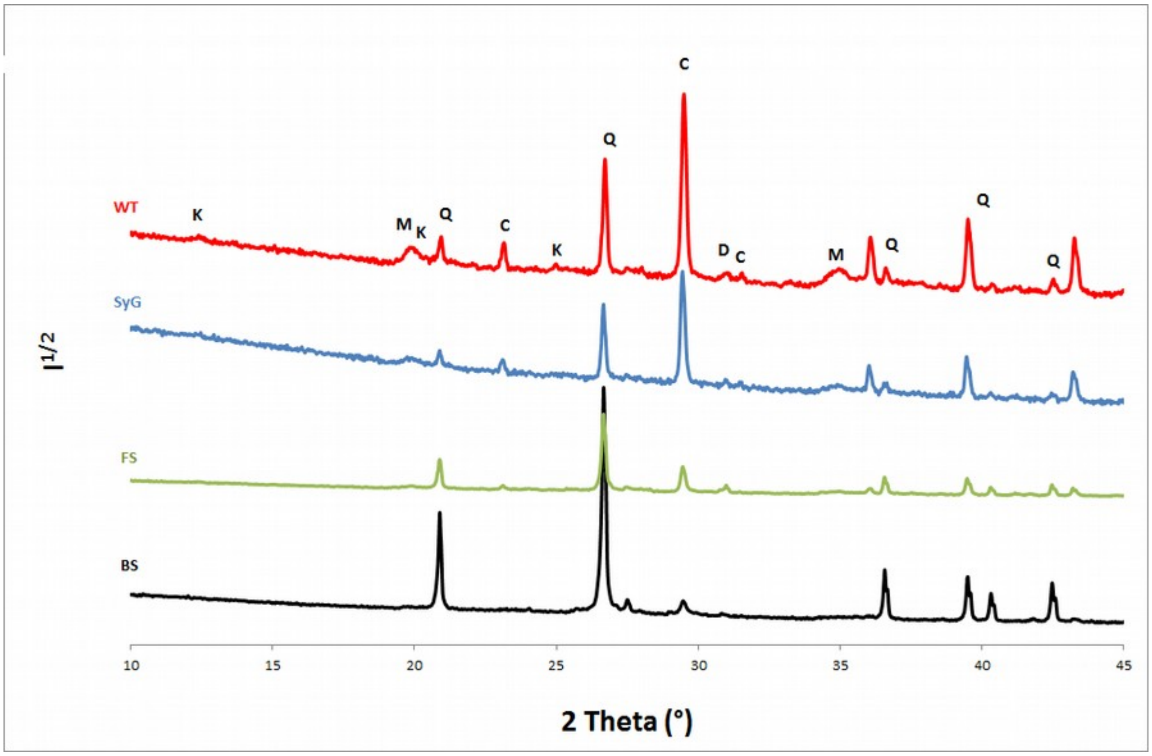
We have put in this file extra tables and figures which are not necessary to read and understand the paper but which allow to check the description of the data that is written in the text.



Q: quartz, D: Attaya:dolomite, C: calcite, M: muscovite, K: kaolinite, P: palygorskite, G: gypsum.

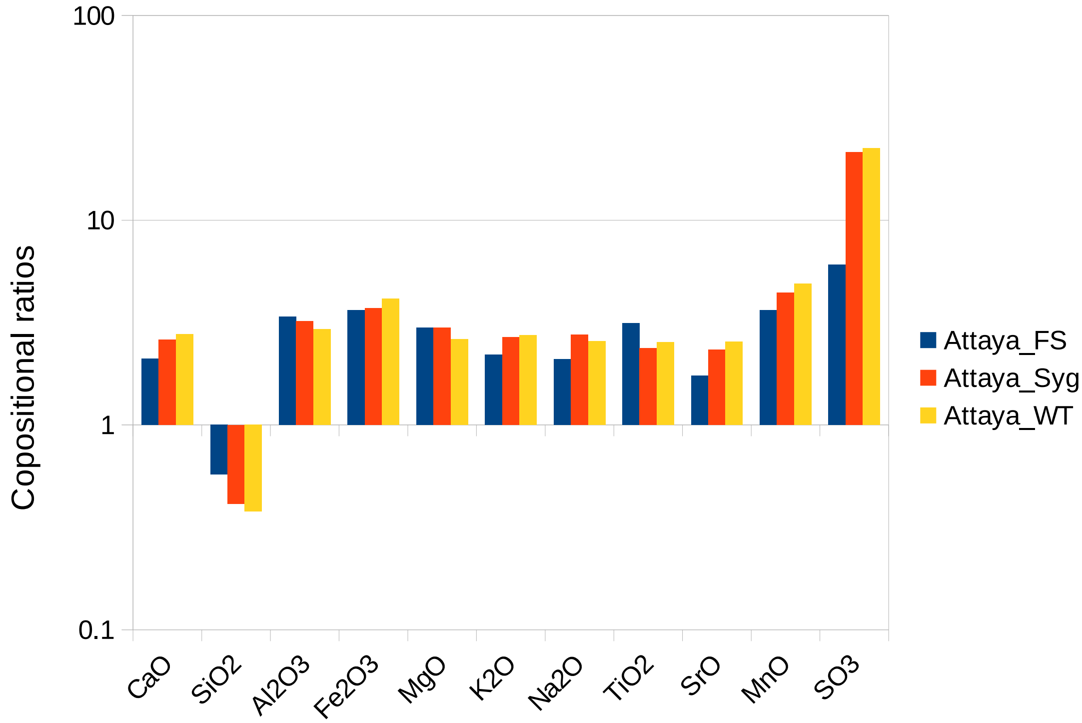


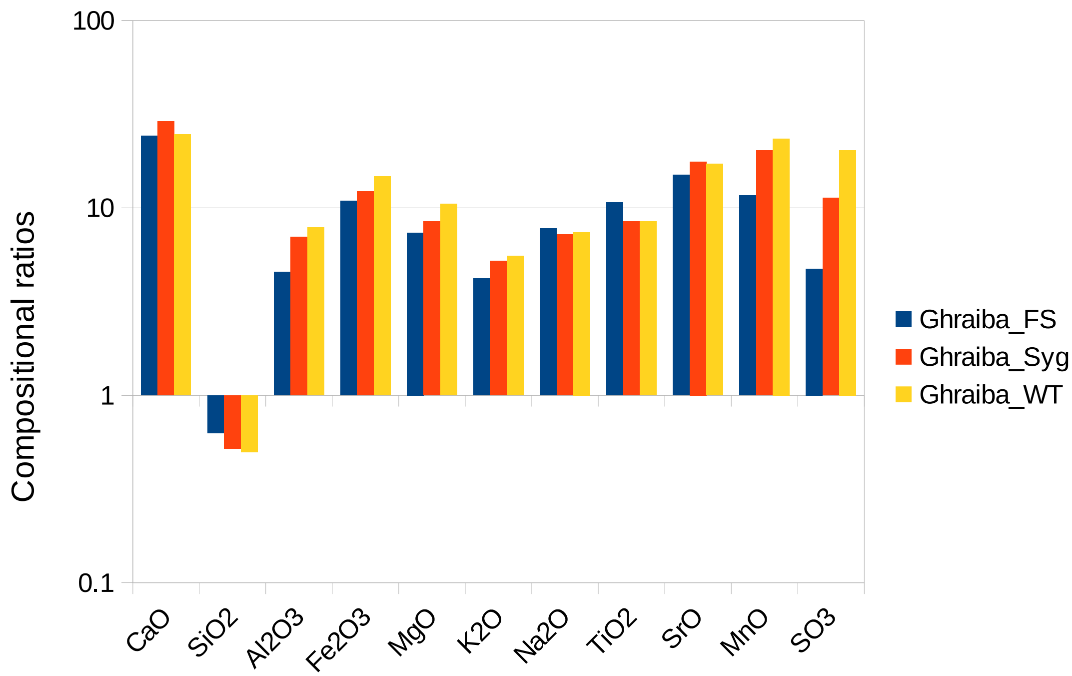
Hsar; Q: quartz, D: dolomite, C: calcite, M: muscovite, K: kaolinite, P: palygorskite, G: gypsum.



Cherrarda: Q: quartz, D: dolomite, C: calcite, M: muscovite, K: kaolinite, P: palygorskite, G: gypsum.

Figure S1. Diffractograms of all 16 samples including parent soils (BS), fine sieved soils (FS), wind tunnel aerosols (WT) and SyGaVib aerosols (SyG) grouped by soil origin. The ordinate axis exhibits a relative square root intensity scale that has been rescaled for each spectrum and a shifted origin.


100
10
1
0.1
Copositional ratios
CaO
SiO2
Al2O3
Fe2O3
MgO
K2O
Na2O
TiO2
SrO
MnO
SO3
Attaya_FS
Attaya_Syg
Attaya_WT


100
10
1
0.1
Compositional ratios
CaO
SiO2
Al2O3
Fe2O3
MgO
K2O
Na2O
TiO2
SrO
MnO
SO3
Ghraiba_FS
Ghraiba_Syg
Ghraiba_WT

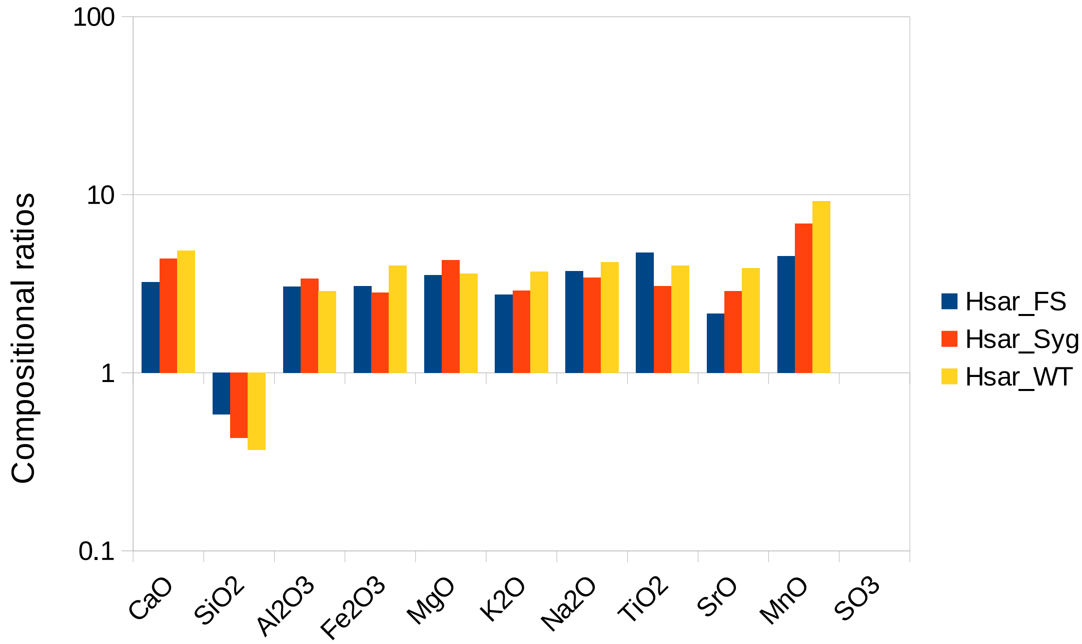


Figure S2. Compositional ratio of child samples to parent soil. and

µm sieving	Attaya	Cherarda	Ghraiba	Hsar
800 - 2000	2.0%	1.2%	2.1%	1.7%
400 - 800	7.1%	6.0%	33.6%	11.9%
315 - 400	5.0%	12.9%	10.3%	8.0%
250 - 315	9.0%	7.0%	15.5%	13.4%
200 - 250	6.9%	8.8%	7.7%	9.3%
160 - 200	18.2%	17.7%	11.9%	14.7%
100 - 160	22.2%	20.6%	9.5%	19.9%
80 - 100	12.9%	12.2%	4.5%	5.6%
63 - 80	8.3%	9.4%	3.1%	8.0%
40 - 63	5.4%	3.1%	1.5%	5.2%
0 - 40	3.1%	1.0%	0.3%	2.4%

Table S1. Size distribution of soils expressed as the mass fraction found in each sieving size.

	Quartz	Calcite	Dolomite	Microcline	Muscovite	Kaolinite	Palygorskite	Gypsum	Halite
Attaya_BS	85%	10%	0.5%	1.7%	1.6%	0.6%	0.8%	0.1%	0.5%
Attaya_FS	42%	36%	5.8%	1.4%	7.6%	2.2%	3.8%	1.0%	0.7%
Attaya_SyG	18%	61%	2.5%	0.4%	11%	2.7%	2.5%	2.0%	0.4%
Attaya_WT	18%	55%	2.7%	0.2%	10%	2.3%	2.6%	9.2%	0.0%
Cherarda_BS	92%	2%	0.2%	2.4%	1.4%	0.7%	0.6%	0.3%	0.5%
Cherarda_FS	69%	21%	5.3%	0.2%	1.2%	2.6%	0.9%	0.3%	0.2%
Cherarda_SyG	22%	54%	2.8%	1.7%	13%	4.5%	0.2%	2.0%	0.4%
Cherarda_WT	20%	58%	1.7%	0.1%	15%	4.8%	0.8%	0.1%	0.1%
Ghraiba_BS	96%	0.7%	0.2%	1.5%	0.8%	0.3%	0.7%	0.1%	0.1%
Ghraiba_FS	59%	17%	9.4%	1.9%	6.8%	2.5%	2.3%	0.2%	0.8%
Ghraiba_SyG	28%	42%	8.9%	0.2%	9.2%	7.2%	2.0%	2.2%	0.4%
Ghraiba_WT	19%	45%	5.5%	0.4%	17%	8.7%	2.1%	2.7%	0.0%
Hsar_BS	85%	10%	0.3%	1.5%	2.1%	0.1%	1.1%	0.1%	0.1%
Hsar_FS	46%	39%	2.2%	1.3%	4.3%	1.8%	4.4%	0.9%	0.7%
Hsar_SyG	16%	66%	3.1%	1.2%	7.8%	4.2%	1.2%	0.0%	0.3%
Hsar_WT	18%	63%	0.8%	1.6%	8.7%	3.7%	2.4%	2.2%	0.02%

Table S2. Relative mineralogical composition for bulk soil (_BS), fine soil (_FS) and laboratory generated aerosol using SyGAVib and the wind tunnel (_Syg and _WT respectively).

	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	Na_2O	TiO_2	SrO	MnO	SO_3
Attaya_Syg	34%	32%	9%	5.0%	3.5%	2.8%	2.3%	0.67%	0.18%	0.06%	7.5%
RSD	9%	7%	13%	16%	1%	12%	3%	17%	19%	14%	12%
Attaya_WT	36%	29%	8%	5.7%	3.2%	2.9%	1.9%	0.73%	0.20%	0.07%	7.9%
RSD	10%	13%	16%	17%	4%	13%	26%	12%	25%	16%	9%
Cherrarda_Syg	31%	43%	13%	6.0%	2.7%	2.5%	0.2%	0.83%	0.05%	0.07%	0.35%
RSD	4%	3%	3%	10%	8%	7%	28%	6%	21%	7%	18%
Cherrarda_WT	33%	39%	12%	7.6%	3.0%	3.0%	0.2%	0.96%	0.07%	0.09%	0.48%
RSD	12%	10%	14%	17%	5%	13%	32%	14%	22%	16%	17%
Ghraiba_Syg	22%	49%	14%	5.1%	3.4%	2.7%	0.4%	0.91%	0.06%	0.08%	1.7%
RSD	2%	2%	3%	3%	24%	3%	31%	5%	13%	5%	10%
Graiba_WT	18%	47%	15%	6.1%	4.3%	2.9%	0.4%	0.91%	0.06%	0.09%	3.1%
RSD	18%	6%	8%	10%	6%	10%	57%	11%	59%	7%	17%
Hsar_Syg	42%	36%	10%	4.2%	3.6%	2.2%	0.2%	0.58%	0.11%	0.05%	0.67%
RSD	1%	0.5%	1%	1%	3%	1%	31%	1%	1%	2%	2%
Hsar_WT	49%	29%	8%	6.2%	3.1%	2.9%	0.2%	0.78%	0.16%	0.07%	0.76%

Table S3: Aerosol generation repeatability. Averages and relative standard deviations (RSD%) were calculated from replicate filters of all generated aerosols corresponding to each soil. SyGAVib replicates are less variable than those performed with the wind tunnel: median RSD% = 5% for SyGAVib vs. 13% for the wind tunnel. As expected, the highest variability is observed when concentrations were close to the detection limits. Bulk and fine sieved soils were measured using pressed pellets without replication so that the uncertainty observed typically comes from the method itself: approximately 5% for all elements.