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# ASPECTS REGARDING DUST EMISSIONS AT CEMENT FACTORIES IN ROMANIA AND METHODS TO REDUCE THEM

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**Abstract:** Cement plants are making sustained efforts to ensure that environmental pollutants' emissions fall within limits set by European standards. To this end, to reduce dust emissions, air collection and filtration systems are introduced into the technological flow before being released into the atmosphere. The main points of dust collection are related to the process of obtaining clinker, as an intermediate product that enters the composition of cement, but also to the final method of manufacturing cement. The paper presents experimental results on dust emissions at the evacuation points of a Romanian cement plant and identify where filters can be introduced.
**Keywords:** cement factory, technological flow, dust emission, bag filter, authorized maximum limit

## 1. INTRODUCTION

Directive 2008/50 / EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe provides for an upper limit for particulate matter $PM_{10}$ / $PM_{2.5}$ 70% of the average limit value for 24 hours (i.e., about 28 g / m$^3$ for PM10 and 17 g / m3 for PM2.5). The limit value of 35 g / m$^3$ should not be exceeded more than 35 times in a calendar year. The lower assessment threshold for the two categories of suspension powders was set at 50% of the limit value. The measurement of $PM_{2.5}$ must include at least the total mass concentration and the concentrations of compounds suitable for characterizing its chemical composition (sulfur oxides, nitrogen oxides, sodium, potassium, ammonia, chlorine, calcium, magnesium, but also elemental carbon or organic carbon). The same directive provides that for suspended dust and substances to be analyzed from suspended dust (e.g., lead), the sampling volume must be related to environmental conditions, particularly the temperature and atmospheric pressure recorded on the measurements' date (Directive 2008/50 / EC).

Like other industrial activities, the cement industry is strictly regulated by national and international environmental protection legislation. This means that pollutant emission levels are determined mainly by applying pollution abatement technologies (e.g., dust filtration) to comply with regulations (Kuenen, 2019).

Most cement plants in Romania say they have made substantial financial efforts, substantially reducing pollutants' emissions. These emissions are below the norms regulated by both its regulations and those imposed by the EU.

Thus, according to the official website of the Heidelberg Cement cement plant, Fieni, Dâmbovița County, the average dust concentrations at the exit from the clinker oven and the grill cooler were well below the maximum limits provided by the integrated environmental permit. (Figure 1).

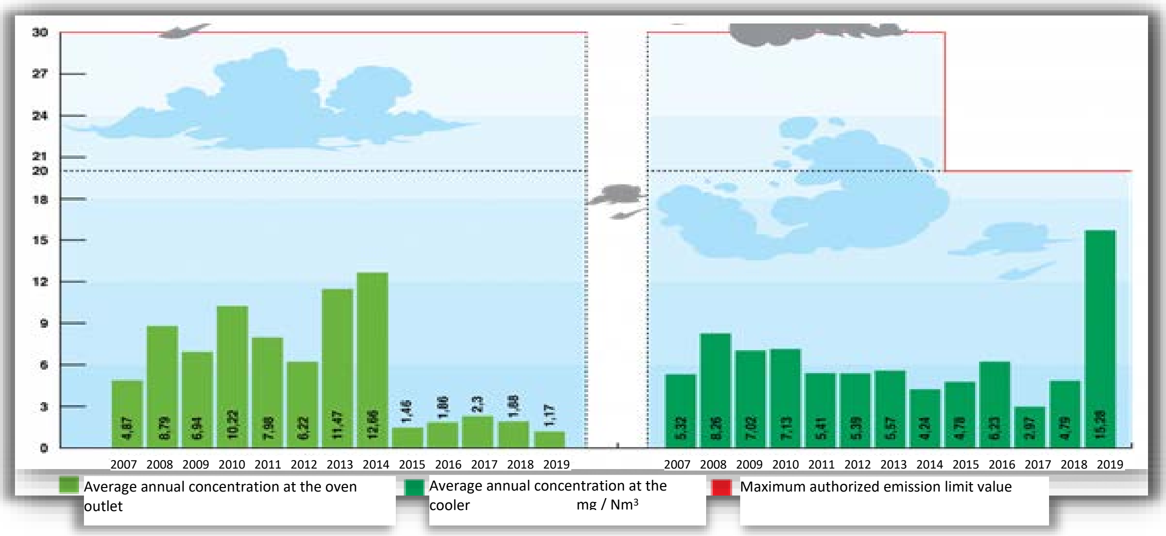


Figure 1 – The average annual powder concentration of the Fieni cement factory (mg/Nm$^3$), (https://www.heidelbergcement.ro/ro/fabrica-de-ciment-fieni-0)

The main sources of dust in the cement industry are stacks of the kiln system. Other dust emissions occur in the various pre-processing / grinding processes (raw materials, fuels, cement). The dust emission may also result from the storage and handling of raw materials, fuels, clinkers, and cement and used vehicle traffic at manufacture (Abu-Allaban, 2011; Kuenen, 2019).

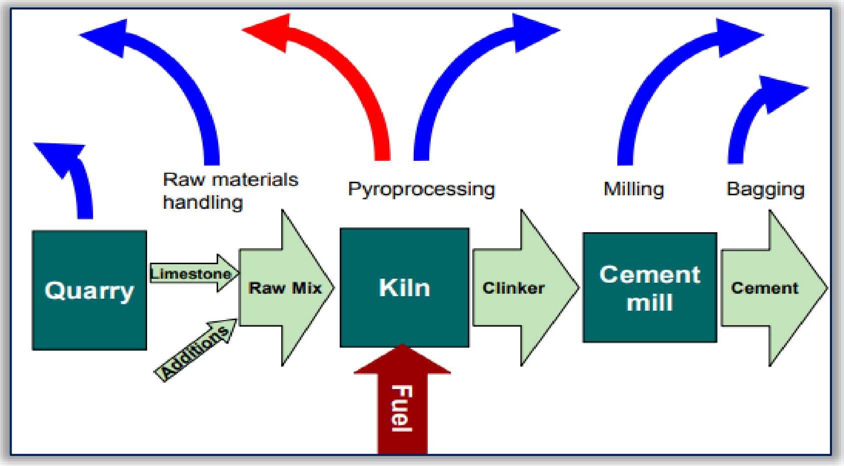


Figure 2 – The general technological flow for obtaining cement, (*Kuenen, 2019*)

Cement production begins in quarries, with the excavation of limestone and clay. They are crushed and then transported to the factory by conveyor belt systems and/or rail. Limestone, marl/clay, and alternative raw materials are dosed according to recipes established by factory laboratories, dried in drying towers, and routed to flour mills (raw mill). The drying of the raw materials is done with gases from the clinker oven, and when it does not work, gases from the auxiliary grate are used.

The grinding of the raw materials is done in two-chamber ball mills, from the mill, the material being transported to dynamic separators. The fine part is transported pneumatically or with elevators to the silos of raw materials, and the coarse part returns to the mill. The final product must fully comply with the requirements imposed by the European product standard SR EN 197-1: 2011 (Purnomo, 2018; Uwasu, 2014).

The mixture of ground raw materials (flour) from the storage silos is dosed and transported to a 4-stage heat exchanger, where it is preheated from 60°C to approx. 850°C. The heat is taken from the oven's hot gases, which passes through the heat exchanger counter currently with the flour fed on top.

The flour, preheated and partially decarbonated in the heat exchanger, is introduced into the rotary kiln where it reaches a temperature of about 1450 °C and is transformed at the exit of the kiln, by sudden cooling, into a new, crystalline, granular-looking material called Portland clinker which is an intermediate product, but essential in the manufacture of cement. Sudden cooling of the material takes place in a grate cooler, from about 1350°C to 100°C, with air from the fans.

Metals introduced into the furnace by raw materials or fuel will be present either in the recesses or in the clinker. The vast majority of heavy metals are stored in the clinker. Extremely volatile metals such as mercury and thallium are not incorporated into clinker to the same degree as other metals. Many heavy metals evaporate at high temperatures and then condense on clinker, on the partially reacted raw materials or on the dust particles.

After pre-conditioning, the furnace's gases go through a depollution system (which finally includes bag filters) to separate the dust before evacuation to the chimney. To obtain cement, the following mixture is used: the clinker obtained in the oven, furnace slag, gypsum, and grinding additives (Purnomo, 2018; Uwasu 2014).

The granulated blast furnace slag is dried in a rotary dryer using hot air recovered from the grate cooler and/or natural gas from the auxiliary hearth and a bed dryer fluidized with natural gas. They are extracted from silos, dosed, and then fed into cement mills. Cement mills are tubular ball mills, bicameral, and operate on a closed process. The mill's material is transported to a dynamic separator, which separates the fine part (cement) from the coarse part. The cement is taken over by a transport relay and stored in the cement silos, the coarse part returning to the mill.

Pollutant emissions are formed from reactions in the technological process and the combustion of fuels are substances formed either from a single element or composed of several chemical elements. Concentration limits differ depending on the nature of the pollutant, the manufacturer's nature, and the country of emission. The degree of persistence in the environment differs from pollutants to pollutants and can be influenced by weather conditions. Each phase of the technological process of cement manufacturing is a point of emission of pollutants.

The paper presents the vulnerable points in cement manufacturing's technological flow, likely to be equipped with separators and dust filters, and the experimental results performed on a set of measurements for dust emissions at one of the largest cement plants in Romania. It also presents the general aspect of the construction of dust filters used on cement plants' technological flow.

## 2. MATERIALS AND METHODS

On the technological flow of cement manufacturing, a series of separators and dust filters are necessary to reduce emissions into the atmosphere. They are mounted in vulnerable points, where the amount of dust released is relatively large, as shown above.

Thus, in the area of the raw material mill (Figure 3) are located both the separators (2) and the cyclones for separating the coarse dust (3), but also the filter with pulse-jet bags (9), which collects the dust resulting from the evacuation of the ground mixture. When feeding the mill, there is a drying tower (6) provided with dust collection cyclones.

The pulse jet filter is a filter with filter bags that requires compressed air at 6-7 bar, passed through 5-micron filter elements, and dried (dew point - 40 °C). Filter cartridges require max. 4 bar, which still requires the use of a dust suction fan.

Dry electrostatic filters (or electrofilters, see Figure 7) separate the finest dust particles resulting from the combustion of gases up to a temperature of 420 °C, by artificial electric charge (at high voltage). The principle is mainly used for hot gas in the dedusting of incineration plants and the production of metals and the cement industry.

The processed gas loaded with dust enters the horizontal electrofilter and is brought to a consistent flow pattern by distributing the gas and the entire filter profile. The comparative advantages of using electrostatic filters compared to other particle collecting devices are:

≡ the possibility of using carrier gases at high temperatures (200-250°C);
≡ have a minimal pressure drop (10-25 Pa), so that the costs of electricity consumed by fans is minimal;
≡ the collection efficiency is too high (94-99%) if the use is suitable for the type of dust, but if the properties of the dust are not well known, this efficiency decreases to 92%;
≡ can cover a wide range of particle sizes and dust concentrations, but are most effective for particles smaller than 10 microns.

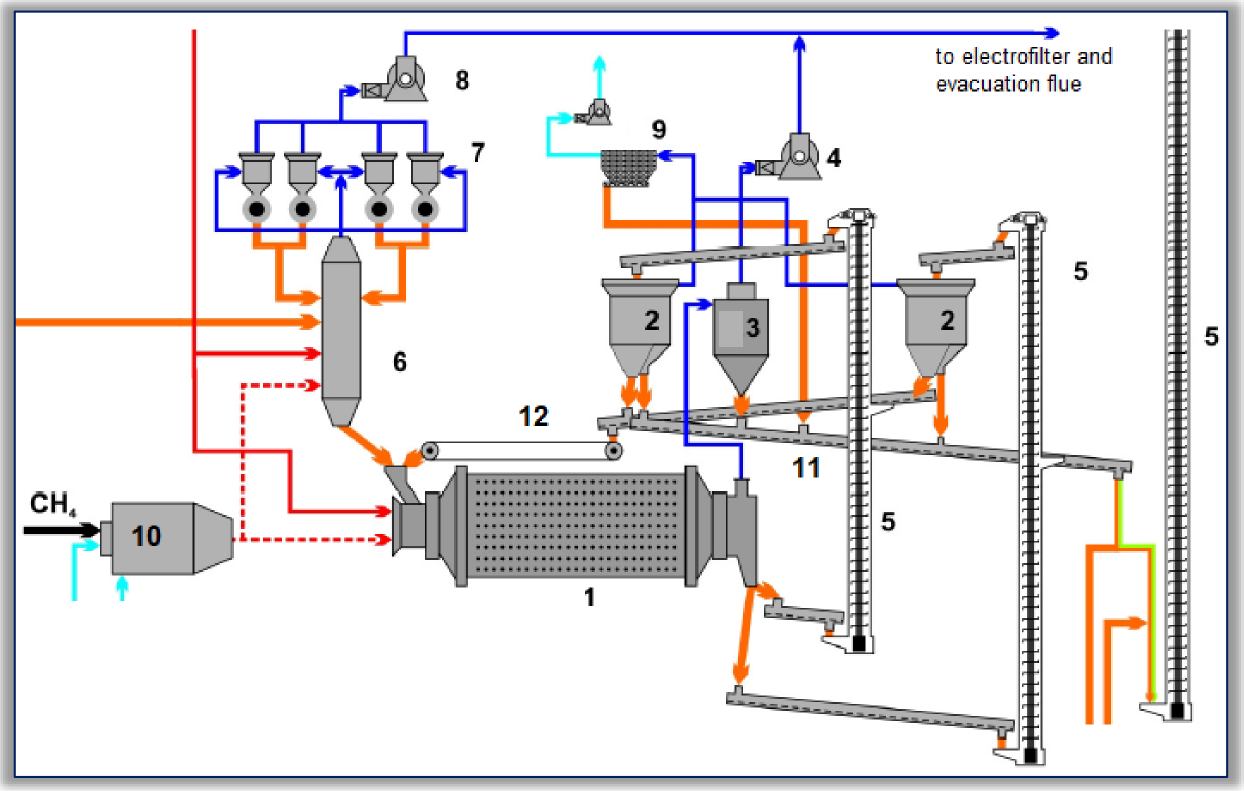


Figure 3 – Arrangement of dust filters in the area of the flour mill (raw materials)
1. flour mill; 2.separatoare; 3. cyclone dusting mills; 4.dusting fan; 5.elevatoare; 6. drying tower; 7. drying tower dusting cyclones; 8. fan tower dust removal; 9. pulse-jet filter dust separator and attachments; 10. auxiliary burner; 11. fine material transport gutter; 12.grain and coarse material transport belt (from https://www.saem.ro/wp-content/uploads/2016)

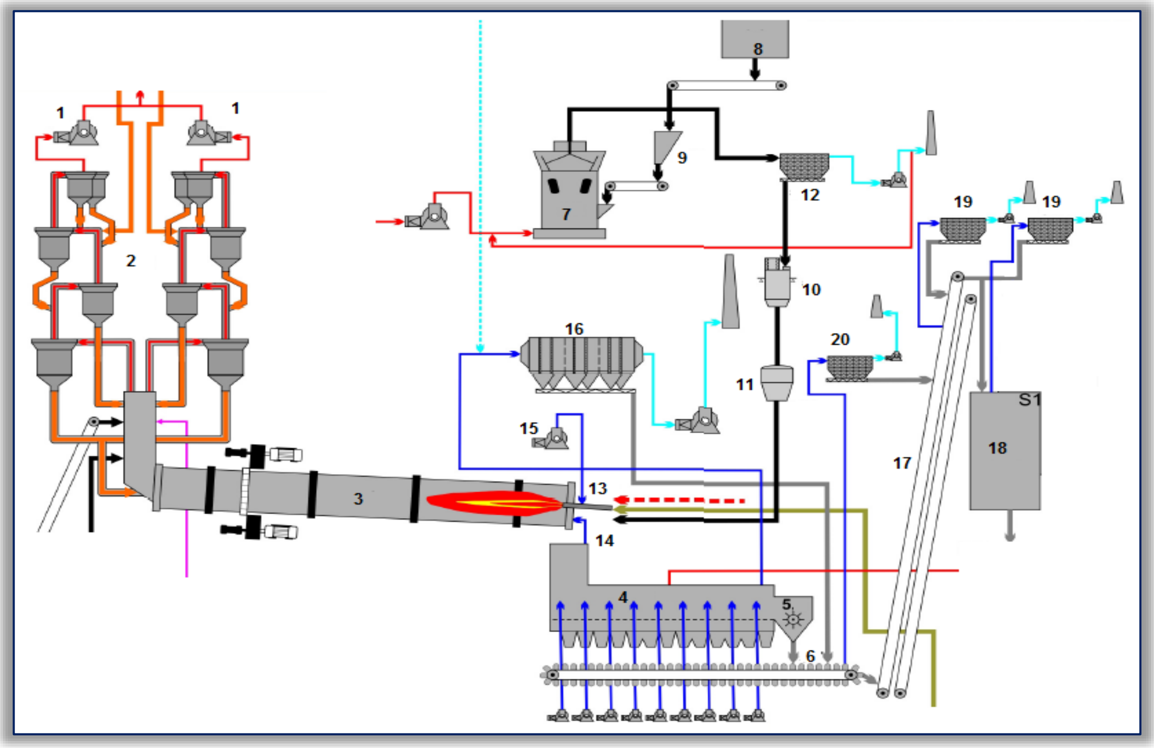


Figure 4 – Arrangement of dust collection systems in the area of the rotary clinker oven
1. fans; 2.heat exchangers; 3. rotary oven; 4. grill cooler; 5.clincher crusher; 6. clinker carriers; 7. coal mill; 8. coal silo; 9.coal hopper; 10.ground coal silo; 11. dosing system; 12. filter with coal mill dust removal bags; 13. burner; 14. extension furnace; 15.primary air fan; 16.electrofilter for the grill cooler; 17.cliner transport belts; 18. clinker silos; 19. strip dust filters and clinker silos; 20.clinker transport dust removal filter (from https://www.saem.ro/wp-content/uploads/2016/06/ENERGOMONTAJ-Romania_Cement-factories.pdf)

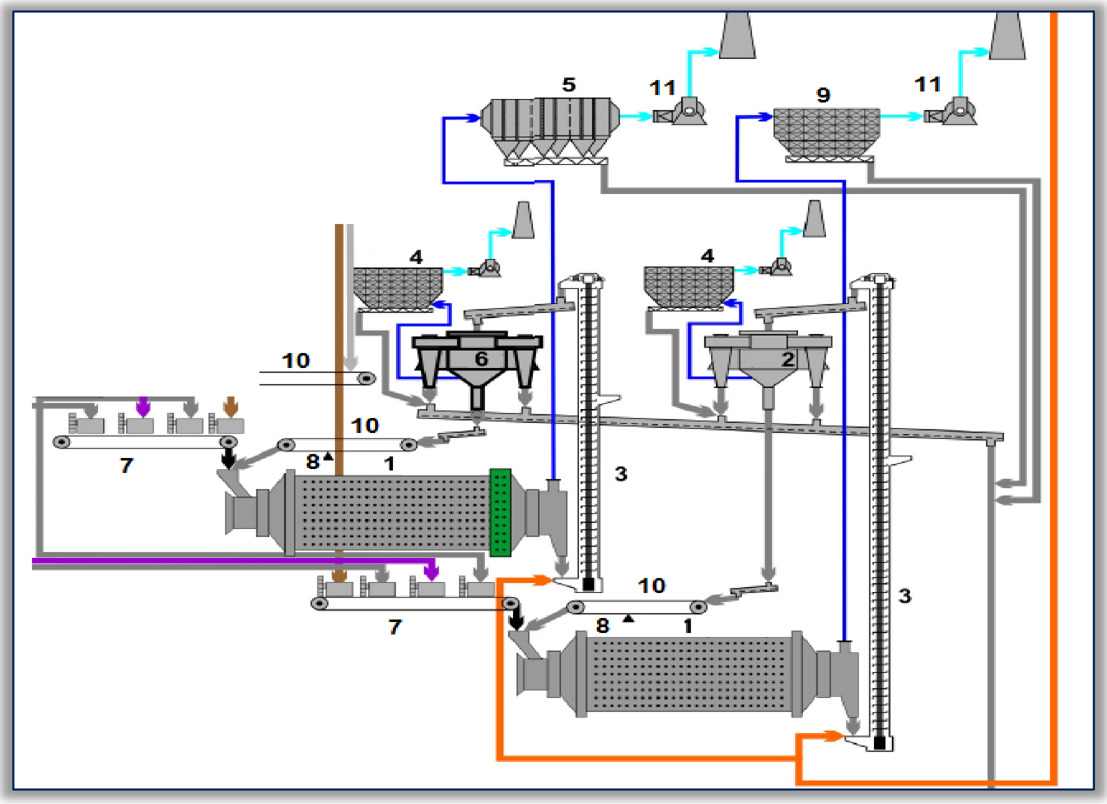


Figure 5 – Area of mills for grinding and obtaining cement (from https://www.saem.ro/wp-content/uploads/2016)
1. cement mill; 2. separator; 3. elevators; 4.filter with dust bags attached; 5.electric filter dust mill cement; 6.variable speed separator; 7. material dosing system; 8.weighing device; 9. filter with bags for dusting cement mill; 10. conveyor belts; 11. fans

In the rotary kiln area for obtaining the clinker (Figure 4), there are several separators and dust filters, mostly since the processing of the primary fuel (coal mill 7) and the alternative fuels is performed. The area is provided both with a bag filter dedusting system (12), for the coal mill, and a high capacity electrofilter dedusting system (16) for the clinker grill cooler (4) and the bag filter (20) for the evacuation of dust to the transport system under the grill cooler. Also, in this area, it is necessary to dust the storage silos of the clinker (18) and the transport systems therein (17). In this sense, the bag filters (19) are provided. The transport of the gas loaded with material dust is done by suction with fans' help located after dust traps and before the flue gas chimneys.

In the area of ball mills for grinding clinker and obtaining cement (Figure 5), there are also dust removal systems equipped with bag filters or electrofilters. The figure shows that the area is provided with two cement mills (1), fed by a particular system with appropriate dosing devices for each grinding mixture component. Separators (2) and (6) are each provided with a bag filter (4) to dust them and their annexes, but each mill has, in turn, its dust removal system, respectively, an electrofilter (5) and a bag filter (9).

These are not the only dust removal systems on a cement plant's technological flow, as we presented at the beginning of the paper. There are also dedusting systems in the areas of cementing and some of its components, as well as in the area of marl and limestone crushers or raw material dryers.

In order to highlight the dust concentrations of the gases discharged into the atmosphere on the technological flow of a cement factory in Romania, the paper presents the values of these concentrations obtained experimentally in March 2019.

In general, emissions are measured by different methods, either with fixed-mount monitoring equipment (EMC) or with mobile equipment by the test house (test house measurements).

The results of these measurements, concentrations, and/or emission volumes of the various compounds are determined under certain specific chimney conditions (e.g. moisture, oxygen level). They must be converted to the standard conditions defined by the cement manufacturer and local authorities.

The raw materials used in the factory for the production of clinker were made of limestone (74.2%), marl (21.25%), pyrite (1.15%), sand (3.4%), given that the productivity of the raw material mill was 283.6 t /h.

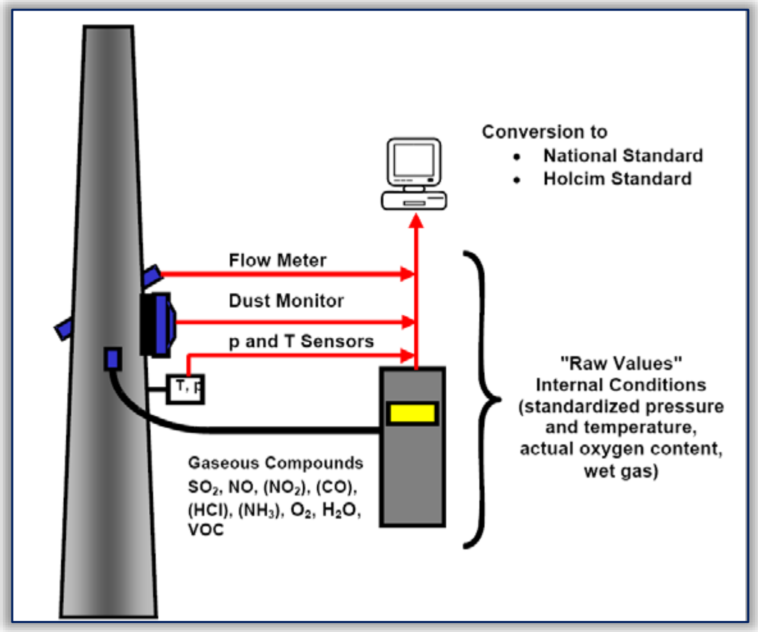

Figure 6 – Scheme of the arrangement of the experimental sampling equipment

Unprocessed values are the values indicated directly by the equipments. These values are defined under certain (internal) conditions and are usually not converted to the dry gas stage or an oxygen reference level. In a calculation program, unprocessed values must be converted to the local and factory standards.

The fuel used in the rotary kiln to make clinker consisted of coal (coke) (61%), used tires (16.7%), plastic (1.7%), fluff (8.6%), agricultural waste (0.6%), lower coal (11.4%). The calorific value of coke was, on average, about 6450 kcal/kg, while the average calorific value of alternative fuels was about 4925 kcal / h (weighted average).

Clinker (76.8%), gypsum (5.9%), limestone (13.3%), powder (4%) were used to obtain the cement, the productivity of the cement mill being about 135 t/h, obtaining a Portland cement with a specific surface Blaine 4150 cm2 /g.

Two measurements were performed, and the results presented in the paper represent their average. According to SR ISO 9096: 2005 and SR EN 13284-1: 2015, the measurement procedure is taken over: the essential equipment being ISOSTACK Basic. The atmospheric air temperature during the day the measurements were made was between 3–10°C.

**3. RESULTS**

The results of the experimental determinations on the dust concentration of the gases discharged into the atmosphere at the chimneys of the cement plant are presented in Table 1.

Table 1. Dust emission parameters at different characteristic points of the technological flow of the analysed cement plant

| No. | Emission source | Dedusting equipment | Dust emission, $mg/Nm^3$ | Gas flow, $Nm^3/h$ | Gas speed, m/s | Temperature at measuring point, °C |
|---|---|---|---|---|---|---|
| 1 | Grate cooler | Electrofilter | 11.01 | 282009.1 (21% $O_2$) | 19.39 | 222.0 |
| 2 | Coal mill | Bag filter | 24.57 | 25634.1 (10.5% $O_2$) | 10.30 | 90.1 |
| 3 | Bagging machine | Bag filter | 0,92 | 25947.4 (21% $O_2$) | 11.34 | 17.5 |
| 4 | Marl crushers | Bag filter | average 1.25 | 23856.8 (21% $O_2$) | 14.50 | 9–10 |
| 5 | Cement mill – separator output | Bag filter | 4.13 | 34275.6 (21% $O_2$) | 9.86 | 59.6 |
| 6 | Cement mill – mill output | Bag filter | 1.87 | 48776.6 (21% $O_2$) | 7.91 | 55.8 |
| 7 | Limestone crushers | Bag filter | average 3.19 | 20886.2 (21% $O_2$) | 16.86 | 12.0 |
| 8 | Slag dryer | Bag filter | 1.45 | 74589.3 (21% $O_2$) | 28.24 | 54.1 |

From the data presented in the table, it is observed that the highest concentration of dust is the gas discharged to the chimney system chimney in the area of the coal mill (24.57 mg / $Nm^3$ gas), followed by the exhaust chamber of the cellar grill dust extraction system. 11.01 mg / $Nm^3$ gas. However, the values of dust emissions at the emission sources from the technological flow at the analyzed cement plant were (at the time of the measurements) within limits allowed under the Integrated Environmental Permit of 30 mg / $Nm^3$ dry conditions.

No exceedances of the values allowed in any vulnerable point were observed, and the measurements at the exhaust chimneys highlighted this.

The exhaust gas flows to the chimneys are also presented in the table, at specific oxygen concentrations and velocities of the gas in the pipe, in dry conditions. The gas temperature at the exhaust chimneys is also specified, which differs depending on the place of gas collection.

It is usual for the level of dust concentrations to be at a minimum level, given that both centrifugal coarse dust separation cyclones and filter elements arranged in bag filters have been introduced into the technological flow, their capacity is different depending on the value of the exhaust gas flow.

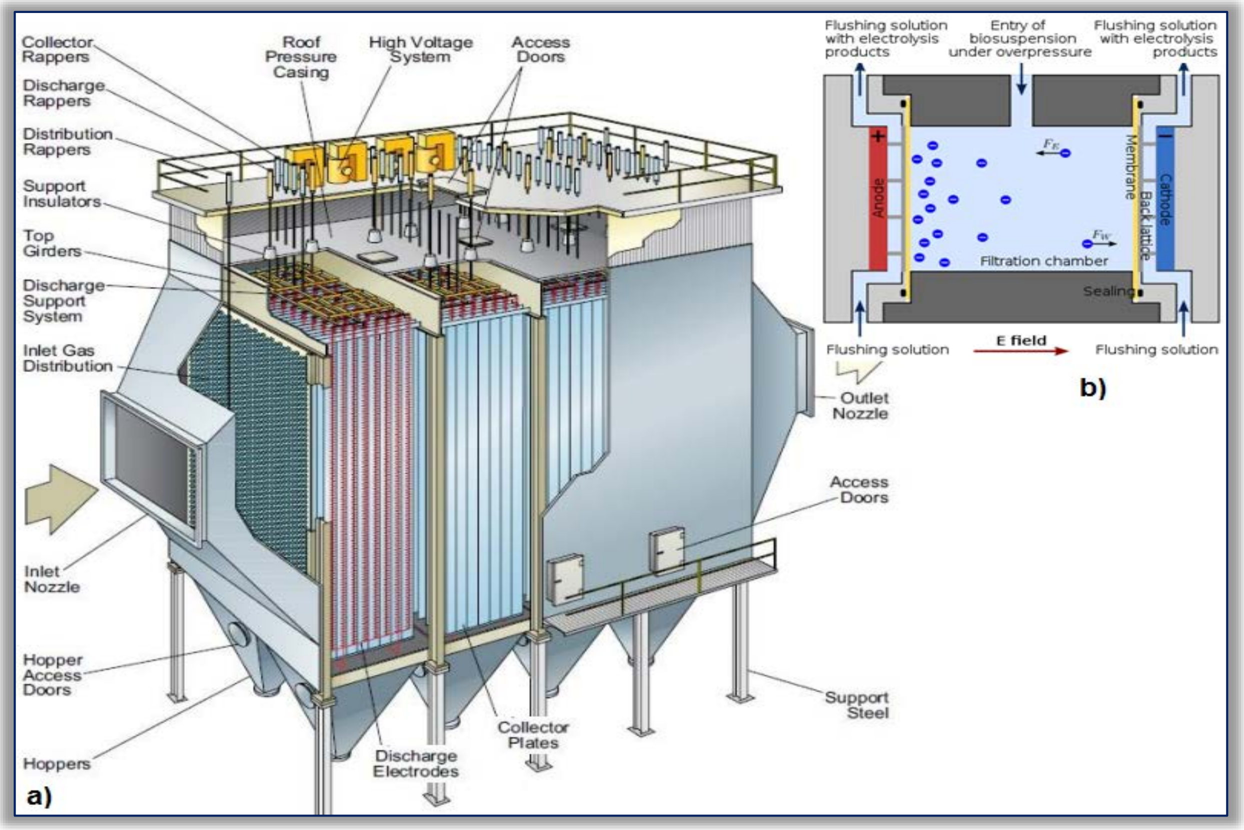


Figure 7 – Horizontal electrostatic precipitator: construction diagram (a) and operating principle (b) (https://etd.ohiolink.edu/)

The working process of a bag filter is shown schematically in Figure 8. Bag filters are machines that perform the separation by filtration in the gravitational field of heterogeneous gas mixtures (gas-solid). They retain solid particles from gaseous mixtures on the filtration surface. It is used in the cement industry to separate solid particles (dust, material powders) from the air, according to the schemes presented above and the technological flow of the cement plant (Bhargava, 2016; Liu 2019).

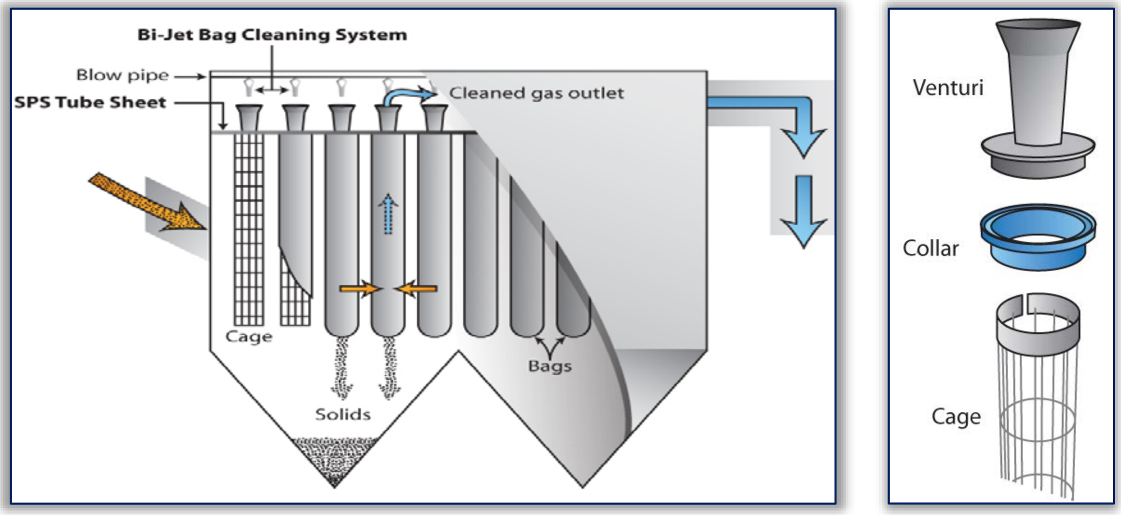


Figure 8 - Schematic diagram of a bag filter (http://www.redecam.com/bag-filters)

## 4. CONCLUSIONS

The cement industry is probably the largest concentrator of emissions, not only of greenhouse gases or other harmful gases, loaded with pollutants for the environment (water, air, soil) and material dust (dust).

The whole technological flow is filled with dust separation equipment, dust which is obtained together with the gases at the specific exhaust chimneys. Most such equipments are filters with bags of different capacities and filter materials specific to each gas-solid mixture released in a particular work area of the factory.

All cement factories in Romania have made special financial efforts to comply with European standards on dust emission concentrations ($PM_{10}$ and $PM_{2.5}$).

Following the measurements performed by an authorized laboratory to perform the measurements, at the beginning of spring 2019, the experimental results obtained at one of these factories show that these levels fall within the authorized operating limits.

However, it is necessary that the efforts to comply with the limits provided by the regulations be continuous, and as the dust removal equipment undergoes positive changes, from a constructive and functional point of view, they should be introduced quickly on the technological flow of the factories, so that dust emission levels to decrease even further.

**Note**:

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