CEMENT PRODUCTION AND ENVIRONMENT

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ABSTRACT

Air quality in the surroundings of three cement plants, which are the most representatives for different industrialization levels (one in Belgium, one in Algeria and one in Vietnam), is estimated by gaseous and dust concentration measurements and fall-out dust networks. Heavy metals, especially the ecotoxic elements are determined. The deposition rates are presented as a function of source-distance in order to emphasize the pollution dispersion varying with prevailing winds. The measured data are compared with the calculation results from Berliand model; different equipment for air quality control is proposed.

1. Introduction

Thanks to the adoption of clean technology, the industrial activity, which is known for a long time as a pollution source, has succeeded in developed countries in reduction of industrial rejects. The situations still remain dramatically endanger in developing countries, where, often due to economical constraint, the standards are not respected. The surrounding environment such as the air, water and soil as well as the public health are threatened.

In this present paper, by comparison of the environment situation in the vicinity of three cement plants, Obourg in Belgium, Algiers in Algeria and Haihong in Vietnam, we attempt o emphasize the difference of air quality in the surroundings of these cement plants. The air quality depends on applied technologies, combustible and air-cleaning devices. Therefore, the different options of air-cleaning devices should b proposed in order to improve the air quality in the neighbouring of cement plants.

The brut date is referred from Environment Department of Obourg Cement Plant, by Catholic University of Louvain, University of Blida and Civil Engineering University of Hanoi. They are dust and gas emission at Obourg and Haphong Cement Plants, fall-out dust in the surroundings of Obourg and Lager Cement Plants.

2. Experimental conditions

2.1. Sampling

Dust samples were taken in the successive chambers of the electrostatic precipitators of Obourg Cement Plant in order to determinate the composition of soluble and insoluble elements contained in settled dust.

Most of the fall-out dust samples were taken with dust deposition gauges. The unit of fall-out dust is manifested in pollutant mass (g, mg, μg) per deposition surface (m²) during one day (d). A permanent network realized by Public Service Scientific Institute (ISSeP) consist of eight dust deposition gauges; a supplemental network of four dust deposition gauges was set up by Catholic University of Louvain (UCL). They were set up in an area about 40 km² surrounded the Obourg Cement Plant. A network of nine dust deposition gauges and two reference gauges were located in the surrounding of the Algiers Cement Plant, over an area about 00 km². The polyethylene gauges are painted in black in order to limit proliferation of algae. A diameter of 12 cm, 20 cm or 40 cm, is a compromise between good sampling characteristics and the necessary quantity of water collected during the 1-month sampling periods [1]. The gauges are installed at a height of 1.5 m from the ground and their contents are collected at less every month ([2]. Such a period covers a wide spectrum of meteorological and pollution circumstances.

The aerosol sampling was carried out in the vicinity of the Haiphong Cement Plant, over an area about 1 km². The suspended dust and gas are measured in pollutant mass (g, mg) per volume of air (m³).

Most of the samplings were realized during 1994-1995.

2.2. Analysis

The gases are determined by colorimeter and gas chromatography (GC). They are measured in mass per volume of humid gas (mg/m³ gas humid) or normal dry gas (mg/Nm³).Ion chromatography (IC) detects soluble Cl^-, NO_3^-, SO_4^{2-}, Na^+, K^+, NH_4^+. A few elements (Cd, Pb, Cu, Hg, Ca, F) are determined by atomic absorption spectrometry (AAS). The ions and these elements are expressed on mass per volume of standard solution (mg/l) or (µg/l). The other elements (As, Ba, Br; Ce, Co, Cr, Cs, Eu, Fe, K, Na, La, Rb, Sb, Se, Sm, Th, U and Zn) are measured by instrumental thermal neutron activation analysis (INAA). They are measured in mass of element per total mass (mg/g) or (µg/g).

3. Results and discussions

Dust collected at electrostatic precipitator (ESP):

In the succession of chambers after the clinker kiln (smoke chamber, funnel, chamber 1,2,3,4 and stack), the concentration of the ions and most of the volatile elements is increased. On the contrary, the refractory elements have a concentration that is decreased in the succession of these chambers (Fig.1, Fig.2 and Fig.3). This phenomenon can be due to volatilization that distills off the metals or their components with a low boiling point, namely Hg, As, Se, Pb, Cd, Cs and Br [3]. Clinker production is processed at high temperature (1500°C) [4]. Upon leaving the reaction chamber (kiln), the waste gas temperature decreases and the metal vapors condense onto the surface of the smallest particles or remain in vapor phase. The electrostatic filter efficiency is more and more increased following the cambers; so it is capable to collect the fine particles at the last chamber. Most of the heavy particles (refractory elements) are settled at the first chamber. It is obvious that most of the ecotoxic metals (Pb, Cd, Sb, Hg and As) are largely associated with the fine particulate matter, which is only slightly retained by air-leaning device (ESP). This is once more affirmed when the concentration of these elements contained in the fall-out dust would be determined.

Emission rate

Gaseous emission samplings have been carried out at the highest stack of Obourg Cement Plant during several campaigns in 1992 (Fig.4). The dust emission data that we take in consideration is realized during the last ten years. The obtained results show that the emission rates are always maintained below the tolerance levels (Fig.5).

The ambient air in the surrounding of Haiphong Cement Plant that is evaluated through suspended dust and gas concentration (SO_2, NO_2, CO, CO_2), should be considered as strongly polluted for urban environment (Fig.6)[5].

Fig.1: Variation of ion concentration at ESP

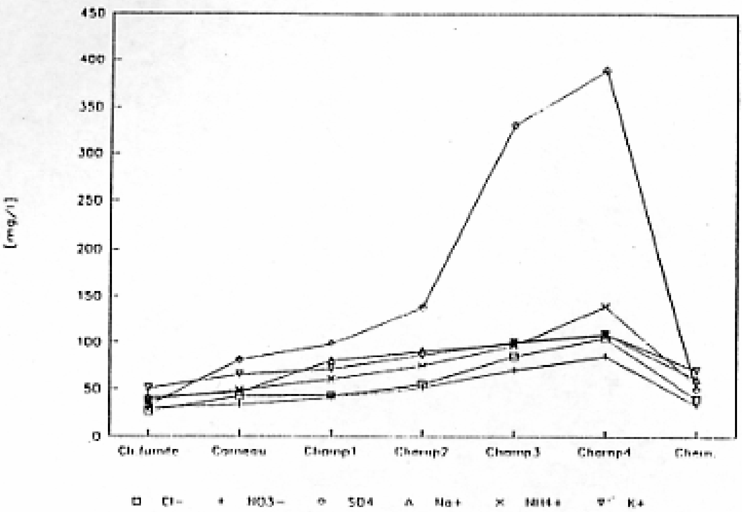

Fig.2: Variation of volatile elements concentrations at ESP (Cs, Br, As, Se, Hg)

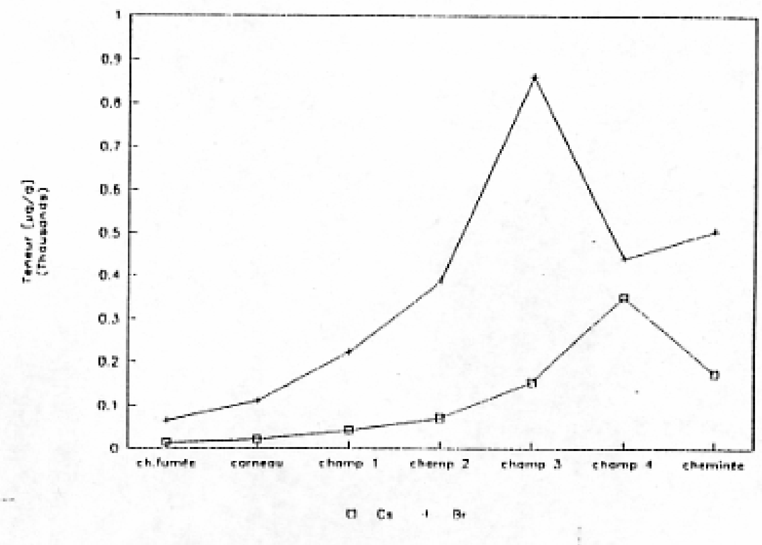

Fig.1: Variation of ion concentration at ESP

Fig.2: Variation of volatile elements concentrations at ESP (Cs, Br, As, Se, Hg)

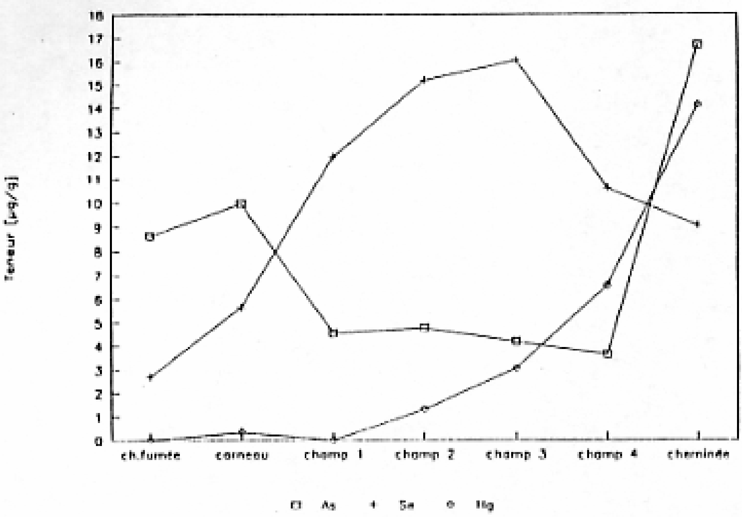

Fig.3: Variation of refractory elements concentrations at ESP (Eu, U, Sm,Th, Sc)

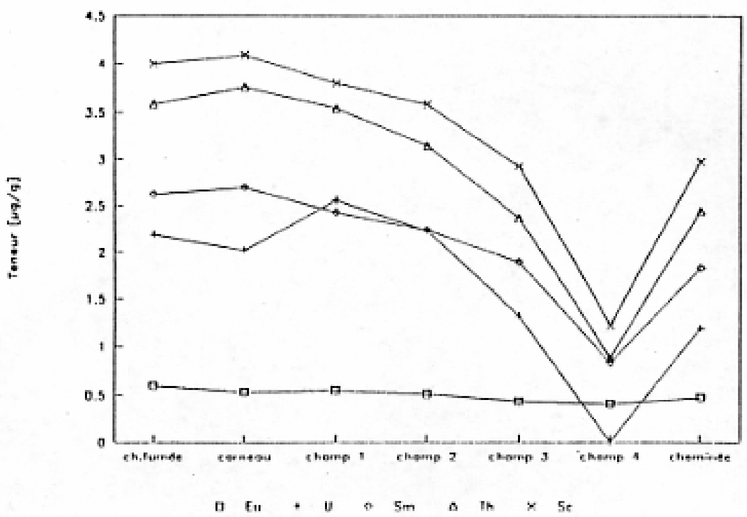

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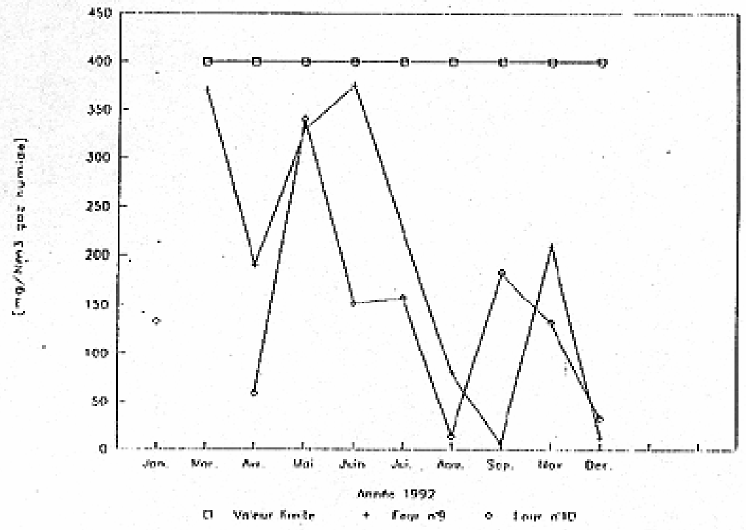
Fig.3: Variation of refractory elements concentrations at ESP (Eu, U, Sm, Th, Sc)

Fig.4: Gaseous emissions at Obourg Cement Plant

SO_2 emission



NO_2 emission

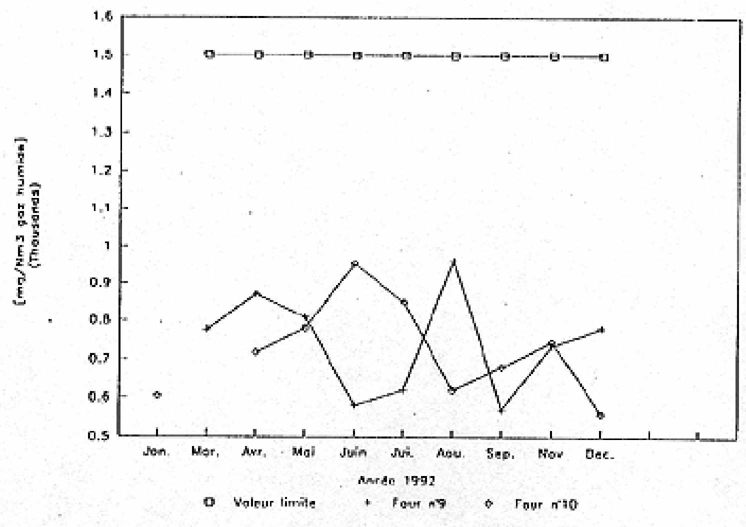


Fig.4: Gaseous emissions at Obourg Cement Plant
SO_2 emission
NO_2 emission

Fig. 5: Dust emission at Obourg Cement Plant

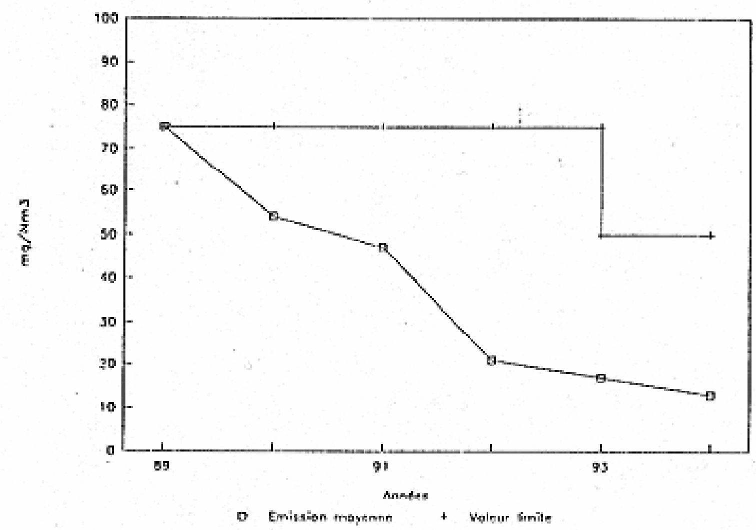


Fig. 6: Pollutants emissions at Haiphong Cement Plant
Campaign I (August 1993)

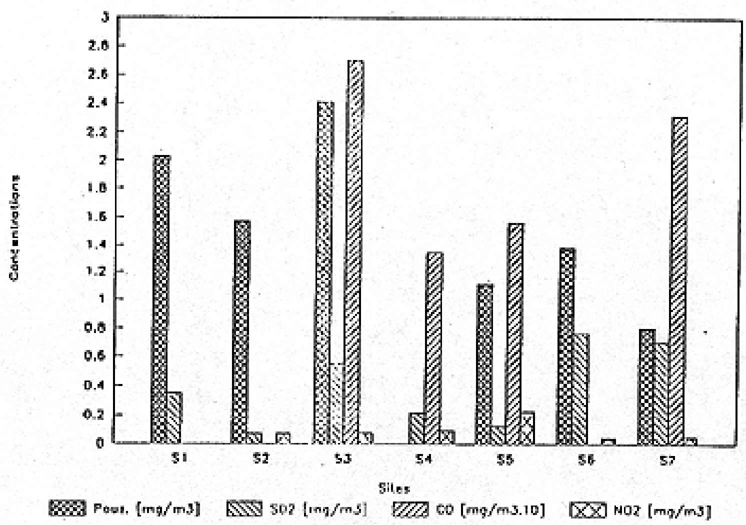
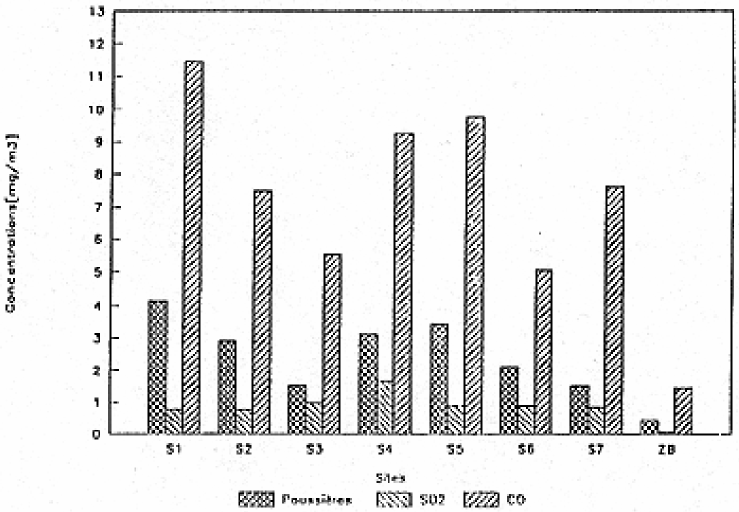


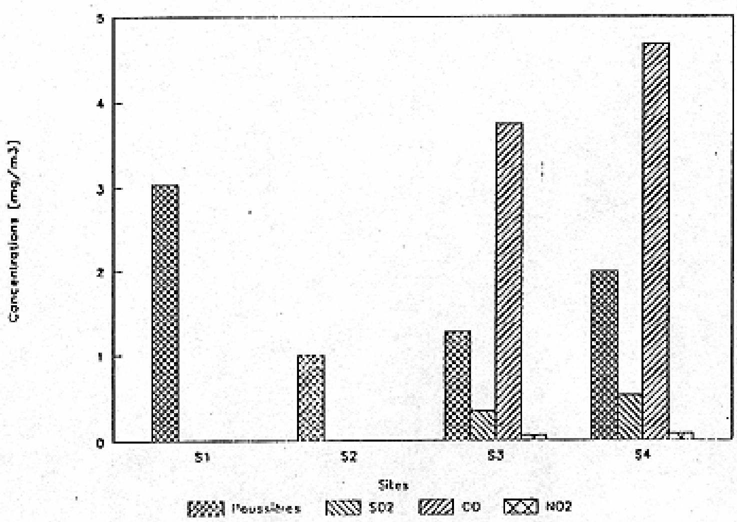
Fig.5: Dust emission at Obourg Cement Plant
Fig.6: Pollutants emissions at Haphong Cement Plant

Campaign 1 (August 1993)

Campaign 2 (March 1994)



Campaign 3 (July 1995)



Campaign 2 (March 1994)

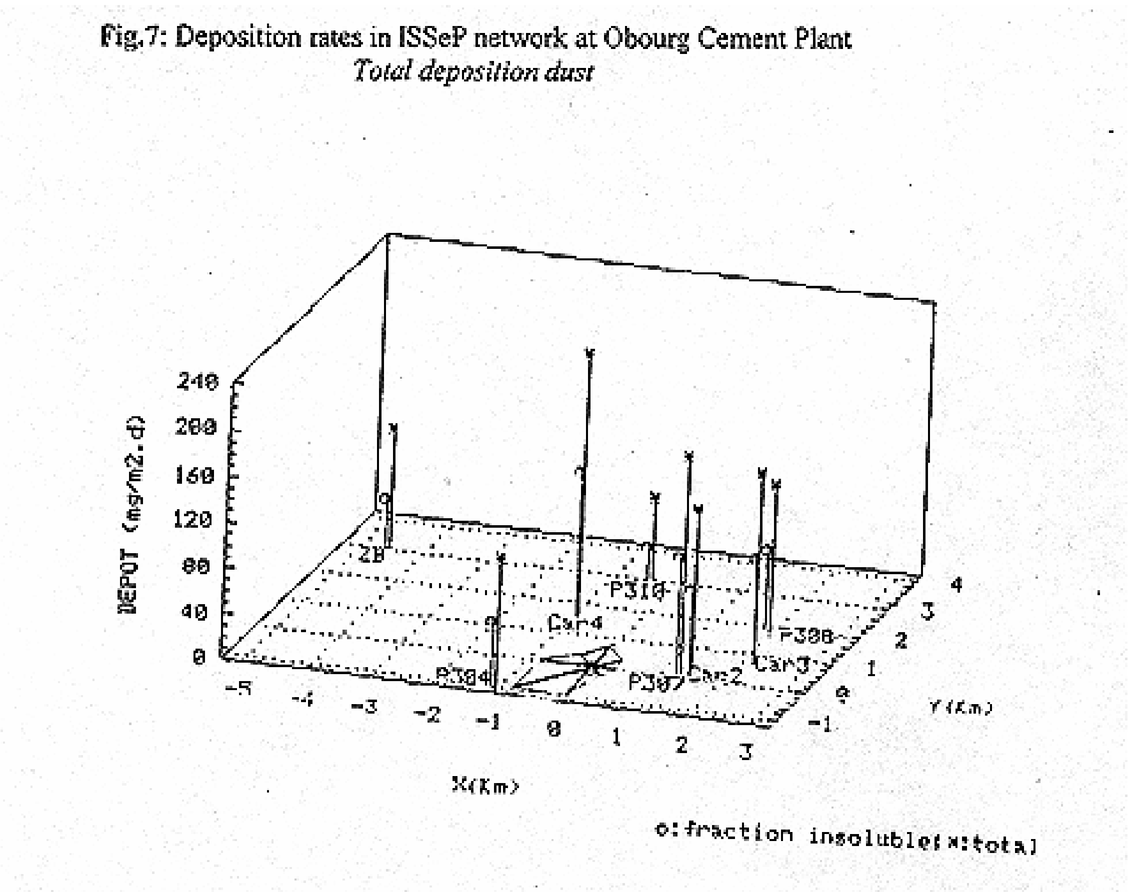
Campaign 3 (July 1995)

Atmospheric deposition

It is beyond the scope of this paper to scrutinize all the results provided by the measurement campaigns. Only the total deposition dust and those elements that are characteristic of cement production activity or are particularly ecotoxic were of interest to us, i.c. Ca, Na, K, Cd, Pb, Hg, Cr, Zn, As ...

Fig.7 displays the mean-year deposition rates of total fall-out dust and heavy metals in the permanent sampling network in the neighbouring of Obourg Cement Plant. Fig.8 displays the total deposition dust in the sampling network in the surrounding of Algiers Cement Plant. Fig. 9 shows the deposition rates as a function of source-distance in the UCL network and Algiers network, taking into account the prevailing winds (south-west at Obourg region and south or east at Algiers region).

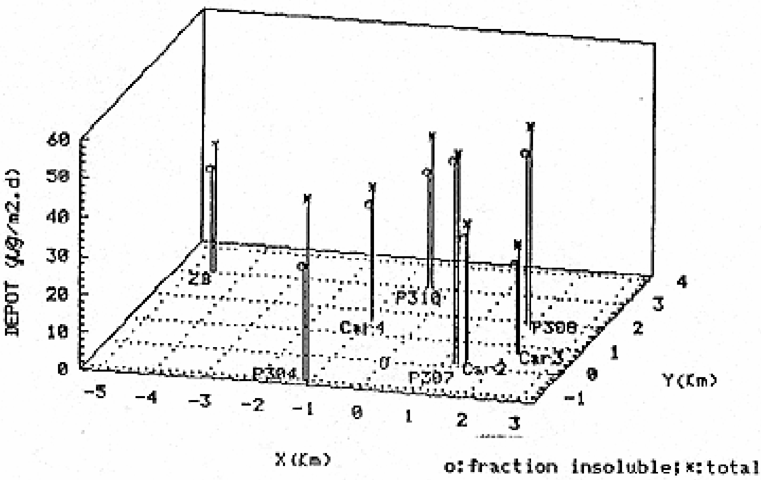
Fig.7: Deposition rates in ISSeP network at Obourg Cement Plant
Total deposition dust



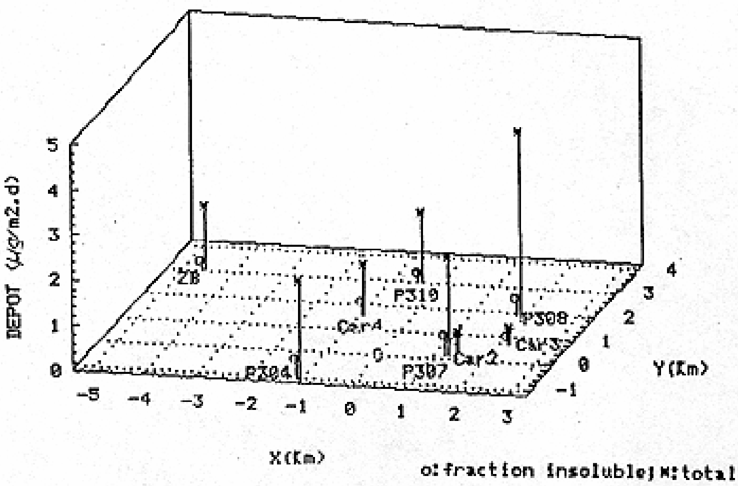
At all sampling sites around Obourg Cement Plant, the mean-year total deposition dust is below the TA Luft tolerance level of 350 mg/m².d [6]. The water-soluble, considerably more aggressive than the insoluble fraction for soil, is about one half of the total deposition [7]. The Ca. Typically characteristic of cement production activity, presents higher concentrations at the quarries (Car.2, Car.3, Car.4) and at the sites downwind the plant. The deposition rates for the elements Pb, Cd, Cr, F and Hg are below the TA Luft limit values of 250 μg Pb/m².d and 5 μg Cd/m².d; below the ISSeP guide values of 250 μg Cr/m².d and 0.5 mg F/m².d [8].

Pb deposition

Pb deposition

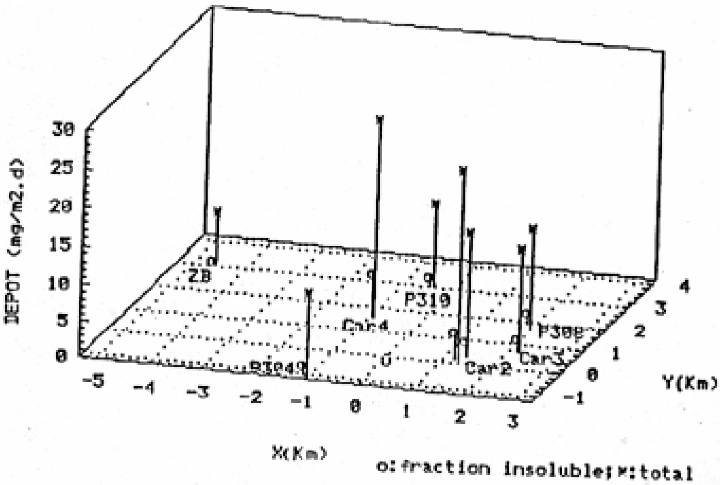


Cd deposition

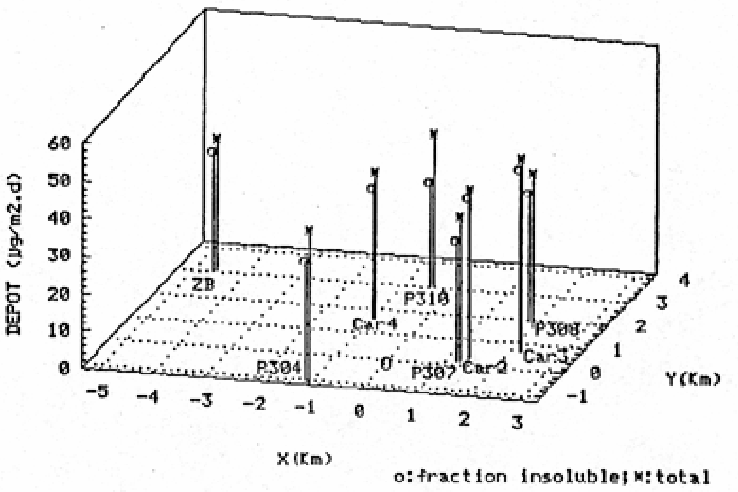


Cd deposition

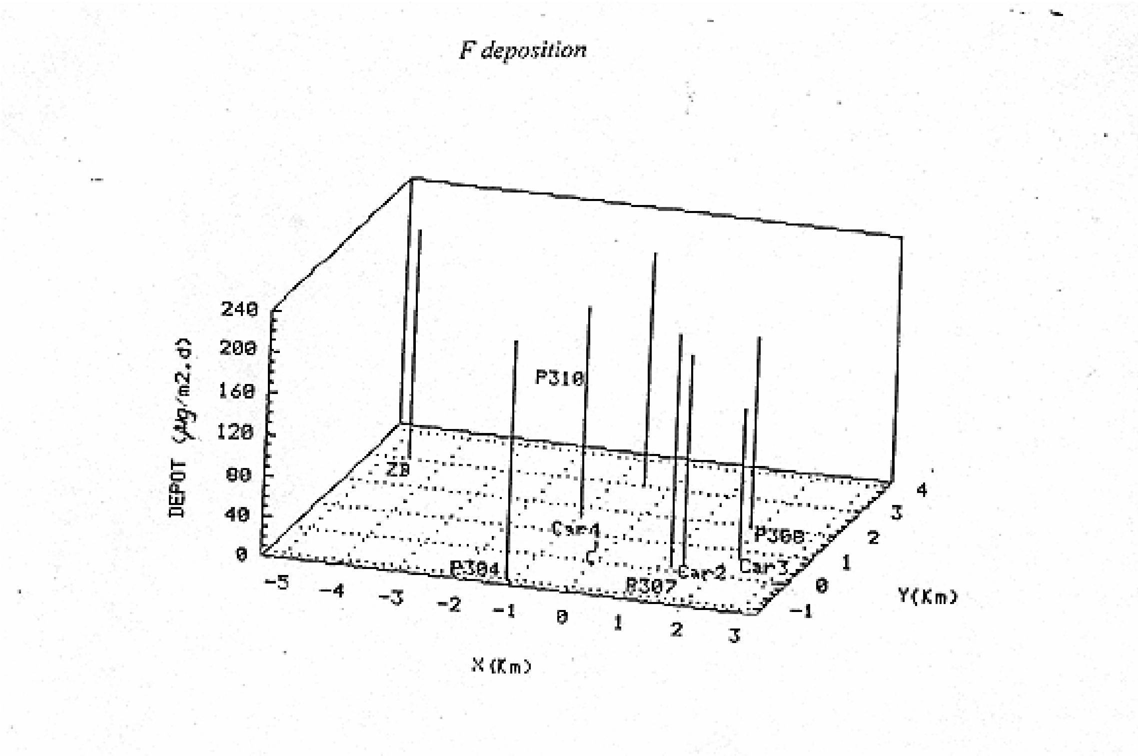
Ca deposition



Cr deposition



Ca deposition
Cr deposition



F deposition

The elements Ca, Cd and Hg are predominantly water-soluble, whereas Pb and Cr are largely retained on the filter material, e.g. associated with the insoluble fraction. It is interesting to note that, in the comparison with limit values, the volatile elements are found in higher proportions than the refractory elements. This "distillation" phenomenon of the elements with low boiling point results in heavy metal enrichment of the dust laden waste gases. All attempt to increase the air-cleaning devices efficiency should reduce the total mass emitted by stack, but it would not have a big influence for the volatile elements. For this reason, new basic criteria, in which first priority is given to the collection efficiency of fine particulate matter and gaseous pollutants, are strongly recommended.

In Fig.8 it is obvious that the environment in the surrounding of Algiers Cement Plant is strongly polluted. The mean-year total depositions at all sampling sites are exceeded the TA Luft limit values. They are about 16 times higher at site S_5, 3.6 times higher at S_6 and slightly exceeded at the further sites (S_1 and S_8). The concentration of Na, one of the characteristic elements of cement production activity is considerably high, about 16% of total deposition. The deposition rates for the toxic heavy metals as As, Cr and Zn are below the ISSeP guide values. With respect to the other elements, it is difficult to conclude something because there are not the limit values for these elements at present. However, by comparing the deposition rates of these elements in two situations, it appears that the depositions rates for the refractory as Sm, Sc and Ce are about three to ten times higher at Algiers than at Obourg. They are only about two to three times higher for the volatile elements as As, Zn, Rb, Cs and Br. A lower efficiency of filters at Algiers Cement Plant influences much more for the retention of refractory elements than of the volatile elements.

Of course, the comparison is more qualitative than quantitative because there is a lot of differences between the two situations (combustibles, combustion technics, types of air-cleaning devices, stack height....).

Fig. 8: Total deposition dust at Algiers Cement Plant

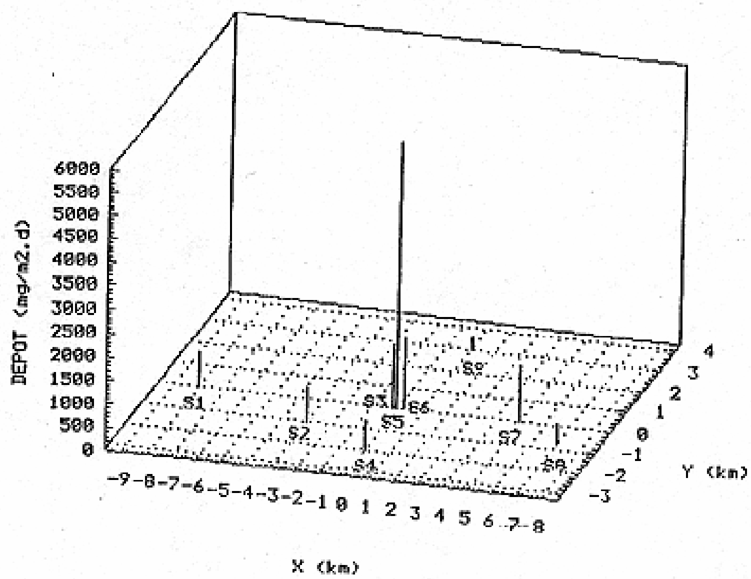


Fig.9: Deposition rates as a function of source-distance

UCL network

Zn deposition

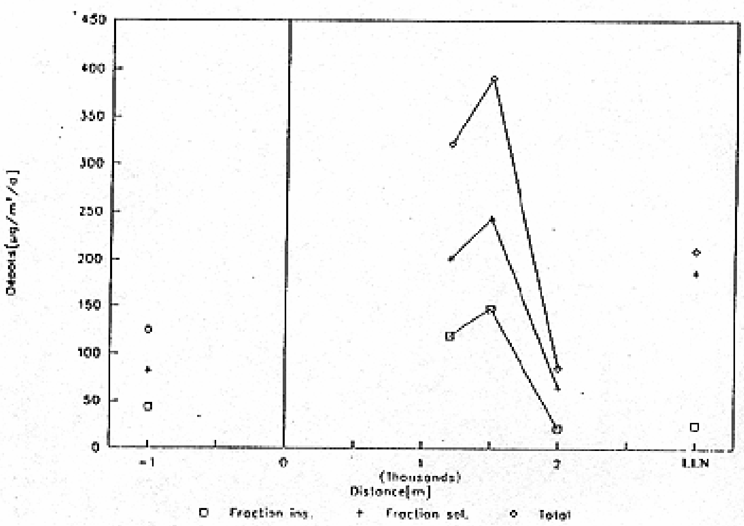


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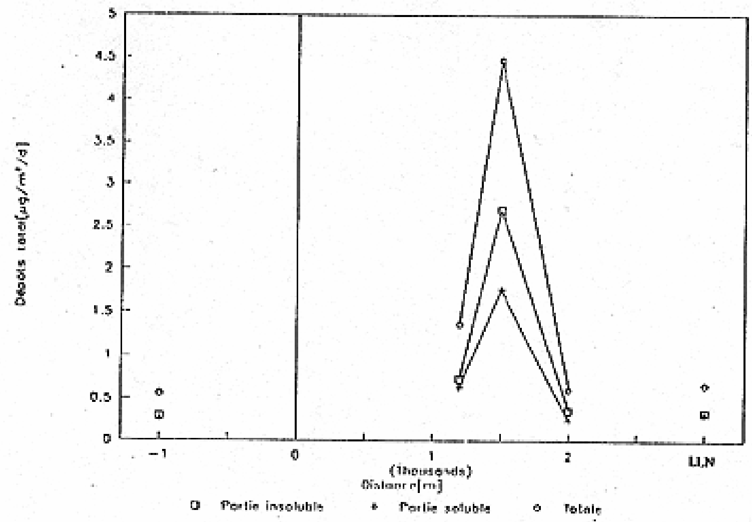
Fig.8: Total deposition dust at Algiers Cement Plant

Fig.9: Deposition rates as a function of source-distance

UCL network

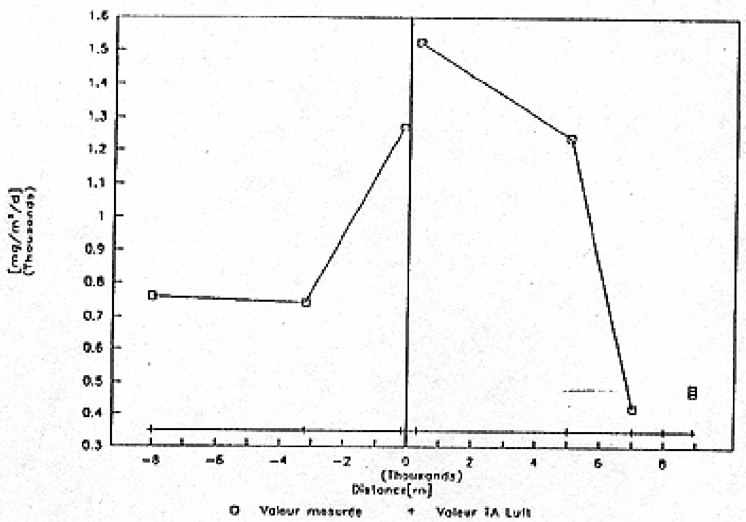
Zn deposition

As deposition



Algiers network

Total deposition dust



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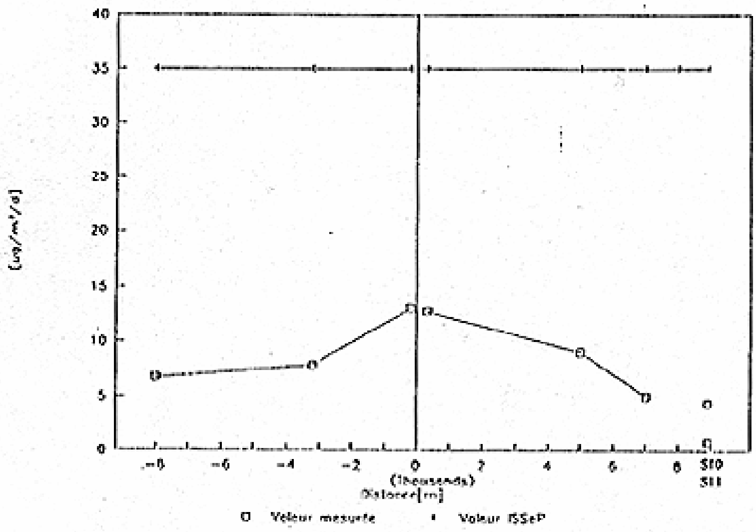
As deposition

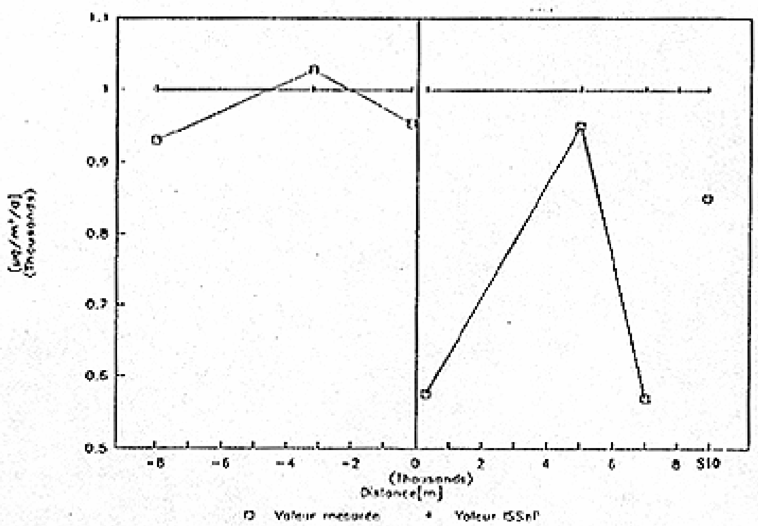
Algiers network

Total deposition dust

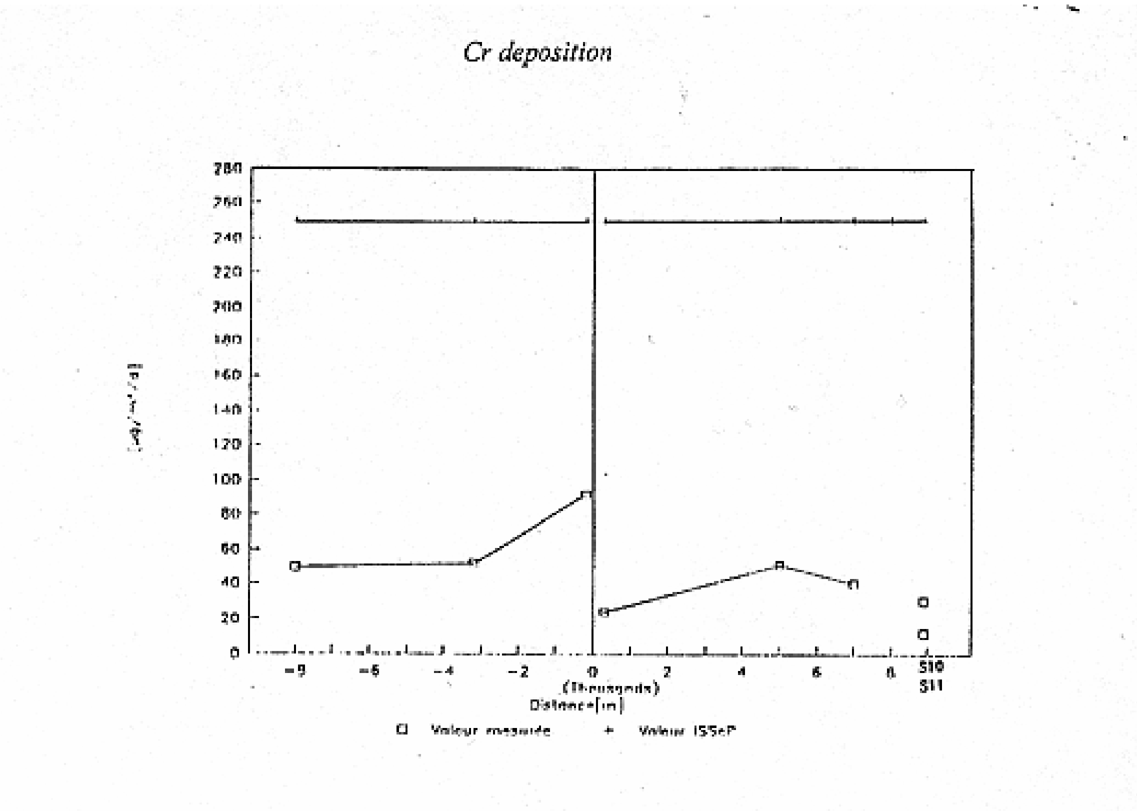
As deposition



Zn deposition



As deposition
Zn deposition



Cr deposition

Fig. 9 shows the total deposition dust and the deposition rates of most of elements are progressively decreased with increasing the source-distance. They have the values considerably higher at the gauges that are located under the plume than at the gauges outside. The highest deposition rates for most of elements are observed at site 3 in the UCL network, about 1.5 km of source-distance. This is probably the maximum concentration of pollutants emitted by the highest stack reaches the ground at a distance where the dust deposition gauge 3 is installed.

Atmospheric dispersion

Berliand model was applied to estimate the dispersion of pollutants from continuous, point source like the stacks of Obourg Cement Plant and of Haiphong Cement Plant. It bases on the basic dispersion equation so-called generalized Gaussian plume formula, but it takes into considerations the settlement of particulate matter [9]. For a quick estimation of maximum downwind ground concentration (C_{max}), created by a point source, and respectively maximum distance of immission (X_{max}), it's preferable to use the simplified Berliand model presented as the following:

- Necessary parameters:
  - Flux of gas, L [Nm^3/s]
  - Mean temperature of gas at kiln exit, t_o [°C]

- Mean temperature of surrounding air, t_a [°C]
- Temperature of gas at stack exit, t_s [°C]
- Emitted dust concentration, c [mg/Nm³]
- Stack height, H [m]
- Internal diameter at stack exit, D [m]
- Ejected velocity of gas, W [m/s]

■ Formulas of calculation:

- Emission rate, M:
  M = 10^{-3}L.c [g/s]

- Distinctive criterion between a hot source and a cool source:

$$f = 10^3 \frac{W^2 . D}{H^2 . \Delta T} \quad \text{where } t_s - t_a$$

- Intermediary coefficient V_m:

$$V_m = 0.65 \sqrt[3]{\frac{L.\Delta T}{H}}$$

- Distance of maximum ground level concentration X_{max} :

$$X_{max} = d . H \text{ [m]}$$

where d is an empirical value that is determinated by diagram on function of f and V_m.

- Maximum ground level concentration:

$$C_{max} = \frac{A. M.F.m.n.}{H^2 . \sqrt[3]{L.\Delta T}} \; [mg / m^3]$$

Where:
A - Empirical coefficient, taking into account of atmospheric temperature gradient
F - A coefficient which takes into account of settling velocity of particles and efficiency of filters
m, n - Plume standard deviations in lateral and vertical, respectively are determinated by diagram in function of ejection velocity

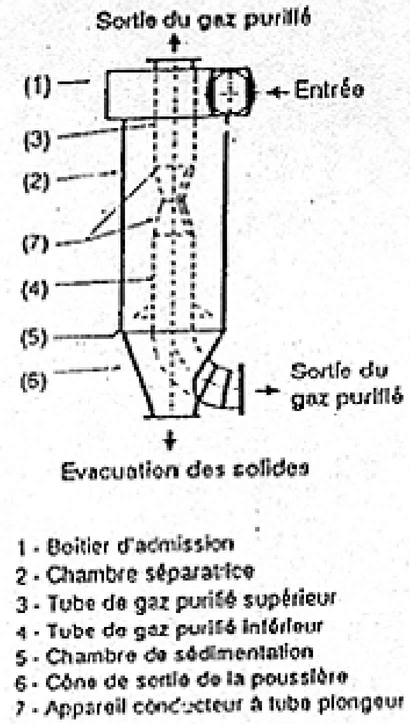
It seems likely to find a good coincidence between the calculated results and the measured values [10]. Like all the models, Berliand model still has limitations and it is strongly influenced by meteorological conditions. However, this model should be considered as a good means for estimating pollution levels around a point source. This is useful therefore, in environment impacts assessment studies of different industries.

Pollutants control equipment propositions

The high efficiency electrostatic precipitators are strongly recommended for cleaning of waste gases from clinker production kilns. For other process (limestone and coal grinding, limestone crushing, clinker and cement stock...), the fabric filters, the high efficiency cyclones may be applied.

In developing countries, the same recommendations are suggested for the new cement plants. For the others, the improving environment measures have to take. In dry climate countries like in Algeria, the fabric filters are recommended but they are inadvisable in humid air condition. The high efficiency cyclones are the most suggested by their reasonable price and their simple characteristics of use. The Hurriclon double tube cyclone is proposed to control dust, even wastes gases (Fig.10). It allows to deal with a volume debit much higher than at the conventional cyclones and with a very slow resistance [11]. The cyclone with spiral drivers showed in Fig. 11 is suggested for dust control in small cement plants or like the first stage of filtration before a higher efficiency air-cleaning device [12].

It appears likely that the production equipment, the technologies and the combustion technics are the most important factors of air control en cement plants. At Haiphong Cement Plant, an air-cleaning device of 99.9% efficiency like electrostatic precipitator should reduce the maximum downwind ground concentration to 1.24 mg/m^3, that a concentration eight times still higher than TA Luft limit value of 0.15 mg/m^3.



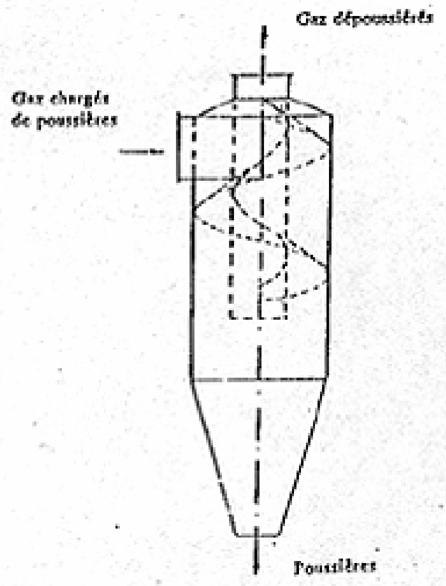


Fig.10: Hurriclon cyclone **Fig.11**/ Cyclone with spiral drivers

4. Conclusions

The main factors for the environment quality, especially the environments in the surroundings of cement plants are the following:

The performance of equipment is the most important. The measures of improving the performance of technology equipment and pollutants control equipment should to take parallel. The maintenance of equipment is also important, sometimes there is a determined factor in the industrial air control.

The combustible type determines the nature of emitted elements. In comparison with the total deposition, the toxic elements as As, Zn, Cr... are found in higher proportions at Obourg Cement Plant (As: 0.003%, Zn: 0.35%, Cr: 0.05%;;; calculated approximately) than at Algiers Cement Plant (As: 0.001%, Zn: 0.08%, Cr: 0.012%...), where natural gas is used for combustion.

In the last years at Obourg Cement Plant, the classic fossil combustibles, especially the coal, are substituted by other forms of combustible; this results a diminution of CO_2 emission [13].

The prevailing winds play an important role of pollutants dispersion. Atmospheric deposition is significantly higher at close-to-source sites and decreases with increasing source-distance. On the other hand, the emission levels remain in higher values under winddirection than outside winddirection; at the same distance from the source, the ground deposition levels outside the plume could be five times lower than that under the ax of plume. The accurate knowledge of the windfield is particularly necessary for construction site study.

It is of primary necessity to evaluate the air quality around any industrial unit in order to emphasize the adverse effects to ecological system and human health. For cement production activity, one of the most potentially polluted industrial branches, the dust deposition network should to set up in the surroundings of cement plants.

The will to apply standard is important too, especially in developing countries where the norms are often ignored.

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