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# Pollution Sources Diagram Methodology Applied to Cement Manufacturing

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***Abstract*— This paper presents an application of a methodology developed with the objective of optimizing environmental licensing and the evaluation of environmental impacts, through a stepwise and tiered approach whereby pollution sources are identified and analyzed systematically and in a coordinated and integrated manner, resulting in the Pollution Sources Diagram (PSD). It allows an agile and lean technical analysis and a more effective decision-support tool to the environmental agencies and government, which in turn are conditioned to offer more and more results to the society with less human and financial resources, which leads to the search for new tools for public environmental management and sustainable development. This paper presents the application of the PSD Methodology to the cement industry case. The results suggest that the methodology has the potential to enable more agile and efficient technical analysis by environmental agencies, thus contributing to faster responses to society and to the improvement of prevention, pollution control and environmental quality.**

***Index Terms*—environmental management, pollution prevention and control, government, sustainable development.**

## I. INTRODUCTION

The transformation of natural resources into products useful for life in society allowed the development of civilizations and, for the most part, the environment was able to provide such resources in the quantity demanded and absorb the residues arising from the imperfection of the applied transformation processes. However, especially since the industrial revolution, the increasing amount of materials extracted from nature and the significant increase of pollutants generated led to a scenario with significant environmental impacts, which in some cases were no longer local and reached regional and global dimensions.

In the second half of the twentieth century, with the worsening of pollution episodes, environmental agencies were created and public environmental policies were published in several countries, and the concept of sustainable development was also coined [1].

The economic activities, essential for the development of societies, have since been subject to environmental pollution control rules and the granting of environmental permits and licenses, and even loans by some international institutions, have come to depend on previous assessment of the environmental impacts caused and the mitigation and compensation measures that would be adopted. Since the imposition of such procedures, environmental agencies face the challenge of meeting society's increasing and more complex demands, managing conflicts and reconciling economic and social development with preservation of the environment [2]-[6].

However, the characteristic slowness of environmental licensing and permitting processes forces government to adopt more modern and effective management practices to meet the expectations and concerns of taxpayers. The subjectivity and imprecision in the technical analysis stand out among the main challenges of environmental licensing [7].

In order for environmental impacts to be adequately assessed, the environmental technical analysis must include three components, namely: manufacturing process, environmental controls and environmental legislation. Such information is available for research, but it is sparse and non-integrated, which hinders and limits the work of many environmental agencies. In this sense, it is necessary to seek new and more appropriate tools, which contribute to a more agile and assertive decision making by environmental agencies and governments [8].

For this purpose, the present work presents an application of Pollution Sources Diagram (PSD), a methodology of technical analysis for the optimization of the environmental licensing and granting of permissions. The PSD Methodology provides a coordinated and logical route for the integration of the relevant technical information for the accomplishment of a fast and standardized analysis. The methodology also represents more security and quality, thus contributing to the development of corporate processes and technological tools to obtain more effective results in the field of public environmental management and also to improve environmental control and quality [8].

To demonstrate the PSD methodology was chosen the cement industry case, an important sector for the society that presents diverse sources of pollution that, if they are not controlled properly, can result in negative environmental impacts.

## II. METHODOLOGY

PSD Methodology, as presented in [8], was applied to the case of the cement industry, considering the following steps:

- Step 1 – Represent the macroprocess: knowledge of the industrial process is fundamental for understanding the relevant environmental aspects and for carrying out a complete and assertive environmental analysis. The representation of the macroprocess must be done in a summary block diagram, containing beginning and end, considering in high level the main processes, as well as their main inputs and outputs. Each process must be named,

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described and identified with a unique code, so as to ensure the traceability of information throughout the analysis.

- Step 2 – Perform the hierarchical decomposition of processes: the second step is to define the scope of the environmental analysis, by decomposing the processes to a level that covers the sources of air, water and soil pollution, even though the sources of pollution are not known at this stage, in order to avoid lack of focus and the adoption of subjective criteria during the environmental analysis. Represent the type of industry under analysis in a block on the first line. Establish the first level of hierarchical decomposition based on the processes obtained in the first step, in order to obtain a structure similar to an organization chart. Select a process and perform the decomposition in simpler processes, obtaining the second level of hierarchical decomposition, and so on up to a level that allows the understanding of the activities performed that may represent potential sources of pollution.
- Step 3 – Identify pollution sources: select a process in last level of hierarchical decomposition and identify if there are sources of pollution with: (i) emissions to air (point source, diffuse emissions or fugitive emissions); (ii) releases to water (surface waters (e.g. lakes, rivers, dams, and estuaries), coastal or marine waters, and stormwater); (iii) releases to land (solid wastes, slurries, sediments, spills and leaks from processing activities and the storage and distribution of raw materials and products); and/or (iv) waste generation. Each source must be identified with a unique code, so as to ensure the traceability of information throughout the analysis.
- Step 4 –Describe the pollution source: select one of the sources of pollution identified in step 3 and indicate the related:

(i) environmental aspect;
(ii) pollutants generated;
(iii) pollutants prevention measures and its performance;
(iv) pollution control equipment/system or measures adopted and its performance and associated generation of waste; and
(v) emission estimation method or environmental monitoring equipment/system and its performance and results.

Also, it is recommended, if data is available, indicate information related to waste management: waste identification and its quantity and kind of transfer:
(i) recycling and energy recovery: recovery of solvents, organic substances, metals and metal compounds, inorganic materials, acids or bases, catalysts, pollution abatement residues, or the refining or reuse of used oil;
(ii) treatment prior to final disposal: physical, chemical, biological or thermal treatment and treatment in municipal sewage treatment plants; and
(iii) disposal: landfills, land application, underground injection, storage off-site prior to final disposal, and tailings and waste rock.

If there is another source of pollution contained in the same process, return to step 4; If not, return to step 3. Repeat until all the processes with the highest level of detail are considered in the hierarchical decomposition.

As a result of the application of the methodology is obtained the Pollution Source Diagram (PSD), with all relevant information for the decision-making process.

In this work, in order that the methodology was applied, specialized literature on the cement manufacturing process [9]-[16] and referring to environmental control and related legislation [17]-[24] was considered as references.

It is important to note that the PSD methodology can be applied to both a productive sector and a specific activity or industrial plant. In the first case, the first four steps must be considered, whereas in the second case it is necessary to apply the seven steps originally envisaged. The objective of this paper was to evaluate the applicability of PSD methodology to a cement industry, however the methodology could be applied to a specific plant or unit, also following steps 5 to 7, in which case it should also consider the law applicable to the place where the plant is installed or intends to install.

The processes were modeled using Bizagi Modeler software, version 3.1.0.011, a business process management solution based on Business Process Modeling Notation (BPMN) [25] and PSD Diagram was created using WBS Schedule Pro software.

## III. Results

The methodology was applied at the sector level to the cement industry, with the results presented below:

### A. *Step 1 – Represent the macroprocess*

Cement manufacturing macroprocess was represented in a summary block diagram, considering in high level the main processes (material handling, clinker burning, and cement handling), as well as their main inputs and outputs, as shown in Fig. 1. In this work the production of Portland cement by dry route was chosen because it corresponds to a more modern process and with lower energy consumption [12]. Each process was named, described and identified with a unique code, so as to ensure the traceability of information throughout the analysis, as show in Table I [13].

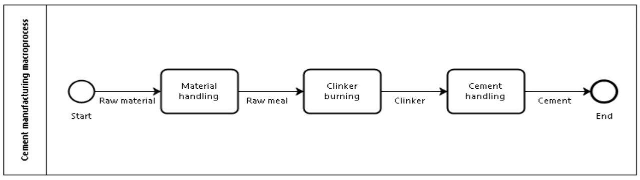


**Fig. 1. Cement manufacturing macroprocess diagram.**

**Table I. Summary of the main cement manufacturing processes [13].**

| ID | Name | Description, inputs and outputs |
|---|---|---|
| 1.1 | Material handling | Inputs: Raw material Outputs: Raw meal<br>Calcareous raw materials are crushed and then mixed and milled with other components such as iron oxide, alumina and silica to produce raw meal, which is carefully monitored and controlled. This step also comprises the preparation of the fuel. |
| 1.2 | Clinker burning | Inputs: Raw meal, fuels Outputs: Clinker, off-gas<br>The raw meal is fed into the kiln, being subjected to consecutive stages consisting of: drying / preheating, calcination (release of $CO_2$ from limestone) and sintering or clinkering. The product resulting from the burning, called clinker, is then cooled to with air and transported to intermediate storage. |
| 1.3 | Cement handling | Inputs: Clinker Outputs: Cement<br>The cement is produced from the milling together of clinker with gypsum in the cement mill. The cement produced is stored in silos, from where it goes to dispatch and packaging stages. |

### B. *Step 2 – Perform the hierarchical decomposition of processes*

In the second step was applied hierarchical process decomposition. The main processes of cement manufacturing obtained in Step 1 were selected and decomposed in simpler processes, obtaining the second level of hierarchical decomposition, and so on up to a level that allows the understanding of the activities performed that may represent potential sources of pollution to air, water and soil, even though the sources of pollution are not known at this stage. The processes obtained were identified, named and described according to specialized literature on cement processes [9]-[16]:

- Material handling:

This process was decomposed into two processes: raw material handling (1.1.1) and fuel handling (1.1.2). As the processes were still very comprehensive, was applied a further level of hierarchical decomposition. So, raw material handling was decomposed into three processes (raw material storage (1.1.1.1), raw material processing (1.1.1.2), and raw material transport (1.1.1.3)). Besides that, raw material processing was subdivided into two processes: 1.1.1.2.1 raw material crushing and 1.1.1.2.2 raw material grinding. Fuel handling was divided into three processes: fuel storage (1.1.2.1), fuel preparation (1.1.2.2), and fuel transport (1.1.2.3).

Calcium is the element of highest concentration in Portland cement and can be obtained from calcareous raw materials (e.g. limestone, chalk, marl, sea shells, and aragonite) [13]. Cement plants are typically located close to naturally occurring these materials, which are extracted from quarries, providing calcium carbonate ($CaCO_3$). Small amounts of materials such as iron ore, bauxite, shale, clay or sand may be needed to provide the extra mineral ingredients, iron oxide ($Fe_2O_3$), alumina ($Al_2O_3$) and silica ($SiO_2$) necessary to produce the desired clinker. Raw material is quarried and transported to primary/secondary crushers and broken into 10 cm pieces. After crushing, the raw materials are mixed and milled together to produce raw meal [9]-[11]. Raw material storage includes the unloading operation and disposition in piles or bins [12].

Fuels comprises conventional kinds such as coal, petroleum coke and heavy oil and alternative fuels (e.g. tires, oil waste, plastics, and solvents). The preparation of fuels includes operations such as crushing, drying, grinding and homogenization and units such as silos and storage sheds for solid fuels, tanks for liquid fuels, as well transport devices and kiln feeding systems [13]-[16].

- Clinker burning

This process did not need to be decomposed since it was already at the last level of hierarchical decomposition and its decomposition already resulted in sources of pollution.

Precalcined meal enters the kiln at temperatures of around 1000°C. Fuel (such as coal, petroleum coke, gas, oil and alternative fuels) is fired directly into the rotary kiln at up to 2000°C to ensure that the raw materials reach material temperatures of up to 1450°C. The chemical decomposition of limestone generates typically 60% of total carbon dioxide ($CO_2$) emissions of the cement manufacturing process, whereas fuel combustion generates remaining $CO_2$.The kiln is a brick-lined metal tube 3-5 m wide and 30-60 m long that rotates about 3-5 times per minute, and the raw material flows down through progressively hotter zones of the kiln towards the flame. The intense heat causes chemical and physical reactions that partially melt the meal into clinker [10], [11].

From the kiln, the hot clinker is cooled using large quantities of air, part of which can serve as combustion air. Coolers are essential for the creation of the clinker minerals which define the performance of the cement. In this process, the combustion air is preheated, thereby minimizing overall energy loss from the system [9]-[13].

The clinkering process can be summarized in four stages [13]: 1. Evaporation of uncombined water from raw materials, as material temperature increases to 100°C; 2. Dehydration, as the material temperature increases from 100°C to approximately 430°C; to form oxides of silicon, aluminum, and iron; 3. Calcination, during which carbon dioxide (CO2) is evolved, between 900°C and 982°C, to form CaO; and 4. Reaction of the oxides in the burning zone of the kiln, to form clinker at temperatures of approximately 1510°C.

- Cement handling

It was decomposed into two processes: cement grinding (1.3.1) and cement loading (1.3.2). It was not necessary to proceed with the decomposition of the processes, as it has already been possible to identify some sources of pollution at this level. In this stage, natural gypsum or anhydrite (up to 5%) and other mineral compounds are added to the clinker during grinding to meet product characteristics. The resulting cement is conducted in a closed-circuit system to the storage silos, from where it is shipped in bulk, or directed to the packing machines and subsequent shipment.

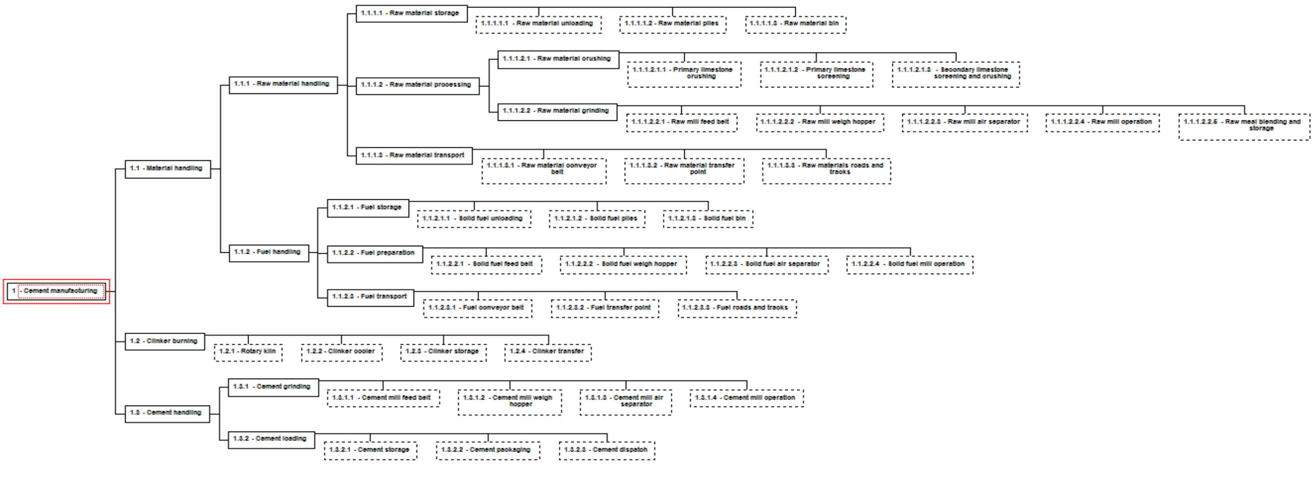


**Fig. 2. Pollution Sources Diagram applied to cement manufacturing.**

### A. *Step 3 – Identify pollution sources*

Processes in last level of hierarchical decomposition was selected in order to identify if there were sources of pollution with: (i) emissions to air; (ii) releases to water; (iii) releases to land; and/or (iv) waste generation. Each source was identified with a unique code, to ensure the traceability of information throughout the analysis.

As a result the PSD framework was obtained, as shown in Fig. 2. Continuous border boxes represent the processes, while boxes with dotted edges represent the sources of pollution identified for a given process in the last level of hierarchical decomposition. It was identified 35 sources of pollution, being 24 sources referring to material handling, 4 sources associated to clinker burning, and 7 sources referring to cement handling.

### B. *Step 4 –Describe the pollution source*

The pollution sources identified in Step 3 were grouped considering similarity criteria and were described considering specialized literature, especially [12] and [13], and complementarily [14]-[24], as shown below:

- Sources: 1.1.1.2.1.1 Primary limestone crushing, 1.1.1.2.1.2 Primary limestone screening, and 1.1.1.2.1.3 Secondary limestone screening and crushing (crushing of raw materials).

\- Environmental aspect: emissions to air.
\- Pollutants generated: PM.
\- Pollutants prevention measures: enclose/encapsulate dusty operations, proper and complete equipment maintenance, and use automatic devices and control systems.
\- Pollution control equipment/system or measures and associated generation of waste: fabric filter.
\- Emission estimation method or environmental monitoring equipment/system: USEPA AP42 CH11.6 – PM (kg/Mg of material process, considering fabric filter, to the sources listed above): 0.00050, 0.00011, and 0.00016, respectively. Periodic monitoring may be used if necessary.

- Sources: 1.1.1.1.1 Raw material unloading, 1.1.1.1.2 Raw material piles, 1.1.1.3.3 Raw materials roads and tracks, 1.1.2.1.1 Solid fuel unloading, 1.1.2.1.2 Solid fuel piles, and 1.1.2.3.3 Fuel roads and tracks (bulk storage areas and stockpiles).

\- Environmental aspect: emissions to air.
\- Pollutants generated: particulate matter (PM) (diffuse dust emissions).
\- Pollutants prevention measures: open pile wind protection, water spray and chemical dust suppressors, paving, road wetting and housekeeping, humidification of stockpiles, and by matching the discharge height to the varying height of the heap, if possible automatically, or by reduction of the unloading velocity.
\- Pollution control equipment/system or measures and associated generation of waste: Not applicable (NA).
\- Emission estimation method or environmental monitoring equipment/system: Conventional high volume (Hi-Vol) samplers with wind direction activators can be used to measure dust emissions.

- Sources: 1.1.1.3.1 Raw material conveyor belt, 1.1.1.3.2 Raw material transfer point, 1.1.2.3.1 Fuel conveyor belt, 1.1.2.3.2 Fuel transfer point, 1.2.4 Clinker transfer, and (raw material, fuel, and clinker transport).

\- Environmental aspect: emissions to air.
\- Pollutants generated: PM.
\- Pollutants prevention measures: coverage or closure of conveyor belt and transfer points, proper and complete equipment maintenance, use automatic devices and control systems, and by using conveyor belts with adjustable heights.
\- Pollution control equipment/system or measures and associated generation of waste: Fabric filter in transfer points, if necessary.
\- Emission estimation method or environmental monitoring equipment/system: No data (ND).

- Sources: 1.1.1.2.2.1 Raw mill feed belt, 1.1.1.2.2.2 Raw mill weigh hopper, 1.1.1.2.2.3 Raw mill air separator, 1.1.1.2.2.4 Raw mill operation, 1.1.2.2.1 Solid fuel feed belt, 1.1.2.2.2 Solid fuel weigh hopper, 1.1.2.2.3 Solid fuel air separator, 1.1.2.2.4 Solid fuel mill operation, 1.3.1.1 Cement mill feed belt, 1.3.1.2 Cement mill weigh hopper, 1.3.1.3 Cement mill air separator, and 1.3.1.4 Cement mill operation (grinding mills for raw materials, coal and cement).

\- Environmental aspect: emissions to air.
\- Pollutants generated: PM.
\- Pollutants prevention measures: enclose/encapsulate dusty operations, proper and complete equipment maintenance, use automatic devices and control systems, and mobile and stationary vacuum cleaning,
\- Pollution control equipment/system or measures and associated generation of waste: electrostatic precipitator (ESP), fabric filter (FF) or hybrid filters; dust arising from off-gas cleaning units;
\- Emission estimation method or environmental monitoring equipment/system: USEPA AP42 CH11.6 – PM (kg/Mg of material process, considering fabric filter, to the sources listed above): 0.0016, 0.010, 0.016, 0.0062, 0.0016, 0.010, 0.016, 0.0062, 0.0012, 0.0047, 0.014, and 0.0042, respectively. Periodic monitoring may be used if necessary.

- Sources: 1.1.1.1.3 Raw material bin, 1.1.1.2.2.5 Raw meal blending and storage, 1.1.2.1.3 Solid fuel bin, 1.2.3 Clinker storage, and 1.3.2.1 Cement storage (raw materials, fuel, clinker, and cement silo storage).

\- Environmental aspect: emissions to air.
\- Pollutants generated: PM.
\- Pollutants prevention measures: proper and complete equipment maintenance, use automatic devices and control systems, and mobile and stationary vacuum cleaning.
\- Pollution control equipment/system or measures and associated generation of waste: fabric filter.
\- Emission estimation method or environmental monitoring equipment/system: ND.

- Source 1.2.2 Rotary kiln [12]:

\- Environmental aspect 1: emissions to air.
\- Pollutants generated: particulate matter (PM), fine dust ($PM_{10}$ e $PM_{2.5}$), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), total organic compounds (TOC), Polychlorinated dibenzo-p-dioxins

(PCDD) and dibenzofurans (PCDF), metals and their compounds,
Hydrogen chloride (HCl) and hydrogen fluoride (HF), ammonia ($NH_3$), polyaromatic hydrocarbons (PAH), Benzene, toluene, ethylbenzene and xylene (BTEX), and other organic pollutants (chlorobenzenes, PCB (polychlorinated biphenyls), and chloronaphthalenes).

- Pollutants prevention measures:

(i) PM: proper and complete equipment maintenance; process control optimization, including computer-based automatic control, and by using modern, gravimetric solid fuel feed systems.
(ii) $NO_x$: flame cooling, e.g. high water content, liquid/solid wastes, low $NO_x$ burners, mid kiln firing, addition of mineralizers to improve the burnability of the raw meal (mineralized clinker), staged combustion (conventional or waste fuels) also in combination with a precalciner and the use of optimized fuel mix, and process optimization;
(iii) $SO_2$: optimizing the clinker burning process including the smoothing of kiln operation, uniform distribution of the hot meal in the kiln riser and prevention of reducing conditions in the burning process as well as the choice of raw materials and fuels;
(iv) CO; selection, when possible, of raw materials with a low content of organic matter also reduces the emissions of CO, and improvement in combustion (optimization and quality of the fuel feed, burner properties and configuration, kiln draft, combustion temperature and residence time);
(v) TOC: natural or waste raw materials with a high content of volatile organic compounds (VOC) should not, if a choice is possible, be fed into the kiln system via the raw material feeding route and fuels with a high content of halogens should not be used in a secondary firing;
(vi) HCl and HF: the use of raw materials and fuels containing low chlorine and low fluorine levels;
(vii) PCDD and PCDF: a smooth and stable kiln process, applying process control optimization and use of modern fuel feed systems; minimizing fuel energy use by means of preheating and precalcination; careful selection and control of substances entering the kiln with selection and use of homogeneous raw materials and fuels with a low content of sulphur, nitrogen, chlorine, metals and volatile organic compounds, if practicable; quick cooling of kiln exhaust gases to lower than 200 ºC; limitation or avoidance of waste used as raw material feed if it includes organic chlorinated materials; not using waste fuel feeding during start-ups and shutdowns; monitoring and stabilization of critical process parameters, i.e. homogenous raw mix and fuel feed, regular dosage and excess oxygen; fuels with a high content of halogens should not be used in a secondary firing; and
(viii) metals: Feeding materials with a high content of volatile metals, especially mercury (Hg) and Thallium (Tl), into the kiln system should be avoided.

- Pollution control equipment/system or measures and associated generation of waste:

(i) PM: electrostatic precipitator (ESP), fabric filter (FF) or hybrid filters; dust arising from off-gas cleaning units;
(ii) $NO_x$: Selective catalytic reduction (SCR), Selective Non-Catalytic Reduction (SNCR) and high efficiency SNCR;
(iii) $SO_2$: absorbent addition, wet scrubber, and activated carbon;
(iv) TOC: adsorption on activated carbon can be considered, if elevated concentrations occur;
(v) HCl and HF: absorbent injection or scrubber techniques. Much of the fluoride is captured by the clinker and the remainder is taken out as calcium fluoride ($CaF_2$) together with the particulate material.
(vi) PCDD and PCDF: adsorption on activated carbon, if elevated concentrations occur. Attention point is the hazardous waste generated;
(vii) metals: Non-volatile metals are, to a large extent, captured within the clinker and the remainder is taken out together with the particulate material. One way to minimize mercury emissions is to lower the exhaust temperature. Other option is adsorption of mercury (metallic and ionic) on powdered activated carbon injection. Attention point is the hazardous waste generated.

- Emission estimation method or environmental monitoring equipment/system: (i) estimation method: USEPA AP42 CH11.6 (PM, $SO_2$, $NO_x$, CO, $CO_2$, and TOC) [13]; (ii) monitoring: continuous (kiln processes (pressure, temperature, $O_2$ content, CO, $NO_x$, and $SO_2$), and air emissions (exhaust volume, humidity, temperature, dust, $O_2$, CO, $NO_x$, and $SO_2$)), and regular periodic monitoring (TOC, HCl, HF, $NH_3$, PCDD/F, metals and their compounds, and under special operating conditions BTX (benzene, toluene, xylene), PAH (polyaromatic hydrocarbons), and other organic pollutants (e.g. chlorobenzenes, PCB (polychlorinated biphenyls), chloronaphthalenes) [12]. It is important to emphasize that CO monitoring is especially critical when using electrostatic precipitators or hybrid filters due to explosion risks. In this case, when a critical CO level is reached, the environmental control equipment should be shutdown, which, depending on the time, can lead to a significant increase in the emission of particulate matter. For this reason, the CO concentration should be monitored continuously and measures should be taken in such a way as to cause the least possible interruption in the operation of ESP or hybrid filters (e.g. ranges of between 1–29 minutes per year, respectively < 0.001–0.009% of the total kiln operation).

In units where waste is reused (coprocessing), the installation of an air quality monitoring station may be necessary, especially when there are residences near the plant.

- Environmental aspect 2: waste generation
- Pollutants generated: PM (Miscellaneous (depends on raw materials, fuels and waste fed in the rotary kiln));
- Kind of transfer: collected dust can be recycled back into the production processes whenever practicable. This recycling may take place directly into the kiln or kiln feed or by blending with finished cement products.

• Source 1.2.3 Clinker cooler:

- Environmental aspect: emissions to air.
- Pollutants generated: PM.
- Pollutants prevention measures: proper and complete equipment maintenance, and use automatic devices and control systems.
- Pollution control equipment/system or measures and associated generation of waste: electrostatic precipitator (ESP), fabric filter (FF) or hybrid filters; dust arising from off-gas cleaning units.

- Emission estimation method or environmental monitoring equipment/system: Periodic monitoring may be used if necessary.

• Source: 1.3.2.2 Cement packaging, and 1.3.2.3 Cement dispatch (cement loading).
- Environmental aspect: emissions to air
- Pollutants generated: PM
- Pollutants prevention measures: proper and complete equipment maintenance, use automatic devices and control systems, mobile and stationary vacuum cleaning, and use flexible filling pipes for dispatch and loading processes, equipped with a dust extraction system for loading cement in the loading floor of the lorry.
- Pollution control equipment/system or measures and associated generation of waste: fabric filter
- Emission estimation method or environmental monitoring equipment/system: Periodic monitoring may be used if necessary.

An environmental aspect common to all sources mentioned above is the emission of noise (e.g. chutes and hoppers, any operations involving fracture, crushing, milling and screening of raw material, fuels, clinker and cement, exhaust fans, blowers, and duct vibration) which, in general, can be characterized as follows:
- Environmental aspect: Noise emissions
- Pollutants generated: Noise
- Pollutants prevention measures: Regular maintenance of production and control equipment.
- Pollution control equipment/system or measures and associated generation of waste: Sound insulation of equipment; natural noise barriers, such as office buildings, walls, trees or bushes.
- Emission estimation method or environmental monitoring equipment/system: ISO 1996-1:2016, and ISO 1996-2:2017 [26],[27].

Regarding waste management, the main waste generated is collected dust from air pollution control equipments. In general, collected dust can be recycled back into the production processes whenever practicable. This recycling may take place directly into the kiln or kiln feed or by blending with finished cement products. The main limiting factor is the alkali metal content, which can damage the inner liner of the rotary kiln. Others limiting factors are the content of other metals and the content of chlorine, because they can contribute to negative effect on metal emissions and impair product quality requirements, respectively.
It is also recommended that the handling of fuels and hazardous waste be carried out in a paved area with appropriate drainage to avoid leaks and contamination of the soil and to transport to the rainwater galleries.
Finally, about releases to water, in general, cement production does not generate wastewater. Just small quantities of water are used to cleaning processes, being recycled back into the process. In any case, it is recommended that a stormwater pollution prevention plan be adopted. It is important to note that its effectiveness is directly related to the control of air pollution, especially to fugitive and diffuse emissions.

## IV. Discussion

A Pollution Source Diagram (PSD) was obtained, as a result of the application of the methodology at a sector level with all the necessary information to understand how the cement process works and how its inputs, outputs and losses can impact the environment. The main sources of pollution have been mapped and identified as well as the pollutants generated and the main prevention and control measures applicable, allowing a high-level view that can serve as a starting point for environmental analysis of specific cement companies.
The main objective of this paper was to demonstrate the application of the PSD methodology to a sector, regardless of the specifics of a given enterprise. To apply PSD methodology to a specific cement production enterprise it is need to perform steps 5 to 7 with specific data, in order to evaluate environmental monitoring and control, assess pollution source compliance and consolidate a specific Pollution Sources Diagram (PSD).
The Pollution Sources Diagram (PSD) obtained in this work can be a useful tool to prevent and minimize environmental impacts resulting from a cement manufacturing process and provide important feedback to environmental agencies to update policy measures and guide technical analysis in similar cases, since a database can be built and serve as a knowledge base, reducing subjectivity and lack of focus throughout the process.

## V. Conclusion

In this paper was presented a pragmatic approach to establish an optimized technical analysis in the environmental licensing process, several times criticized for reasons like slowness and subjectivity. For this, PSD methodology was applied to cement industry case. It was possible in a relatively simple framework to identify the main sources of pollution of cement industry, consolidating the necessary information to the decision process.
The results suggest that methodology can be a useful tool for environmental agencies since it allows for a faster and more complete environmental analysis, better subsidizing the decision-making process by environmental agencies.
The systematization of the identification and analysis of pollution sources, through a coordinated and integrated form of environmental compliance assessment, using a tool that enables the construction and updating of workflows and a knowledge base common to the technical staff can contributes for greater agility and assertiveness in the decisions taken by the environmental agencies and govern.
Finally, the methodology can contribute not only to the simplification of environmental licensing or of optimization the process of evaluation of environmental impacts, but also to the monitoring of these impacts, allowing the comparison between what was planned and the reality after the granting of environmental permit or license and the consideration of aspects of synergy and cumulativity in the analysis of new industries, with better results in environmental control and quality, contributing thus to sustainable development.

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