Natural Mineral Particles extraction in filters from Gran Canaria dust collectors

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Final Degree Project to obtain a Degree in Marine Sciences

Final Degree Project

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Abstract

In this study, a humid-ultrasonic method of Saharan dust particles extraction from the collecting filters was set-up. Saharan dust samples were collected in cellulose filters (Whatman 41) with high volume dust collectors installed on Tafira Baja Campus.

Two ultrasonic-humid extraction cycles were carried out. Subsequently, an image analysis (ImageJ program) was carried out, from a Leika MZ6 stereomicroscope photographs. The particle identification and parametrization (area, perimeter and circularity) were used to calculate the Saharan dust concentration, the cumulated grain size distribution curves, and the statistical parameters (mean size, sorting, skewness and kurtosis) with Gradistat V9.1 program. As study results it can say that the optimal time of cellulose filter extraction is less than 20 minutes; that the ultrasonic-humid extraction method could be consider texturally stable; that the more sample weight, the more sequential extractions could be obtained; and respect to the Saharan dust texture, the mean particle size was coarse silt, the sorting was poorly, the skewness very negative and, the kurtosis very leptokurtic. Furthermore, this extraction method for Saharan dust particles had not been studied before from this type of cellulose filters and will facilitate textural and mineralogical future studies.

Keywords:

Saharan dust; dust collectors; cellulose filters; total suspended particles (TSP), natural mineral particles (NMP), Saharan dust texture

1. Introduction and objectives

Gran Canaria is located off the west coast of North Africa, in the eastern Atlantic (Fig. 1), and geographically close to the west of the Sahara Desert (a major source of natural particles, NMP), and, as a result of its proximity, is regularly affected by Saharan dust, on average about 30% of the time each year (*Criado and Dorta, 2003*), with and average duration of 3-5 days per event. When this weather condition occurs (haze conditions) the particulate accumulation rate is higher than under non haze conditions. The annual deposition rate of Saharan dust in this region is about 15.6 g/m^2 (*Prospero 1996a, Goudie & Middleton 2001*). The mean grain size of Dust particles is about 15 µm, with about 20% of those being < 5 µm (*Menéndez et al., 2009*).

Figure 1. Geographical location of Gran Canaria and the Canary Archipelago.

The dust sources in the island of Gran Canaria can be autochthonous (particles of diverse origin generated and/or recycled within the insular area) and allochthonous (from the neighbouring African continent and transported during haze conditions).The Saharan Desert generates a wide variety of particles owing to the range of different origin (magmatic, sedimentary and metamorphic) and ages (from Precambrian to Recent) present in Northwest Africa (*Piqué 2001*). The source of the dust components was established, to be in two major areas: the Bodélé depression (Southern of Chad) and the Eastern Mauritania – Western Mali – Southern Algeria area (*Goudie and Middleton, 2001; Menéndez et al., 2007*).

The trade winds, being effective transporters of aeolian dust blow mainly from NE, ENE and NNE at an average speed of 6 m/s. These winds are more effective from June to September. In winter, however, south-westerly storms are customary, generating erosion processes on the island's southern coast and temporally changing the direction of aeolian sedimentary transport and the coastal dynamics (*Pérez-Chacón et al., 2010, 2012*).

The Saharan dust synoptic weather situation is different depending on its seasonality. In summer, high pressure at high altitude over the Sahara can lead to the deflection of Saharan dust in a hook-shaped transport pathway toward the Canary Islands (Faust et al. 2015). In contrast, in winter dust winds blow out of thermal low-level high-pressure cells located over the Western Sahara toward the Atlantic Ocean, linked with deep pressure cells at low altitudes (<2000 m) close to the Canary Islands (*Menéndez et al. 2009;* Fig. 2).

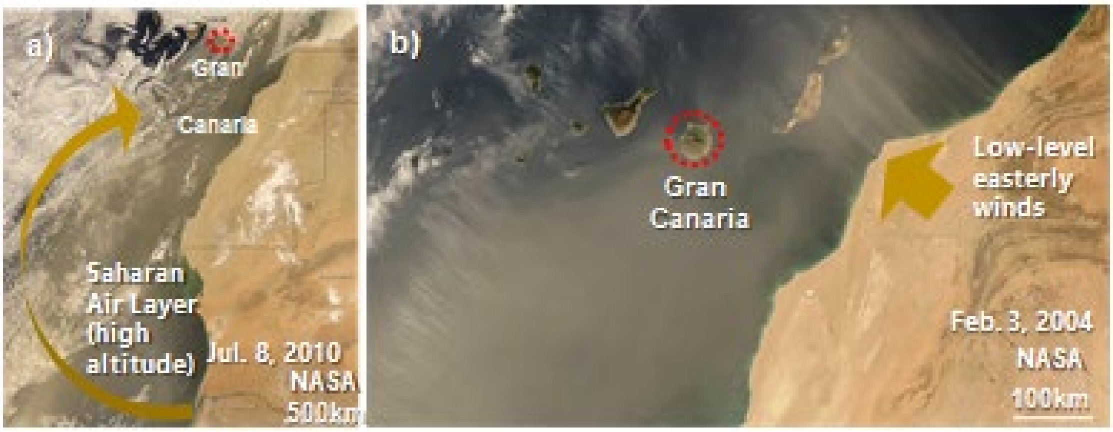

Figure 2. The Saharan dust synoptic weather situations over Gran Canaria: a) summer and b) winter conditions. Modified from *Alonso-Zarza et al., 2020*.

The investigations of the Saharan dust (composition and properties) are relevant on global climate change due to the role of dust in important processes (*Rodríguez et al., 2002; 2011*). Natural Mineral Particles (NMP) produced from windblown soils are a crucial component of the earth-atmosphere system (*Dentener et al., 1996*). They influence climate through the direct effect of absorbing and reflecting radiation (*Ramanathan et al., 2001*), and indirectly, in the optical properties of clouds by modifying the condensation nuclei (CCN) distribution. In this way, both effects contribute to the variation of the Earth's radiation budget (*Charlson et al., 1992*).

Wind erosion generates NMP especially in arid and semiarid regions. The erosion removes the most fertile portion of soil (*Stoorvogel et al. 1997*). Particles from bare soils are suspended and become part of the atmospheric dust load. Dust reduces visibility and pollutes the air, causes accidents, soils machinery, and affects animal and human health (*Griffin et al. 2001*). Dust particles are subject to ageing and mixing processes throughout their atmospheric lifetime. The ageing of dust takes place after long-range transport in air, involve surface chemical reactions with gases such as NO_2, SO_2, HNO_3, O_3 (*Astitha et al. 2010*), and may also involve mixing with marine aerosols and/or anthropogenic pollution (*Ansmann et al. 2018*).

When suspended mineral particles settle, could pollute water bodies, and cause associated problems. However, desert dust is a source of micronutrients such as iron and phosphorus, which are a limiting element in phytoplankton of large ocean regions. Recent experiments in ocean fertilization with Fe (II) (soluble iron) (*Zhu et al. 1997*) provide strong evidence of its important role in the regulation of primary production. Therefore, the entry of atmospheric iron (II) into the ocean could contribute to the regulation of the ocean carbon cycle and global climate (*Zhu et al. 1997*).

Canary soil contains a substantial amount of Saharan dust, as reflected in its mineralogy (*Menéndez et al. 2007; Muhs et al. 2010; von Suchodoletz et al. 2013*). The continuous Saharan dust input remains in soils as background dust, enabling its study.

The dust (airborne) is sampled by high volume dust collectors (Fig. 3). They consist of an upper part (black) where the filter is installed, and a vacuum pump (light grey box), that controls collection time and air vacuum conditions. The filters used are composed of different materials depending on the type analysis. Cellulose filters are used when metals are quantified (*Gelado et al., 2012*). The filters can capture the total of the suspended particles (TSP) or specific fractions using a physical filtration (called "impactor") before the dust particles are trapped in the filter. These "impactors" are different depending on the interest of the study, it is possible to collect different fractions (less than 1 µm (PM1), less than 2.5 µm (PM2.5; *Engelbrecht et al., 2014*), less than 10 µm (PM10; *Rodríguez et al. 2002*), since the impactors retain the coarsest particles and only allows the fine size to pass.

The aim of this study is the optimization of the Saharan dust particles extraction, that previously were collected by filters, to facilitate their textural and mineralogical study.

Fig. 3. High volume dust collectors (MCV brand) located on a building roof from Las Palmas de Gran Canaria Port authorities. Source:http://tecnobioambiental.ulpgc.es/2018/02/instalacion-de-captadores-de-alto-volumen-en-autoridad-portuaria-de-las-palmas/

2. Material and methods

2.1. Particles extraction of the filters

To carry out the objective of this study, it was first necessary to collect the Saharan dust. The professor Maria Dolores Gelado Caballero kindly facilitate them, a set of 6 cellulose filters collected in the roof of the Faculty of Marine Sciences building at the Campus of Tafira, University of Las Palmas de Gran Canaria at 300 m a.s.l., for their subsequent analysis. The sampling periods for each sample and other details, can be seen in Table 1.

Dust samples were obtained in High Volume Collectors (MCV model) and the filters collected the total fraction (TSP). This used cellulose filters (Whatman 41) efficiency is effectively 100% for dust (*Savoie, 1984; Dorta et al., 2002*).

The materials used in this study were: stopwatch, balance, distilled water, 56 beakers or ceramic bowls (Fig. 4), filters, ultrasonic cleaning bath (MLINK), stove, pH-meter (pH-meter GLP 22 model Crison). The computer program used was Microsoft Excel. All the material was available in the Geology Laboratory B-204.

Table 1. Information on the filters provided by Professor María Dolores Gelado Caballero from the Chemistry Department of the ULPGC.

Code	Filter number	Date	Air volume filtered, m^3
4081	1	05/01/2013	815.7
4186	2	09/05/2013	815.8
3220	3	17/01/2011	416.0
4657	4	10/01/2015	815.7
4184	5	07/05/2013	815.8
4082	6	06/01/2013	815.7

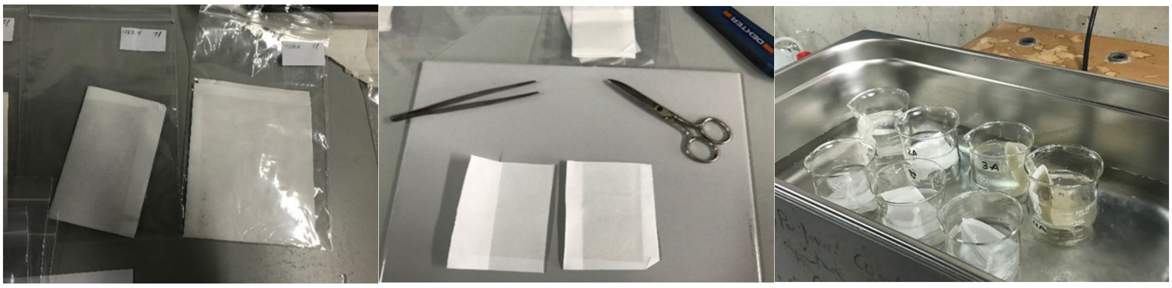

Figure 4. (Left image) Two of the filters provided by Professor María Dolores Gelado Caballero from the Chemistry department. (Centre image) Filter 5 (code 4184) is shown on the left and filter 6 (code 4082) is shown on the right. (Right image) Filters in breakers and in an ultrasonic bath.

The filters provided (Fig. 4) were cut into approximately three equal parts, since initially it was decided to carry out three ultrasonic-humid cycles in case it was necessary to change the conditions and the methodology. Each third of the filter was stored and kept in the laboratory freezer (Fig. 4). To know the possible amount of sample lost (the error), the sample obtained after the procedure and the filter after the procedure were weighed and compared with the result of the weight from the initial filter (with the collected dust particles).

In the first cycle (Cycle I), a third of the filters were used, numbered from 1 to 6, and a blank (number 7). Each filter was placed in a beaker with distilled water, filled up to the edge of the filter and such beakers were placed inside the ultrasonic tank with tap water (Fig. 4).

The bath ultrasound system was started up and the established time periods were waited. Approximately every 5 minutes, from 5 to 35 minutes, the target water was removed from each beaker and placed into a beakers or ceramic bowls. In total, 49 samples from the seven filters were obtained, which were placed in the oven at about 40ºC for two days.

Once the water in the beakers was evaporated, different residues remained in these, the sample. This sample was extracted by scraping with a small spoon and a brush. The collected residue was then weighed, but previously introducing the filter 10 minutes in the stuff to eliminate its humidity.

Due to the scarce amount of sample obtained in the first cycle of filter washing, just another more extraction by ultrasonic-humid cycles were carried out with the rest of the filters (2/3), in order to increase the weight values of the samples and minimize possible errors in the measurements. The second cycle (Cycle II) was performed following the same methodology as the first cycle.

Ph control of the water from the samples was made to assure that no particles aggregation because pH conditions, to avoid the iron-colloids formation and thus facilitate the extraction, accordingly to *Pullin et al. (2002; 2003).* No pH correction was necessary to reach the suitable condition for particle washing from the filter because the pH value of the water extractions was in the 5.2-5.4 range.

The resulted sample weight extracted of each filter was applied to calculate the dust concentration.

2.2. Image analysis and statistics of the particles

In the second part of this study, six images of each recovered particle samples were photographed with a Leika MZ6 stereomicroscope equipped with a photographic camera, at an image resolution of 5.0 megapixels, and a multiple focus (used in order to avoid creation of shadows).

The samples remained for more than two month in these conditions due to the situation caused by Covid-19, but this did not harm the state of the particles that were photographed by Inmaculada Menéndez (tutor of this study), since due to confinement it was not possible attendance of students to the facilities and laboratories.

The images were analysed using ImageJ Program (https://fiji.sc/), bearing in mind the ratio between the pixel scale and the real dimension. The images were binarized to obtain the best discrimination between the background and the particles, (changing the RGB for 8bits images). Finally, some geometrical measurements (area, perimeter) and morphometric characteristic, like the circularity (IC), were analysed. With the area and the circularity index (IC) of each particle the grain size distribution of the mineral particles of each sample were graphed. Statistical parameters were obtained with Gradistat V9.1 program (http://www.kpal.co.uk/gradistat.html).

A great number of parameters describe different morphological characteristic of particles (shape, roundness, irregularity, sphericity of circularity; *Blott and Pye, 2008*). The circularity index (CI) defined by Wadell (1934) as:

$$\text{Circularity} = 4p\ (\text{Area}/\text{Perimeter}^2)$$

The value ranges from 0 (infinitely elongated polygon) to 1 (perfect circle). However, it can also describe the geometrical complexity of the particle, or in other words, indicates how “jagged” its edges are.

As an example, of the most abundant in particles was shown in Figure 5, the number 4 sample. It is a selection of photos, and their particle identification from the image analysis treatment, took from the samples obtained after the six different time extractions.

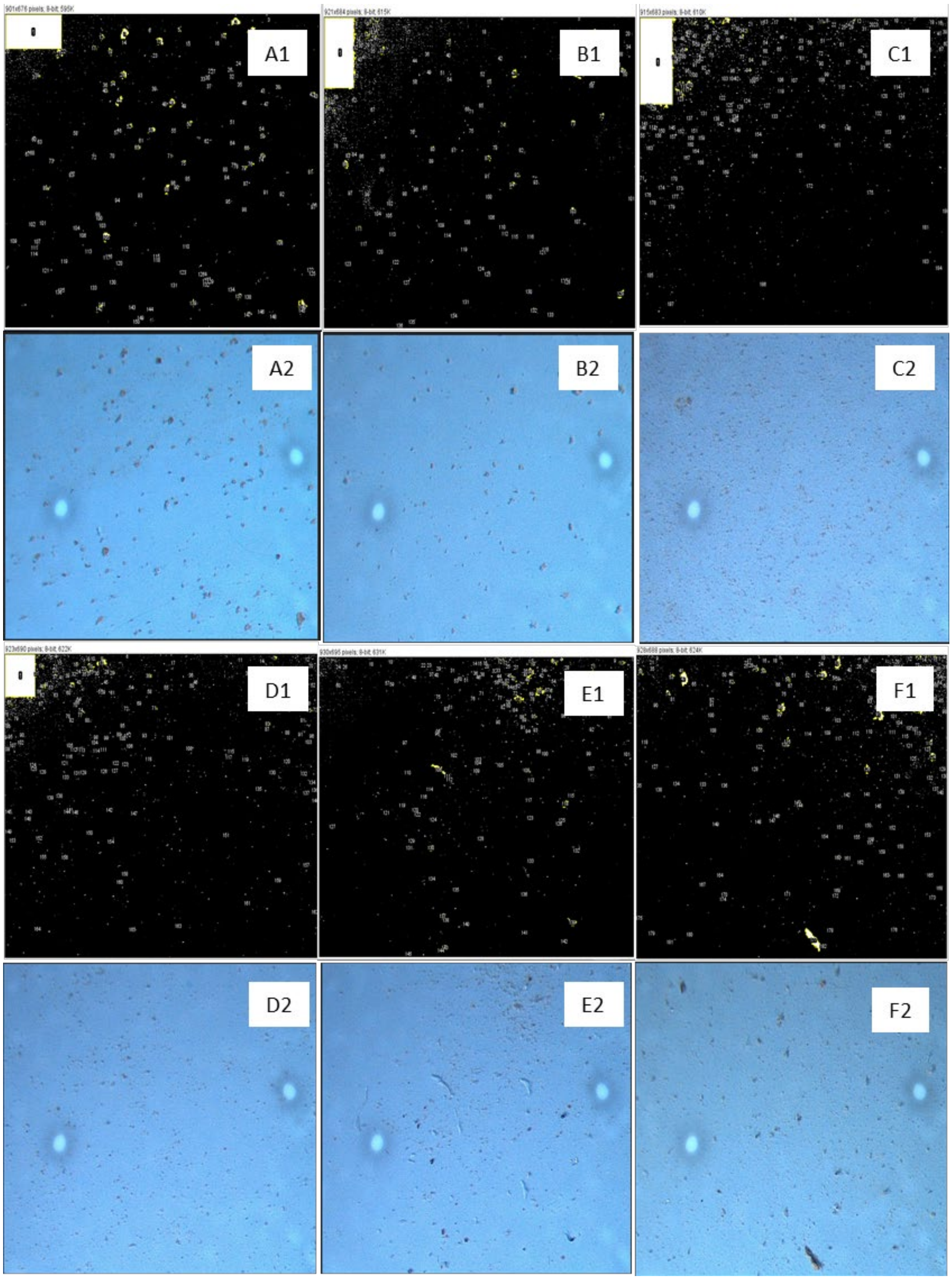

Figure 5. ImageJ program analysis from the sample 4, the most abundant in particles, for the different extraction times. (1) Treated image with the particle identification and numbered. (2) Original image. A) Sample obtained after 5’ of filter treatment. B) Sample obtained after 10’ of filter treatment. C) Sample obtained after 15’ of filter treatment. D) Sample obtained after 20’ of filter treatment. E) Sample obtained after 25’ of filter treatment. F) Sample obtained after 30’ of filter treatment. (Scale: the width of each image represents 6 mm).

3. Results

3.1. Dust extraction by ultrasonic-humid cycles

The results of the first and second ultrasonic-humid cycle are shown in Figures 6-8. In the Cycle I most of the particles fallen in the first five minutes of extraction and the number of various samples were close to the valid limit of the balance measurement (third decimal number).

In the cycle II, using 2/3 of the filter, it was possible to increase the weight values of the recovered samples and thus, be able to carry out the subsequent analyses. In both cycles (Figs. 6-8), it was possible to deduced that the extraction process is effective up to approximately 20 minutes, where the subsequent increases in the weight of the recovered sample seems to be due to the loss of the material that makes up the filter. At this point, fibres start to be abundant (Fig. 5) producing sample even in the blank (7; Fig. 6). In both cycles the filter with more recovery was number 4, followed by number 3.

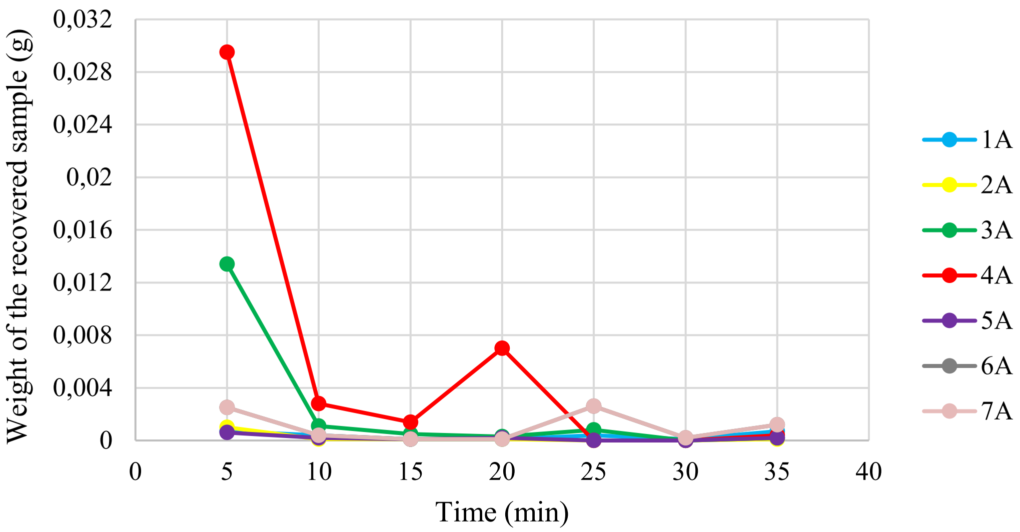

Figure 6. Results of sample extraction in the cycle I.

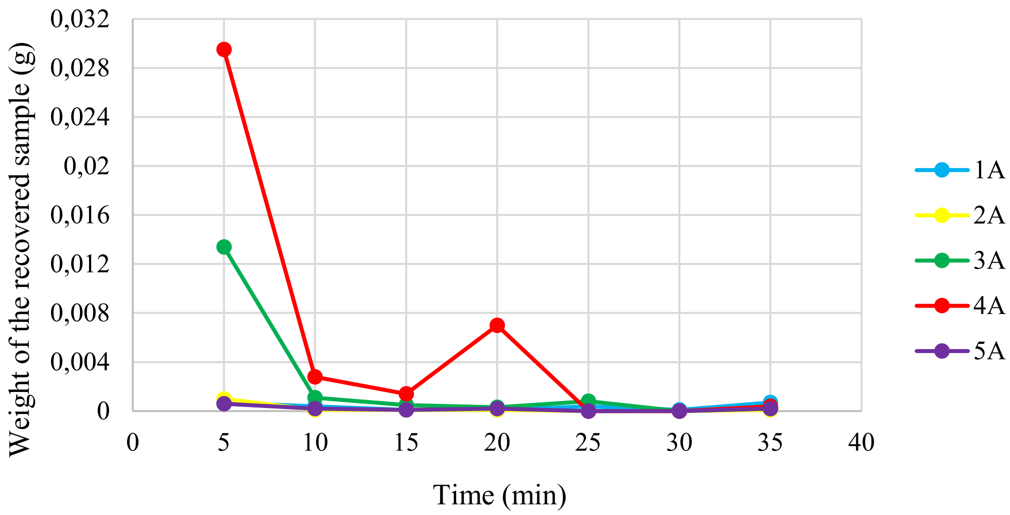

Figure 7. As a simplification of the Fig. 7, to better see the results of sample extraction in the cycle I. We eliminated the series of filters 6, and 7 (the blank).

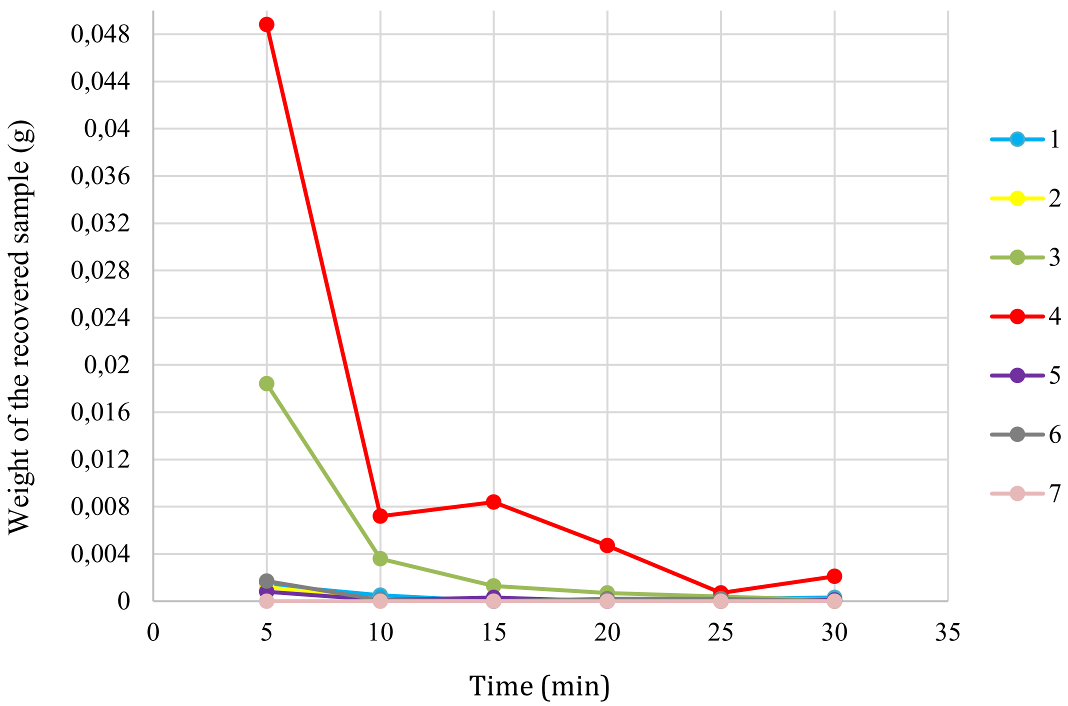

Figure 8. Results of sample extraction in the cycle II.

3.2. Dust concentration

Thanks to the information provided by Professor María Dolores Gelado Caballero (air volume during filter collection (in m^3; Table 1), and the results achieved with the ultrasonic-humid extraction cycles (weight of the recovered sample, in g), it was possible to obtained the dust concentration (µg/m^3) for the measured Saharan dust events over Gran Canaria. These results are shown in Table 2. The highest concentration was obtained from January 10, 2015 (filter 4) and for January 17, 2011 (filter 3). The difference between the cellulose and quartz-fiber filter samples ranged from 13 to 53% less in cellulose filters.

Table 2. Results achieved from the ultrasonic extraction on the Saharan dust concentration.

Sample	Date*	Air volume* (m^3)	Extracted weight (µg)	Weight from Q-fiber* (µg)	Dust (µg/m^3)	Dust from Q-fiber* (µg/m^3)	Extraction efficiency %
1	05/01/2013	416	5000	40000	12	96	13
2	09/05/2013	816	2900	10188	4	12	28
3	17/01/2011	816	40800	167000	50	205	24
4	10/01/2015	816	113000	326460	139	400	35
5	07/05/2013	816	2600	15790	3	19	16
6	06/01/2013	816	9300	17700	11	22	53

*information from the professor Gelado-Caballero.

3.3. Grain size distribution

The grain size distribution of the six filters analyzed is shown in Table 3. It shows, in percentage, the number of particles that correspond to each filter for each selected diameter. In general, most of the particles contained in the filters belong to a specific size range, from 31-17 mm, namely, coarse silt, in a range of 40-81% of the sample. There are two exceptions, at 10 minutes of the process, in filter 1, where 43% of the extracted was very fine sand, at the first minutes of the process, in filter 5, where 60% of the extracted was medium silt.

Table 3. Grain size distribution, in percentage, for dust samples recovered in the ultrasonic-humid extraction in Cycle II. The dominant grain size values, in percentage, of each sample are in bold font.

Diameter in µm, Name Sample	250-126 Fine SAND	125-64 Very fine SAND	63-32 Very coarse SILT	31-17 Coarse SILT	16-10 Medium SILT	9-5 Fine SILT	4-3 Very fine SILT
1-5'	0	30	4	**40**	16	10	0
1-10'	0	2	**43**	29	19	7	0
2-5'	0	0	20	**65**	13	0	0
3-5'	0	2	10	**72**	14	0	0
3-10'	0	2	22	**60**	15	0	0
3-15'	0	0	10	**81**	9	0	0
3-20'	0	0	7	**62**	27	0	0
3-25'	0	0	13	**79**	8	0	0
4-5'	0	8	32	**52**	8	0	0
4-10'	0	0	24	**56**	16	0	0
4-15'	0	0	7	**73**	18	0	0
4-20'	0	0	12	**76**	12	0	0
4-25'	0	2	14	**66**	14	0	0
4-30'	0	3	21	**63**	11	0	0
5-5'	0	0	1	35	**60**	0	0
5-10'	0	1	35	**46**	16	0	0
5-15'	6	4	34	**40**	12	4	0
6-5'	0	4	23	**51**	19	0	0

In Fig. 9, the grain size distribution is shown in more detail. The particles extraction of the filter 1 stop after 10 minutes of the process, and the particle size varies from <125 µm (very fine sand) to <9 µm (fine silt). In filter 2, the particles all came off in the first 5 minutes of the process and correspond to sizes between <63 mm (very coarse silt) and <16 µm (medium silt). Filters 3 and 4 were the ones with the highest content of dust particles. In filter 3, the particles detached from it in a time range from 5 to 25 minutes, and the size range of the extracted particles varies from <63 µm (very coarse silt) to <16 µm (medium silt).

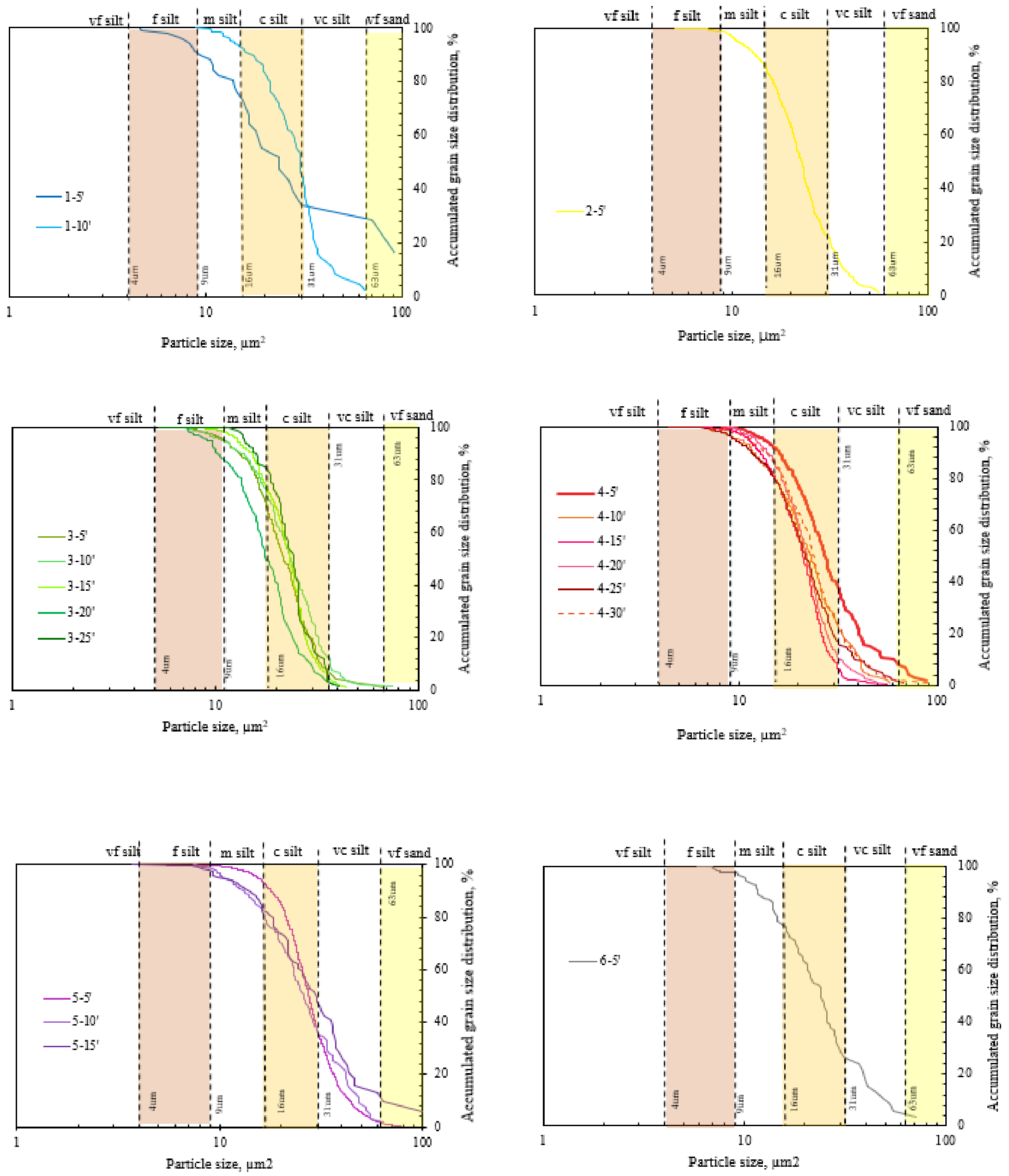

Figure 9. Accumulated grain size distribution curves for the six filters used in ultrasonic-humid extraction method. The obtained samples of each filter were displayed in the same graph.

In filter 4, the particles detached over a time range of 5 to 30 minutes, and the range of particle sizes varies from <125 µm (very fine sand) to <16 µm (medium silt) similarly to filter 3. In filter 5, 15 minutes of process were enough to extract a measurable quantity of particles, which vary in a size range from 125 µm (very fine sand) to 9 mm (fine silt). In filter 6, the particles came off in the first 5 minutes of the process and correspond to sizes from 125 µm (very fine sand) to 16 µm (medium silt).

Finally, the shape of the accumulated grain size distribution of the samples do not eventually change throughout the time extraction, or at least, a clear tendency cannot be observed (Fig. 9).

3.4. Grain size statistics

Four statistical parameters of grain size were considered (Table 4). Regarding the mean particle size, it suits in the more abundant fraction of each sample (coarse silt for all, excepting filters 1 and 5, collected both at 5 minutes, which values were medium silt and very coarse silt, respectively.

Regarding the sorting (that is the distribution of sizes around the average) most of the samples obtained are poorly (values from 1 to 2), or very poorly classified (values from 2 to 4) in samples 1-5', 5-15' and 6-5'.

Skewness parameter, the symmetry or preferential spread to one side of the average, is very negative for all samples (< -0.3 values).

Finally, the kurtosis, the degree of concentration of the grains in relation to the average, for all samples the results is very leptokurtic (values greater than 3).

The circularity parameter has allowed us to differentiate two groups of particles. A group made up to aggregates generated inevitably during the drying process in the extraction cycle, which have an average circularity. And a second, group of particles with a much more varied circularity.

Table 4. Statistical parameters of the particles extracted from the dust filters.

Sample	Mean	(Denomination)	Sorting	Skewness	Kurtosis
1-5'	13	Medium silt	3.7	-0.83	2.94
1-10'	26	Coarse silt	1.9	-3.38	18.16
2-5'	25	Coarse silt	1.5	-3.92	31.94
3-5'	23	Coarse silt	1.6	-3.77	27.86
3-10'	23	Coarse silt	1.7	-3.34	22.00
3-15'	26	Coarse silt	1.4	-7.15	72.96
3-20'	12	Coarse silt	1.7	-2.79	15.54
4-5'	27	Coarse silt	1.8	-2.18	13.94
4-10'	27	Coarse silt	1.6	-3.82	30.82
4-15'	25	Coarse silt	1.4	-7.05	65.52
4-20'	24	Coarse silt	1.5	-5.13	45.48
4-25'	23	Coarse silt	1.7	-2.90	21.26
4-30'	26	Coarse silt	1.7	-3.73	26.27
5-5'	40	Very coarse silt	1.5	-6.83	65.54
5-10'	23	Coarse silt	1.9	-2.00	10.54
5-15'	22	Coarse silt	2.6	-2.03	7.68
6-5'	21	Coarse silt	2.1	-2.07	9.55

4. Discussion

4.1. Dust extraction by ultrasonic-humid cycles

The particles extraction from filters in the ultrasonic-humid cycles seems to produce the major amount in the first period (five minutes). At the end of the third extraction of the cycle I, the filters were folded, and this is because we folded them in the other side. This could explain the peak at the 20' extraction (Fig. 5). Spite the fact that the Cycle I extraction was in very scarce; their values are proportional in weight to the samples obtained with the double size of filter (in Cycle II).

4.2. Dust concentration

Cellulose filters are not used to measure the collected dust weight. Thus, the efficiency of the sample extraction of the filters from this study was compared with the quartz-fibre filters used in the same time periods and place (Table 2). The weight sample from the cellulose filter was much less than the quartz-fibres filters (from 13 to 53%), but well correlated (Fig. 10). It is possible that the dust collection was less efficient in cellulose filters. By the other hand, it is assumed that the extraction of the filter matter is not 100% effective. For example, a 50% of recovery could is consider acceptable for PM10 and PM2.5 impactors (*Jaramillo et al., 2016; Chen et al., 2018*).

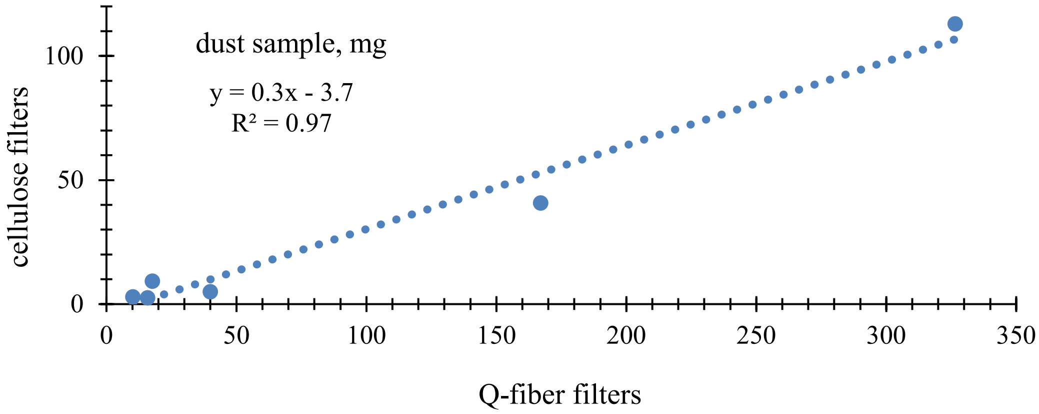

Figure 10. Correlated linear adjustment relationship between the dust sample weights obtained by the cellulose and quartz fibre filters.

Comparing the images of the particles in filters and extracted from the filters (Fig. 11), the later method is, by far, a particle definition improvement, necessary for the image analysis and concentration measurements.

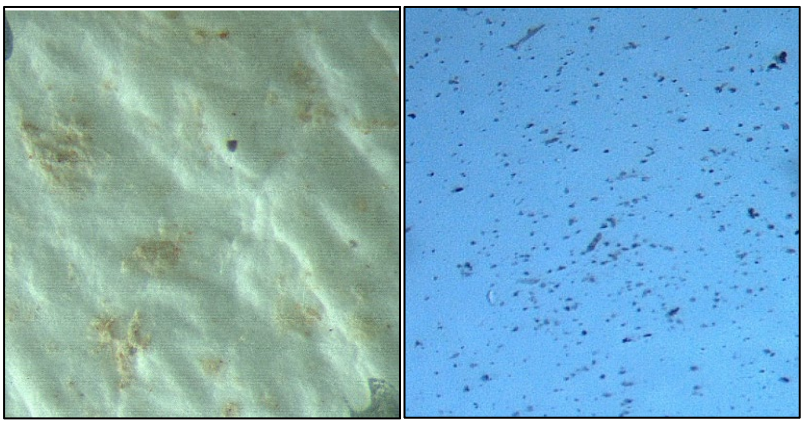

Figure 11. Example of the aspect of the particles in a filter (left) and extracted from the filter (right),

4.3. Grain size distribution

It seems to be a direct relation between the amount of measurable sample and number of recovery time periods where particles are extracted (Fig. 12). It should be considering to determining the extraction time, also noticing that after 20 minutes the cellulose filters start to disintegrate in fibres.

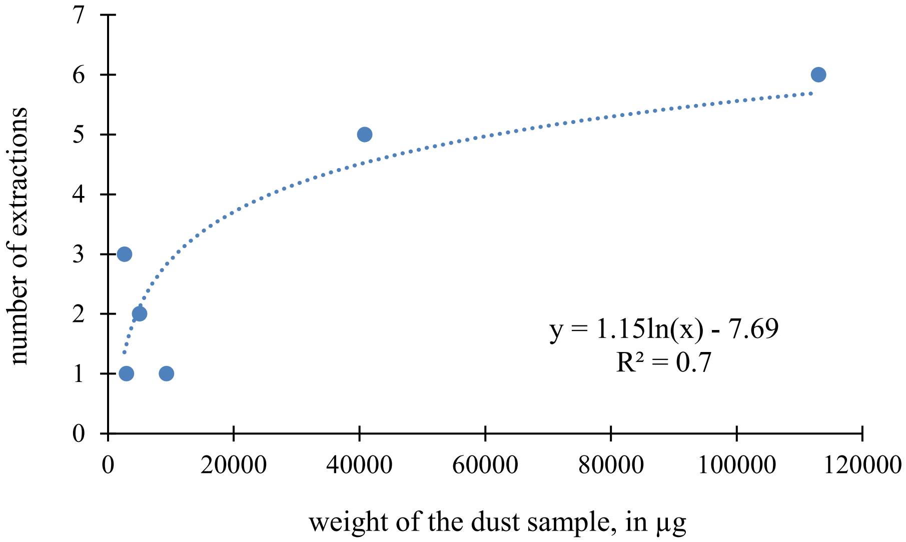

Figure 12. Direct correlation between the number of samples obtained per filter from a sequential extraction from 5 to 30 minutes of ultrasonic bath.

4.4. Grain size statistics

The mean grain size of Saharan dust in collected in Canary Islands in other studies is in the range of 0.5-20 mm *(Rodriguez et al. 2014)*, close to the mean grain size of this study (a mean of 24 mm, coarse silt). However, Saharan dust that reach to the Caribbean the mean grain size is reduced to clay-silt fractions *(Prospero, 1996b)* because the grain size of the plume dust is determined by the distance *(Goudie and Middleton, 2001)*.

The typical skewness of the grain size distribution of Saharan dust is negative *(Menendez et al., 2009)*. In the present work, a very negative values were obtained (from -0.83 to -5.13).

5. Conclusion

The extraction of the dust particles from the filters makes easier and more accurate the subsequent image treatment and data acquisition. In this work a set-up of a humid-ultrasonic method has been done, concluding that:

1) After 20 minutes (Fig. 5), the cellulose filters begin to disintegrate into fibres.

2) The accumulated grain size distribution of the samples does not change substantially throughout the time extraction, or at least, a clear tendency cannot be observed (Fig. 9), so that the ultrasonic-humid extraction method could be consider texturally stable.

3) A direct relationship was found between the weight of the sample and the number of washing samples obtained (Fig. 10).

4) Regarding the sample texture analysis of the Saharan dust samples, the mean particle size was coarse silt, the main sorting was poorly, the skewness very negative and, the kurtosis, is very leptokurtic.

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References

Alonso-Zarza AM, Rodríguez-Berriguete Á, Casado AI, Martín-Pérez A, Martín-García R, Menendez I, Mangas J. 2020. Unravelling calcrete environmental controls in volcanic islands, Gran Canaria Island, Spain. Palaeogeography, Palaeoclimatology, Palaeoecology. Available online 19 May 2020, 109797. https://doi.org/10.1016/j.palaeo.2020.109797

Ansmann, A., Tesche, M., Althausen, D., et al. 2008. Influence of Saharan dust on cloud glaciation in southern Morocco during SAMUM. J. Geophys. Res. 113: D04210. https://doi.org/10.1029/2007JD008785

Astitha, M., Kallos, G., Spyrou, C., et al. 2010. Modelling the chemically aged and mixed aerosols over the eastern central Atlantic Ocean potential impacts. Atmos. Chem. Phys. 10, 5779-5822 https://doi.org/10.5194/acp-10-5797-2010

Blott, S. J., and Pye, K., 2008. Particle shape: A review and new methods of characterization and classification. Sedimentology 55 (1), 31-63.

Charlson, R.J., S.E. Schwartz, J.M., Hales, R.D., Cess, J. A., Coakley, J. R., Hansen, J. E., and D. Hofmann, J., 1992. Climate forcing by anthropogenic aerosols Science 255, 423-430.

Chen, Y., Wild, O., Wang., Y., Ran, L., Teich, M., Größ, Wang, L., Spindler, G., Herrmann, H., van Pinxteren, D., McFiggans, G., Wiedensohler, A., 2018. Atmospheric Environment 195, 141-148

Criado, C., Dorta, P., 2003. An unusual “blood rain” over the The Canary Islands (Spain). The storm of January 1999. J Arid Environ. 55, 765-783. http://doi.org/10.1016/S0140-1963(02)00320-8

Dentener, F.I., Carmichael, G.R., Zhang, Y., Lelieveld, J., Crutzen, P.J., 1996. Role of mineral aerosol as a reactive surface in the global troposphere. Journal Geophysical Research 101, 22869-22889. http://doi.org/10.1029/96JD01818

Dorta, P., Gelado, M. D., Cardona, P., Collado, C., Criado, C., Hernández, J. J., Mendoza, S., Siruela, V., Torres, M. E., Curbelo, D., López, P., Rodríguez, E., 2002. Algunas consideraciones sobre la importancia del polvo de origen Sahariano en el clima del archipiélago canario y su aporte a las aguas superficiales oceánicas.

Engelbrecht, J. P., Menéndez, I., Derbyshire, E., 2014. Sources of PM2.5 impacting on Gran Canaria, Spain. Catena 117, 119-132 http://doi.org/10.1016/j.catena.2013.06.017

Faust, D., Yurena, Y., Willkommen, T., Roettig, C., Richter, D., Richter, D. Suchodoletz, H. v., Zöller, L., 2015. A contribution to the understanding of late Pleistocene dune sand-paleosol-sequences in Fuerteventura (Canary Islands). Geomorphology 246, 290-304 http://doi.org/10.1016/j.geomorph.2015.06.023

Gelado-Caballero, M. D., López-García, P., Prieto, S., Patey, M. D., Collado, C., Hernández-Brito, J. J., 2012. Long-term aerosol measurements in Gran Canaria, Canary Islands: Particle concentration, sources and elemental composition. Journal of Geophysical Research, 117. http://doi.org/10.1029/2011JD016646

Goudie, A. S., Middleton, N. J., 2001. Saharan dust storms: nature and consequences. Earth-Sci Rev. 56, 179-204. http://doi.org/10.1016/S0012-8252(01)00067-8

Griffin, D. W., Garrison, V. H., Herman, J. R., Shinn, E. A., 2001. African desert dust in the Caribbean atmosphere: microbiology and public health. Aerobiología 17, 203-213.

Jaramillo, A., Menéndez, I., Alonso, I., Hernández-León, S., 2011. Textural and mineralogical of terrigenous material from atmospheric inputs in the Canary Basin. Master thesis.

Jaramillo, A., Menéndez, I., Alonso, I., Mangas, J., Hernández-León, S., 2016. Grain size, morphometry and mineralogy of airborne input in the Canary basin: evidence of iron particle retention in the mixed layer. Scientia Marina 80 (3), 395-408 http://dx.doi.org/10.3989/scimar.04344.27A

Menéndez, I., Derbyshire, E., Carrillo, T., Caballero, E., Engelbrecht, J. P., Romero, L. E., Mayer, P. L., Rodríguez de Castro, F. & Mangas, J., 2017. Saharan Dust and the impact on adult and elderly allergic patients: the effect of threshold values in northern sector of Gran Canaria, Spain. International Journal of Environmental Health Research, 27 (2), 144-160. http://doi.org/10.1080/09603123.2017.1292496

Menéndez, I., Derbyshire, E., Engelbrecht, J. P., von Suchodoletz, H., Zöller, L., Dorta, P., Carrillo, T., Rodríguez de Castro, F., 2009. Saharan Dust and the aerosols on the Canary Islands: past and present. In: Cheng, M., Liu, W., editor. Particulates airborne. New York (NY): Nova Science, 39-80.

Menéndez, I., Díaz-Hernández, J. L. Mangas, J., Alonso, I., Sánchez, P. J., Soto, 2007. Airborne Dust accumulation and soil development in the North-East sector of Gran Canaria, Canary Island, Spain. Journal of Arid Environments 71, 57-89. http://doi.org/10.1016/j.jaridenv.2007.03.011

Muhs, D. R., Budahn, J., Skipp, G., Prospero, J. M., Patterson, D., Bettis, D., 2010. Geochemical and mineralogical evidence for Sahara and Sahel dust additions to Quaternary soils on Lanzarote, eastern Canary Islands, Spain. Terra. 22, 399-410. http://doi.org/10.1111/j.1365-3121.2010.00949.x

Pérez-Chacón, E., Hernández-Calvento, L., Fernández-Negrín, E., Romero, L., Máyer, P., Hernández-Cordero, A., Cruz, N., Fernández-Cabrera, E., Peña, C., Mangas, J., Alonso, I., Rodríguez, S., Sánchez, I., 2010. Caracterización del sistema sedimentario eólico de La Graciosa (Archipiélago canario). Report for the National Parks Body, 155.

Pérez-Chacón, E., Hernández-Calvento, L., Fernández-Negrín, E., Máyer, P., Cabrera Vega, L., Cruz, N., Fernández-Cabrera, E., García-Romero, L., Hernández-Cordero, A., Peña, C., Santana-Cordero, A., Mangas, J., Rodríguez, S., 2012. Evolución reciente del sistema sedimentario eólico de La Graciosa (Archipiélago canario): claves para su diagnóstico ambiental. Report for the National Parks Body, 151.

Piqué, A., 2001. Geology of Northwest of Africa. Gebrüder Borntraeger, Berlin.

Prospero, J. M., 1996a. Dust transport over the North Atlantic Ocean and Mediterranean: an overview. In: Guerzoni, S., Chester, R., editors. The impact of desert dust across the Mediterranean. Dordrecht: Kluwer Academic Publishing, 133-151.

Prospero, J. M., 1996b. The Atmospheric Transport on Particles to the Ocean. In: V. Ittekkot, P. Schäfer, S. Honjo, P. J. Depetri editors. Particle Flux in the Ocean. Dordrecht: John Wiley & Sons, 19-53.

Pullin, J. M., Cabaniss, S.E., 2002. The effects of pH, ionic strength, and iron-fulvic acid interactions on the kinetics of non-photochemical iron transformations. I. Iron (II) oxidation and iron (III) colloid formation. Geochimica et Cosmochimica Acta 67 (21), 4067-4077

Pullin, M. J., Cabaniss, S. E., 2003. The effects of PH, ionic strength, and iron-fulvic acid interactions on the kinetics of non-photochemical iron transformations. II. The kinetics of thermal reduction. Geochimica et Cosmochimica Acta 67 (21), 4079–4089.

Ramanathan, V., Crutzen, P.J., Kiel, J.T., Rosenfeld, D., 2001. Aerosol, climate and the hydrological cycle. Science 294, 2119-2124.

Rodríguez, S., Querol, X., Alastuey, A., Plana F., 2002. Sources and processes affecting levels and composition of atmospheric aerosol in the western Mediterranean, J. Geophys. Res., 107 (D24), 4777, http://doi.org/10.1029/2001JD001488

Rodríguez, S., Alastuey, A., Alonso-Pérez, S., Querol, X., Cuevas, E., Abreu-Afonso, J., Viana, M., Pérez, N., Pandolfi, M., de la Rosa, J., 2011. Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer. Atmospheric Chemistry and Physics 11, 6663–6685.

Rodríguez, S., Cuevas, E., Prospero, J., M., Alastuey, A., Querol, X., López-Solano, J., García, M. I., Alonso-Pérez, S., 2014. Modulation of Saharan Dust export by the North African dipole. Atmos. Chem. Phys. 15, 7471-7486

Savoie, D. L., 1984. Nitrate and non-sea-salt surface aerosols over major regions of the world ocean. Concentrations, sources, and fluxes, dissertation. Dep. of Mar. and Atmos. Chem., Univ. of Miami, Miami.

Stoorvogel, J. J., Breemen, N. V., Hansen, B. H., 1997. The nutrient input by Harmattan dust to a forest ecosystem in côte d'Ivoire, Africa. Biogeochemistry 37, 145-157.

Von Suchodoletz, H., Glaser, B., Thrippleton, T., Broder, T., Zang, U., Eigenmann, R., Kopp, B., Reichert, M., Zöller, L., 2013. The influence of Saharan Dust deposits on La Palma soil properties (Canary Islands, Spain). Catena 103, 44-52 http://doi.org/10.1016/j.catena.2011.07.005

Zhu, X. R., Prospero, J. M., Milero, F. J., 1997. Daily variability of soluble Fe (II) and soluble total Fe in North African dust in the trade winds at Barbados. Journal of Geophysical Research 102, 21297-22305.

Wadell, H., 1934. Some new sedimentation formulas. Journal of Applied Physics 5 (10), 281-291

- **Descripción detallada de las actividades desarrolladas durante la realización del TFG**

Las actividades realizadas durante el Trabajo de Fin Grado (TFG) consisten en la continuación de las tareas desarrolladas durante el período de prácticas externas. Por tanto, se ha enfocado en el análisis de las muestras recolectadas con los captadores y extraídas mediante el método de extracción húmeda por ultrasonidos que hemos optimizado.

- **Formación recibida (cursos, programas informáticos, etc.)**

La tutora del TFG ha proporcionado desde el inicio diversos documentos para poder enfocar la línea de investigación del estudio. También ha proporcionado las claves para el manejo de algunos softwares libres, por ejemplo, "ImageJ Program", el cual ha servido para analizar las imágenes obtenidas con el estereomicroscopio Leika MZ6, y el programa GradiStat V9.1, que se ha empleado para el análisis granulométrico y obtención de los parámetros estadísticos de las muestras recolectadas.

En adición a lo anterior, las asignaturas previas, relacionadas con aspectos geológicos y otros aspectos, impartidas en el Grado de Ciencias del Mar, que han sido vitales para el desarrollo del TFG han sido las siguientes:

Fundamentos de Geología I (Primer curso)
Fundamentos de Geología II (Primer curso)
Medios Sedimentarios Marinos (Segundo curso)
Oceanografía Geológica (Tercer curso)
Oceanografía Física (Tercer curso)
Georrecursos Marinos (Cuarto curso)
Meteorología e Interacción Atmósfera-Océano (Cuarto Curso)

- **Nivel de integración e implicación dentro del departamento. Relaciones con el personal**

En el departamento coincidía a menudo con varios alumnos de la facultad o incluso de otras facultades, los cuales también se encontraban realizando el TFG en el campo geológico o realizando otro tipo de trabajos, y, en ocasiones, nos ayudábamos mutuamente. El ambiente de trabajo era el idóneo.

- **Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFG**

Los aspectos positivos a lo largo del TFG han sido los de poseer el material necesario para la ejecución de las distintas funciones tanto en el Laboratorio de Geología como en el domicilio personal, online, además de la alta disponibilidad que ha tenido la tutora para resolver las distintas dudas que iban surgiendo y su alto nivel de implicación y apoyo. No obstante, el aspecto negativo sería la condición extraordinaria generada por el virus Covid-19 que imposibilitó la asistencia desde marzo hasta el final de curso, a las instalaciones, laboratorios, bibliotecas, etc., pero que no frenó el empeño que teníamos desde un principio en este proyecto.

- **Valoración personal del aprendizaje conseguido a lo largo del TFG**

Mediante la realización de este TFG considero que he obtenido una gran soltura y confianza con el inglés además de la experiencia de trabajo en el ámbito de la geología, aprendiendo a manejar diferentes programas, a buscar soluciones ante los problemas que van apareciendo y a coordinar y establecer las pautas necesarias para llevar a cabo un estudio con muestras de este tipo. Mediante el análisis de los resultados obtenidos he aprendido a compararlos y contrastarlos con otros estudios y a comprender realmente diversos procesos que nos rodean diariamente. Además, me gustaría agradecer a mi tutora Inmaculada Menéndez González por la oportunidad que me ha otorgado para completar mi formación en el grupo GEOGAR, por su alta disponibilidad a la hora de resolver las posibles dudas que iban surgiendo y su apoyo incondicional ante las circunstancias.