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Aerosol Emissions from The Cement Plant Chain in The Lomé Port Area (Togo) from 2010 to 2018

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ABSTRACT

Air pollution stands as a serious challenge for mankind. In Togo, industrial pollution, particularly that of cement plants, is getting more and more noticeable. In order to study the aerosol emissions from the cement plant chain in the Port area, mineralization with aqua regia was used for dosing heavy metals contained in the raw materials that are used to produce cement as well as the emitted dust. The CORINAIR method was used to estimate pollutant emissions. In the course of this study, it appears that the cement plant is a source of Metallic Trace Elements (MTE), whose assay results in cement revealed the following quantities: 1.12 mg/Kg for Cadmium; 4.88 mg/Kg for Lead; 7.95 mg/Kg for Copper and 18.86 mg/Kg for Nickel that are dispersed in the atmosphere, in addition to Particulate Matter (PM) emitted during the manufacturing and use process of cement. In 2018, $PM_{2.5}$ and PM_{10} emissions were 0.274 and 0.493 Gg, respectively. Moreover, the clinkering process emitted CO_2, NO_x, Non-methane Volatile Organic Compounds (NMVOCs) and CO respectively at 1095.63; 2.615; 0.038 and 3.066 Gg in the same year. In terms of the trends recorded over the period 2010-2018, pollutant emissions evolve in two phases. A phase of decline between 2010-2014 and a second phase of non-linear growth between 2014-2018. Among the pollutants emitted, only the evolution of SO_2 emissions shows an overall downward trend. These trends may be weakened with mitigating measures such as systematic on-site dust recovery and covering of transport trucks of raw materials and cement delivery.

INTRODUCTION

In recent decades, air quality has been given special attention because of the steady increase in air pollution worldwide, with the release into the atmosphere of toxic elements mainly of anthropogenic origin. This leads to obvious and significant degradation of the environment and ecosystems. Scientific research over the past decade has shown the relationship between air pollution and effects on human health such as cardiovascular and pulmonary diseases, cancers of many human body organs with vital functions, resulting in a reduction in life expectancy in the European Union by more than eight months (European Environment Agency, 2013), mortality and morbidity (Kelly and Fussell 2012; Khan *et al*. 2010; Merbitz et al. 2012; Pope et al. 2011; Raaschou-Nielsen et al. 2011; Sun et al. 2012; Turner et al. 2011). In 2008, the World Health Organization (WHO) reported that 1.3 million annual deaths worldwide are attributable to air pollution, including 82,000 in sub-Saharan Africa (World Health Organization, 2008). Between 2004 and 2008, the WHO recorded a 16% increase in the total number of deaths due to air pollution. Among the different types of air pollution, particulate pollution plays an important role (suspended particulate matter = PM). It is described in previous works as a complex mixture of metals, salts, combustion organic compounds, elemental carbon and microorganisms (Baulig et al., 2009 and 2013; Osornio-Vargas et al., 2011; Perrone et al., 2010, Boublil et al., 2013; Gualtieri et al., 2010; Michael et al., 2013). This air pollution, a real health risk, is due to the presence in the atmosphere of SO_2, CO_2, NO_x, PM, VOCs, etc. In Togo, industrial activity is one of the sources that emit air pollutants whose impacts are very noticeable in the Port area. Studies conducted in the area indicate a high accumulation of trace metal elements in vegetable species grown in market gardening (Gnandi et al., 2008). The high concentration of dust in the air causes respiratory diseases and environmental degradation (Henni-Chebra et al., 2011). In this area, studies have already shown the presence of trace metal elements such as Lead, Copper, Nickel and Cadmium. (Issah et al, 2018). The aim of this study is to indicate the share of emissions of heavy metals and other air pollutants attributable to the cement manufacturing process in the Port area (PA) for the time series 2010-2018.

1. METHODOLOGY

The study methodology is based on the physicochemical analysis of the samples collected.

1.1. Method of sampling and dosage of heavy metals

The samples analysed were taken during the dry season (January and February) from raw materials available at the CIMTOGO plant, cement dust on the ground, cement on the market (finished product) and dust deposits around 100 to 150 m from the plant. The mineralization of the samples with hydrochloric acid and nitric acid was in accordance with NF ISO 11466 (aqua regia Method) (ISO 1995). The dosage of Cd, Pb, Cu and Ni metals is made using the SAA atomic absorption spectrophotometer (brand SAA iCE 3000 SERIES THERMO FISCHER). The metal trace element contents of the samples were determined in relation to the ETM calibration curve with R^2 values exceeding the SAA value of 0.995.

1.2. Method of Estimating Air Pollutants

The methodological approach is that contained in the *EMEP/EEA air pollutant emission inventory* guide intended for air pollutant emission inventories. As the country does not have specific emission factors, the Level 1 method was used. Thus, the estimates of pollutant emissions are based on the fundamental equation that combines activity data with emission factors:

$$\text{Emission} = AD \times EF$$

Or :

AD designates the activity data on the cement plant during a given period; and

EF designates the emission factors of pollutants per unit of AD.

The quantitative data on the clinker used cover the period 2010-2019 while the emission factors are collected in the EMEP / EEA guide.

2. RESULTS AND DISCUSSION

2.1. Results

The physicochemical analyses of the various samples combined with estimates through the CORINAIR method indicated that the cement production chain in the Port area is a source of

emission of metal elements Cadmium (Cd), Lead (Pb), Copper (Cu) and Nickel (Ni) and non-metallic air pollutants such as Particulate Matter ($PM_{2.5}$, PM_{10}), Black Carbon (BC), Non-methane Volatile Organic Compounds (NVOCs) and Nitrogen Oxides (NO_x). The dosage of the samples with aqua regia revealed the presence of Metallic Trace Elements (MTE), whose results are presented in Table 1.

Table 1: Physicochemical analysis results

ETM (mg/Kg)	Cd	Pb	Cu	Ni
Gypsum	0.10	2.20	2.89	11.51
Limestone	0.91	-	0.93	3.96
Clinker	1.43	6,22	7.82	20.57
Cement	1.12	4.88	7.95	18,86
Cement dust	0.97	14.84	13.51	14,76
Surroundings CIMTOGO	2.60	305.28	234.46	50.00
Parc Epervier	0.41	42.80	25.80	22.87

These metals end up in the atmosphere as aerosols in addition to the non-metallic air pollutants calculated for the time series 2010-2018 basing on physicochemical analysis and collection data (DA and FE). The results of the estimation of the MTE are obtained first on the clinker, and second on the quantities of cement produced (Table 2). The $PM_{2.5}$, PM_{10}, BC, NMVOCs, CO, NO_x and CO_2 estimation results are related to the amounts of clinker used in the chain and those of SO_2 to the amounts of cement produced (Table 3).

Table 2: Estimated MTE in clinker and cement between 2010 and 2018

ETM	Cd	Pb	Cu	Ni	Cd	Pb	Cu	Ni
(10^{-5} Gg)	In the clinker				In the cement			
2010	151.58	659.3	828.9	2180.36	72.83	317.34	516.98	1226.45
2011	171.68	746.74	938.83	2469.54	73.67	320.98	522.91	1240.51
2012	166.96	726.23	913.04	2401.68	69.81	304.18	495.54	1175.59
2013	130.28	566.66	712.43	1873.99	74.74	325.64	530.5	1258.52
2014	119.73	520.77	654.73	1722.22	77.07	335.79	547.03	1297.73
2015	223.89	973.83	1224.34	3220.53	79.05	344.41	561.09	1331.08
2016	292.83	1273.72	1601.36	4212.28	75.54	329.13	536.18	1271.99
2017	311.74	135.59	170.47	4484.21	65.34	284.71	463.82	1100.34
2018	301.3	1310.54	1647.66	4334.06	57.63	251.12	409.1	970.52

Table 3: Estimated Pollutants Emitted between 2010 and 2018

Pollutant (Gg)	$PM_{2.5}$	PM_{10}	BC	NMVOCs	CO	NO_x	CO_2	SO_2
2010	0.138	0.248	0.004	0.019	1.542	1.315	551.186	0.195
2011	0.156	0.281	0.005	0.022	1.747	1.490	624.288	0.197
2012	0.152	0.273	0.005	0.021	1.699	1.449	607.133	0.187
2013	0.118	0.213	0.004	0.016	1.326	1.131	473.736	0.200
2014	0.109	0.196	0.003	0.015	1.218	1.039	435.370	0.206
2015	0.204	0.366	0.006	0.028	2.278	1.943	814.136	0.212
2016	0.266	0.479	0.008	0.037	2.980	2.541	1064.845	0.202
2017	0.283	0.510	0.009	0.039	3.172	2.705	1133.586	0.175
2018	0.274	0.493	0.008	0.038	3.066	2.615	1095.630	0.154

2.2. DISCUSSION

For the year 2018, the MTE estimates in the clinker (Figure 1) show a distribution dominated by the Ni to the tune of 57%, followed by Cu 22%, Pb 17% and Cd 4%. This distribution remains the same for MTE estimates in cement Ni (58%); Cu (24%); Pb (15%) and Cd (3%) (Figure

2). This is quite logical if we take into account the addition of limestone and gypsum, whose results of physicochemical analysis are compiled in Table 1 in the crushing process to obtain cement, as well as the raw materials used during the cooking process that are quite rich in lead.

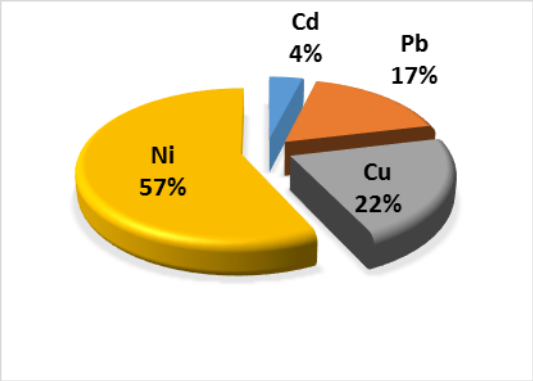

Figure 1: Estimation of ETM in clinker in 2018

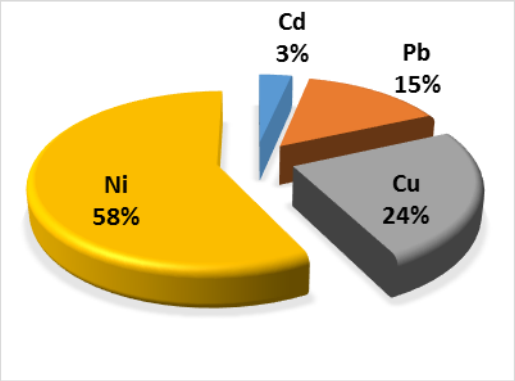

Figure 2: Estimation of ETM in cement in 2018

In the same year and in relation to non-metallic pollutant emissions, CO_2 emissions accounted for 99.40% in terms of mass. The distribution of other pollutants is shown in Figure 3.

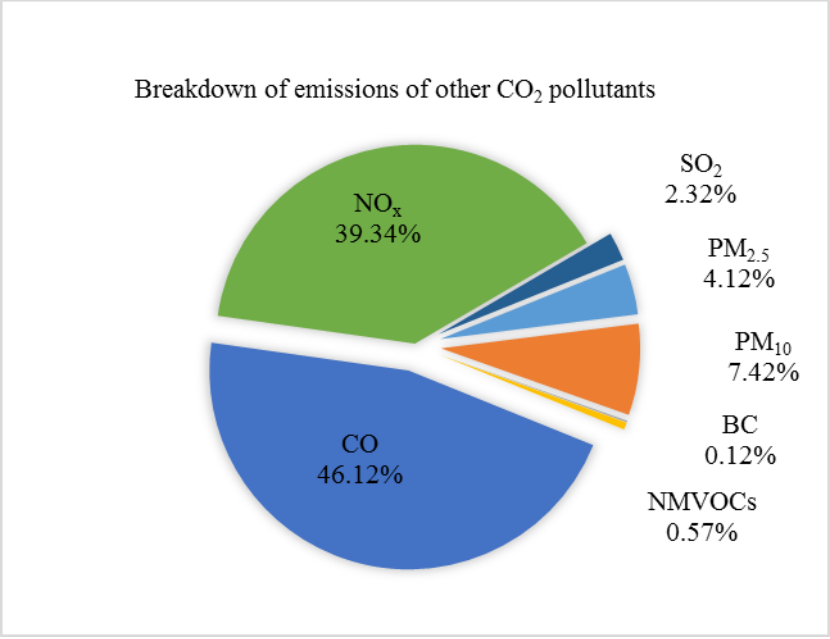

Figure 3: Breakdown of pollutant emissions other than CO_2

The trend analysis (Figure 4 and 5) between 2010 and 2018 confirms, as en 2018, that Ni remains the most emitted ETM in nature by the cement manufacturing chain in the Port area. With regard to the results of the physicochemical analysis, it comes mainly from the clinker used. Besides the Ni, the Cu is the most emitted ETM followed by the Pb and the Cd on the whole time series.

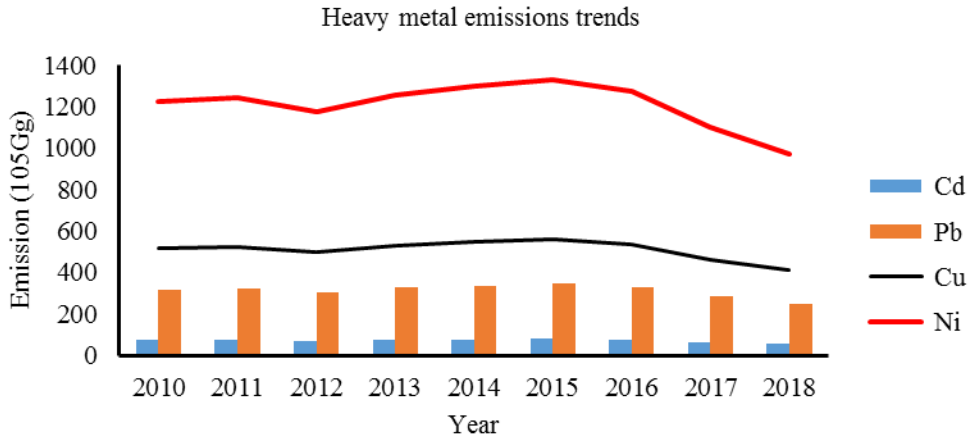

Figure 4: Trends in heavy metals emissions from cement

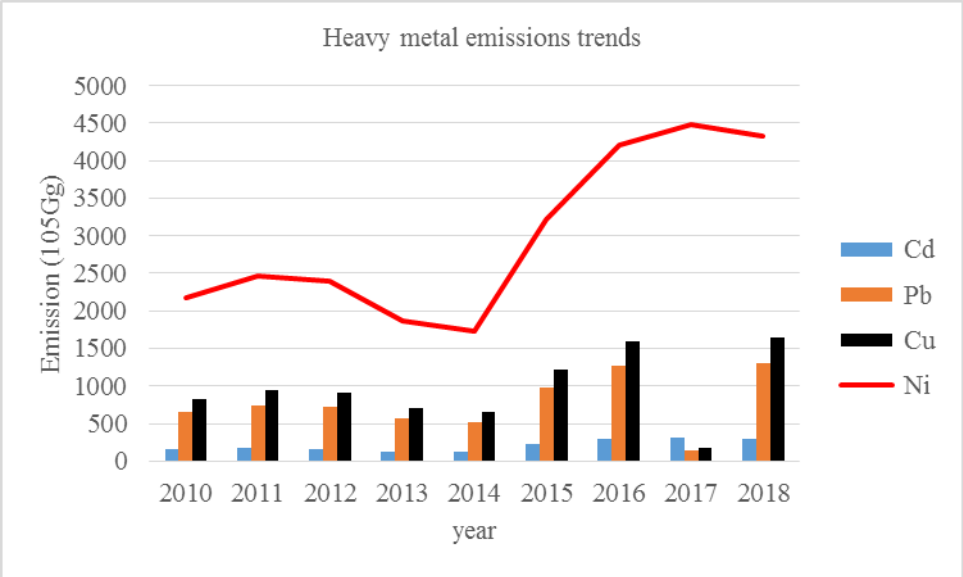

Figure 5: Trends in heavy metal emissions from clinker

The trend in emissions of non-metallic pollutants (Figure 6) is marked by a decrease in emissions of pollutants during the year 2014. Between 2014-2018, the increase is non-linear. These variations are strongly linked to the increase in the quantities of clinker and cement produced each year. As a result, CO_2 emissions are first reduced from 551.186 Gg in 2010 to 435.37 Gg in 2018, and then increased to 1095.63 Gg in 2018. The same is true for PM_{10}, $PM_{2.5}$ and NMVOCs with an estimated value of 0.248; 0.138; 0.019 Gg in 2010 0.196; 0.109; 0.015 Gg in 2014 and 0.493; 0.274; 0.038 Gg in 2018. Among the other pollutants emitted – CO, BC, NO_x and SO_2 –, only the evolution of SO_2 emissions shows an overall downward trend. This is explained by the drop in cement production by CIMTOGO from 2016 to 2018.

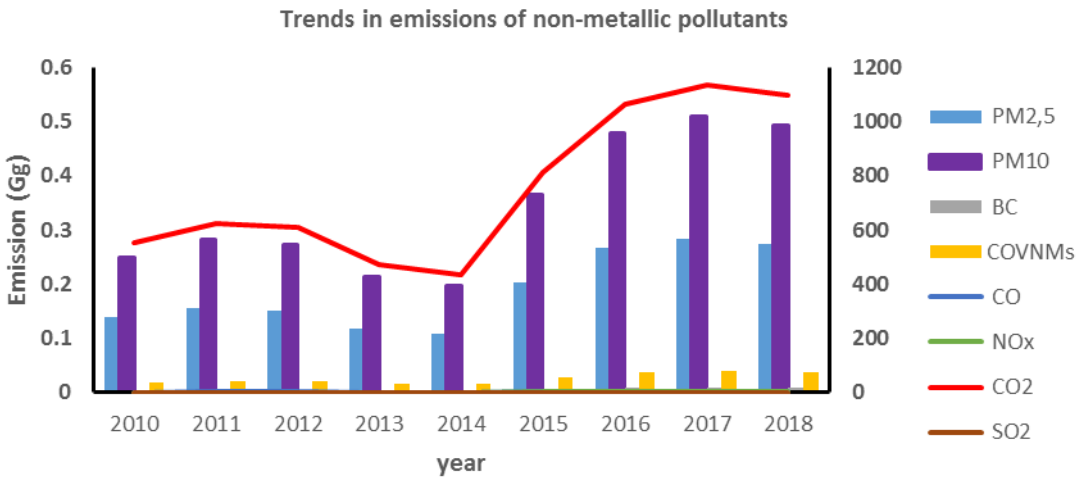

Figure 6: Trends in emissions of non-metallic pollutants

3. CONCLUSION

The raw materials used in the cement production chain contain trace metal elements such as Cd, Pb, Cu and Ni that are partly found in the atmosphere by means of the estimated dust in the form of $PM_{2.5}$ and PM_{10}. In addition to this, the clinkering process estimate revealed emissions of CO_2, NO_x, NMVOCs, CO, $PM_{2.5}$ and PM_{10}, respectively of 1095.63, 2.61, 0.038 and 3.066; 0.274 and 0.493 Gg for 2018. Therefore, the effects of this pollution affect the environment and human health. In view of the effects of the pollutants emitted, the following measures may contribute to their reduction: dust recycling, use of bag filters, installation of PM measuring tools, collection through clinker cooling of dust produced, covering of conveyors, crushers and delivery trucks.

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