E3S Web of Conferences **44**, 00030 (2018) https://doi.org/10.1051/e3sconf/20184400030
EKO-DOK 2018

Analysis of granulometric dust accumulating in supply and exhaust ventilation filters

Bogdan Derbiszewski[1,*], *Anna* Kurek[1]

[1]The President Stanisław Wojciechowski State University of Applied Sciences in Kalisz, 62-800 Kalisz, ul. Nowy Świat 4, Poland

Abstract. The research aim was to analyse and compare the composition of granulometric dust which accumulates in air filters located in central air handling units supporting the production rooms and at the same time the degree and a kind of contamination fraction of atmospheric air in a part of Wrocław situated outside the city centre. Samples were taken in different seasons of the year, such as March and October. The size of pollution particles extracted from ventilation filters was measured with the use of ANALYSETTE 22MicroTec plus laser particle sizer produced by FRITSCH. The results of measurements were generated with MaScontrol software for particle size analysis. In computing research results, the Fraunhofer diffraction theory was used. The comparison of the examined air particles' size in an air supply canal allowed to determine the outside air dust size in Szczepin district on Długa street in Wrocław. Moreover, the influence of the year season on the size of contaminants accumulating in filters was also determined in the course of research works.

1 Introduction

Filters are used in industrial ventilation installations in order to assure protection from contaminating devices located in central air handling unit, as well as in ventilated rooms. In the process of air purification, the filters separate solid particles from the air flow and keep them on their surface. Separating the solids from the air by a single fibre depends mainly on fibre's diameter, solid particle's diameter, the flow speed and the distribution of solid particles approaching the filter [1].

In recent years special attention is paid to particulate matter's fraction: PM_{10} (the diameter smaller than 10 µm) and $PM_{2.5}$ (the diameter smaller than 2.5 µm). These fractions are treated as indicators, concentration of which shows the condition of the air outside. Fine PM10 dust stands for the fraction of particulate matter with particles' diameters smaller than 10 µm. On the other hand, very fine PM2.5 dust is a fraction of particulate matter colloidally fragmented with particles of diameters smaller than 2.5 µm [1]. The recent years have shown that PM2.5 dust is the most hazardous, since it can penetrate to lung alveoli from the bronchial passages and even get to the bloodstream [2]. In Europe the permitted level of PM2.5 in the air is 25 $\mu m/m^3$ and the corresponding level of PM10 is 50 $\mu m/m^3$ [3].

* Corresponding author: b.derbiszewski@pwsz-kalisz.edu.pl

This research paper describes the measurements of dust's particulates' diameter taken from supply filters of ventilation installation located in sewage pumping station in Długa street in Wrocław in March and October with a laser diffraction method. In order to define the granulation size of particles accumulating on filters, a series of ventilation filters from the central air handling unit supporting the production halls of Wrocław municipal services institution was examined. Cassette filters G3 reinforced with a steel mesh (2) were examined.

The analysed filters – cassette filters of G3 class, were taken from the central air handling unit supporting industrial room. The contents of the analysed filters were taken out onto a previously prepared clean surface. Next, the obtained material was sieved on a sieve with meshes' size 2 mm in order to separate fine particles from bigger, unnecessary elements. The particles smaller than 2 mm were analysed in a laser particle sizer with the use of 'wet' method.

Contamination particles on ventilation filters were measured with the use of Analysette 22MicroTec plus laser particle sizer produced by Fritsch (Fig.1). The measurement is fully automated: beginning with taking the sample, through initial estimation of the optimal measurement method and the measurement itself, to cleaning the measurement system and preparing it to further measurements [2].

Fig. 1 ANALYSETTE 22 MicroTec plus laser particle sizer produced by Fritsch, a measurement unit (bigger), and a dispersion unit (smaller) [4].

The particle sizer uses two phenomena while measuring, namely absorption and diffraction. The radiography method is based on optical diffraction phenomenon. The theoretical basis for radiographic method is a description of optical diffraction phenomenon with the Fraunhofer's transform. Optical conformation used to analyse optical images is composed of a source of monochromatic light (laser light), optical conformation forming its light beam, optical image created from suspension of powder's grains in liquid allowing the light through and causing its diffraction on the grains' boarders, optical conformation transforming the allowed light beam, detector of image created from this beam, transducer and a computer registering data. Diffraction method is used in many different industrial branches to perform granulometric analysis of grains, among others in food industry, construction or pharmacy [4].

The image transformed in granulometric devices, as well as the result of the transformation are placed in lenses' focus. Diffraction of light beam appears on the boarders of the centres of permeable (usually liquids) and impermeable (powder's grains), which generates an image in a form of a quasi-diffraction net. Lens focuses all diffracted and allowed light beams. It is the way a diffractive image, so called diffractogram in a form of bright and dark stripes or spots is created. Due to created image, it is possible to calculate the dimensions of the distance between stripes in the net. Identification of grains' sizes is based on measuring the distance between the stripe and an optical axe, as well as the stripe's brightness intensity. Two correlations can be observed on the basis of the created image. The bigger the distance of the stripe form the optical axe, the smaller the size of examined grains. Moreover, the more intense is the brightness of the stripe, the more grains of particular sizes can be found in the analysed sample. The Analysette 22 MicroTec meter uses the opposite Fourier's system, compliant with ISO 13320 standard.

The device consists of a measurement unit, a wet dispersion unit, water supplying and dispersing hoses, an ultrasonic bath, ultrasonic inductors, two laser diodes – green laser and infrared laser, a centrifugal pump, a measuring chamber and MaScontrol computer software [3]. MaScontrol contains all commands connected with Standard Operational Procedures (SOP), which control the whole device and lead to obtaining the results for indicated parameters. These commands apply to the pump, measurements and cleaning.

2 Research results

The results of research were generated by MaScontrol software, used in analysis of particle size. Tables 1–2 and Figures 2–4 present information necessary to conduct comparative analysis of the examined samples. The tables were created on the basis of detailed reports generated by MaScontrol software.

2.1 Filters from the pumping station in Port Południowy

The results of the analysis of granulometric composition of dusts extracted from filters located in the central supply ventilation unit located in the sewage pumping station in Port Południowy, Długa street, are presented below.

Table 1. Comparison of dust's grain composition for the 10-50-90 percentage share for the sewage pumping station Port Południowy.

Pumping station Port Południowy, Długa street								
Measurement number	Measurement date	Flow absorption [%]	Variability coefficient CV [%]	Share Q3 (x) [%] (10-50-90)	Particles size x [µm] (averaged)	Particles size x [µm] (first measurement)	Particles size x [µm] (second measurement)	Particles size x [µm] (third measurement)
1.1	March 2015	11	12.8	10	5.1	5.8	5.1	4.2
			6.6	50	21.7	23.5	21.7	19.9
			4.8	90	51.2	54.5	50.3	48.7
1.2	October 2016	7	6	10	4.2	4.6	4.1	4
			1.5	50	34.5	34.2	34.2	35.3
			1.3	90	126.7	124.4	127.6	128.2
1.3	October 2016	7	3.6	10	2.9	3	2.9	2.8
			5.7	50	17.4	16	17.8	18.3
			9.9	90	49.1	42.9	49.8	54.7

The research paper presents the results concerning samples from March 2015 and October 2016 – two samples. The analyser performed three measurements of each sample as 'particles x measurement' and gives averaged value from these three measurements – Table 1.

Minimal value of absorption – 7%, which is demanded by the device, was achieved for all measurements (Tab.1). Sample 1.1 taken in March 2015 is characterised by averaged parameters of particles' size of 5.1 – 21.7 – 51.2 µm. Sample 1.2 is characterised by much bigger size of particles. It is noticeable that particles of bigger size – 126.7 µm (more than 120 µm) are accumulated there. On the other hand, sample 1.3 taken in October is characterised by the smallest average size of particles. It means that 90% of the particles from the examined sample had an average value lower than 49.1 µm, 50% – lower than 17.4 µm and 10% – lower than 2.9 µm.

Table 2. Comparison of dust's grain composition for the specified percentage share for the sewage pumping station Port Południowy.

Pumping station Port Południowy, Długa street							
Measurement number	Measurement date	Particles size x [µm]	Variability coefficient CV [%]	Share Q3 (x) [%] (averaged)	Percentage share of particles Q3 (x) [%] (first measurement)	Percentage share of particles Q3 (x) [%] (second measurement)	Percentage share of particles Q3 (x) [%] (third measurement)
1.1	March 2015	20	7.2	46	42	45.9	50.1
		45	2.3	85.3	82.6	86	87.4
		125-1000	0	100	100	100	100
1.2	October 2016	20	1	36.6	36.8	36.9	36.1
		45	0.9	57.7	58	58	56.9
		125	0.4	89.6	90.1	89.5	89.3
		355-1000	0	100	100	100	100
1.3	October 2016	20	5	55.5	59.3	54.2	53
		45	4.2	86.8	91.5	86.3	82.5
		125-1000	0	100	100	100	100

Analysing the results presented in Table 2, it can be noticed that the highest percentage share for particles <20 µm is observable in sample 1.3 (55.5%), a little bit lower – in sample 1.1 (46%) and the lowest – in sample 1.2 (36.6 %). The highest granulation is seen in the second sample, for which the highest range of particles is 355–1000 µm. Both for the first and for the third samples the highest range of particles is an interval between 125–1000 µm.

Figures 2–4 present samples' granulation distribution 1.1–1.3. The cumulative curve shows average particle size values for the 10-50-90 percentage share, whereas the frequency curve helps to specify the occurrence frequency of particles of a particular size.

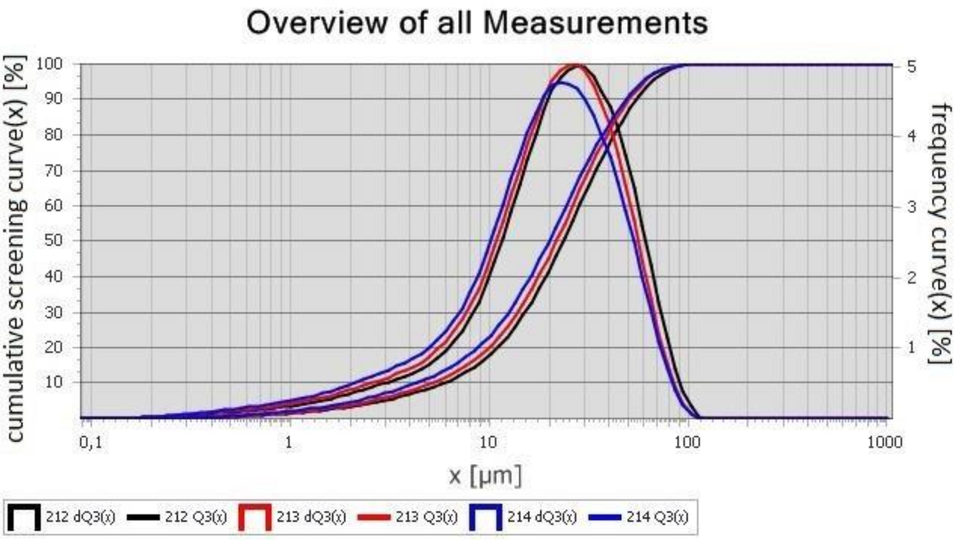

Fig. 2. A diagram of average particle size values for measurement 1.1.

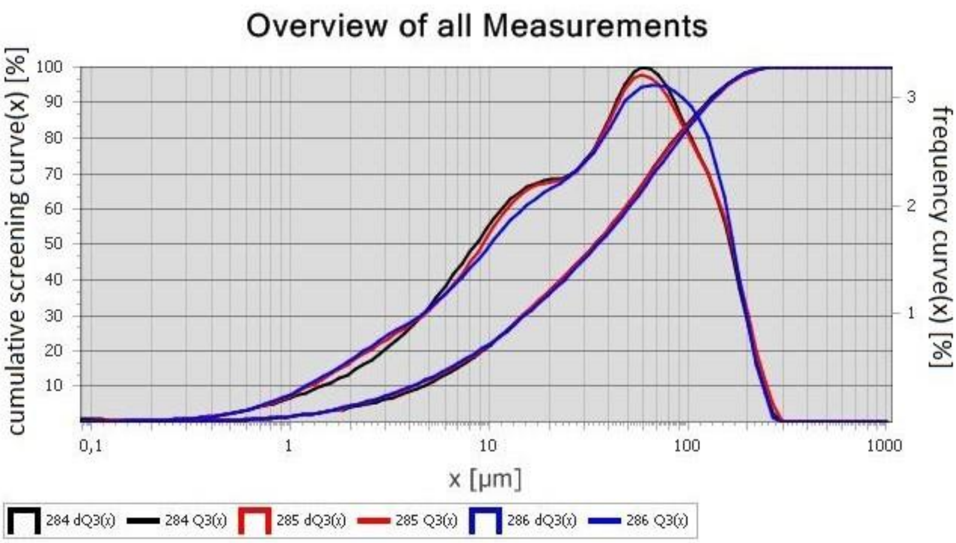

Fig. 3. A diagram of average particle size values for measurement 1.2.

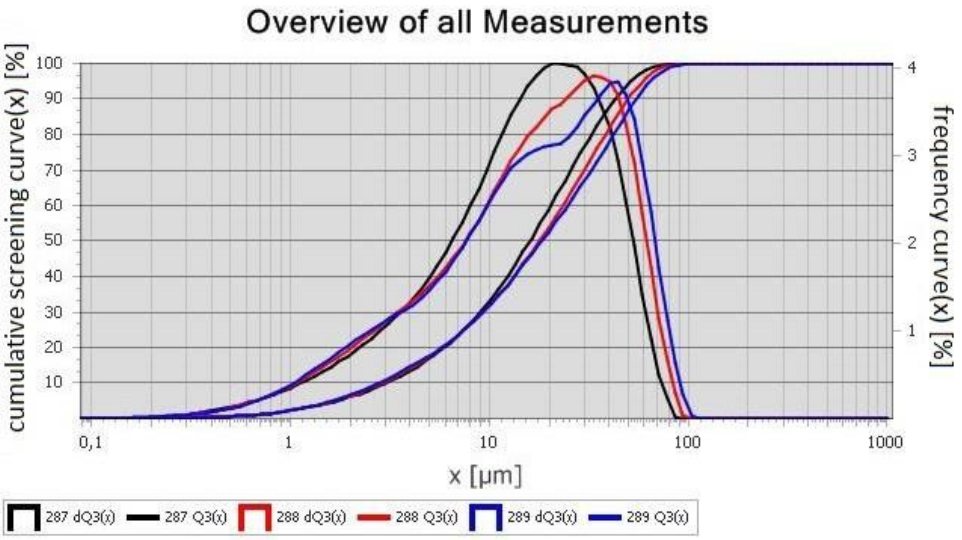

Fig. 4. A diagram of average particle size values for measurement 1.3.

In the case of measuring too big samples (flow absorption over 7–15%), high concentration may cause multiple dispersion of the sample. The optimal value of absorption was not exceeded in any case. The variability coefficient CV for the computation parameters as set by software should not exceed 5%. Unfortunately, in some cases it was exceeded even several times. It may be connected with the sedimentation process resulting from the high density of some samples. The variability coefficient CV is strictly connected with the shape of cumulative curves for a particular sample. The lower the variability coefficient (CV) value, the smaller the distance between cumulative curves for three subsequent measurements of the examined sample. The diagram presenting the granulation size for sample 1.2 (Tab.3) is a good example of the above. The variability coefficient for each percentage share (10%, 50%, 90%) did not exceed 6%. Consequently, the cumulative curves of sample 1.2 almost overlap, creating one averaged cumulative curve. Moreover, the time over which the material is added may influence the final results, especially for those samples for which the variability coefficient (CV) was considerably exceeded. They needed more time for adding the material, so there was less time left for dispersion and creation of an appropriate sample in a suspended form. The maximal time of adding the sample was set in SOP for 30 s.

Analysing the above presented diagrams, it can be observed that the frequency curve showing the occurrence of a particular fraction (in a form of a sine wave) reaches the maximal value on a level of about 4% with the values x [µm] of 18.50 and 35 µm, which corresponds with percentage share of about 60% on a cumulative curve. On the basis of data, it is possible to establish the sizes of particles in the examined samples – from 0.2 do 300 µm. PM10 fraction constituted from 20 to 35%, while PM2.5 from 5 to 8%.

3 Summary

1. The analysis of size and granulometric composition of dust's grains taken form supply installation filters allows for air quality verification in an industrial area in Wrocław, as well as measuring the size and composition of generated dust.
2. Taking into consideration the results of all the examined samples, it can be stated that dust accumulating in outside air filters from the analysed central air handling unit, both from March and October, are characterised with a similar granulation rate. It was

observed that the permitted PM2.5 and PM10 levels of dust concentration [7] were exceeded. Such a situation is observed mainly because there are a lot of industrial companies in Wrocław, emitting various chemicals – sometimes hazardous and also because of the fact that dwellings are heated in cold seasons of the year.

3. The samples collected in March had a maximal registered measure of 54.5 µm, while the samples from October – 128.2 µm.
4. The analysis of the results presented in diagrams 2–4, concerning granulometric composition allows to draw a conclusion that for measurement 1.1 and 1.2 the cumulative share of grains between 1-10 micrometres is 20%, whereas for measurement 1.3 this share is 35% of the whole dust accumulation.
5. In cases when the volume of the air supplied by a particular installation, as well as the mass of dust accumulated in filters is recognisable, their granulometric analysis can constitute a method of PM2.5 and PM10 measurements verification.

4 References

1. K. Juda-Rezler, *The impact of air pollution on the environment*, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2006, s.66
2. http://1filter.pl/pl/baza-wiedzy/filtracja/wymiary-i-rozklad-zanieczyszczen-powietrza-zewnetrznego.html (access date 04.2017)
3. http://www.gios.gov.pl/pl/aktualnosci/294-normy-dla-pylow-drobnych-w-polsce (access date 01.2018)
4. R. Wójtowicz, W. Szatko, Czasopismo techniczne MECHANIKA, wyd. Politechniki Krakowskiej, **2**, Nr 2-M/2012
5. FRITSCH, *Instrukcja obsługi* (Users manual)
6. Materiały reklamowe firmy FRITSCH (Advertising materials of FRITSCH company)
7. https://demo.dacsystem.pl/dane-pomiarowe/manualne/stacja/12/parametry/1506-1450-1449-1451-1452-1453-1454-1455-1507-1509-1511-1448/miesieczny/03.2015 (access date 01.2018)