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Environmental and Health Impacts of Cement Production Activity in Benin

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Abstract

Background: The airborne feature of cement particles present in the air can be a source of lung nuisance to surrounding populations. This study has as aim to evaluate the environmental and health impact of cement dust on the surrounding populations.

Methods: It was a cross-sectional descriptive study that enabled us to select, after systematic random sampling, 200 people in a nearby area (about 500m) away from the factory: Sekandji and 200 people in another area 1.5km from the factory: Agongo. They were submitted to a questionnaire. Measurements of the level of fine particles (PM 2.5) were carried out simultaneously at the factory and in the two areas. The chemical constituent of these particles: silica, alumina, calcium and iron were analysed. The data were analysed with the Epi info 7 and SPSS 17 software. The risk was evaluated by the odds ratio and a p≤0.05 was considered as a significant difference.

Results: The mean age: 39±14 years and the sex of the participants were distributed without significant difference in the 2 areas. In Sekandji about 2 to 3 times more participants suffer more chronic bronchitis (p=0.04) or allergic rhinitis (p=0.04) than in Agongo. The level of fine particles production in the factory (83µg/m^3) is more than 3 times the WHO standard (25µg/m^3), especially the PM 2.5 level in Sekandji is twice superior to that of Agongo. The combined physicochemical analysis of the dust at the 3 sites (inter-site comparison) shows that the chemical elements constituting the klinker: silica, iron, alumina, calcium, are found less in Agongo than in Sèkandji and strongly in factory.

Conclusions: There is production of fine dust at the plant associated in part with respiratory diseases found in the surrounding population.

Keywords: Cement dust; Particle matter; Respiratory disorders; Health impact; Benin

Introduction

Air pollution is a global concern due, among other things, to its impact on human health. According to the World Health Organization (WHO), it causes about 7 million deaths each year [1]. Over the past 60 years, there has been growing evidence of an association between exposure to air pollutants and the development of respiratory diseases [2].

Increased concentrations of fine particulate matter (PM 2.5) have been reported in different populations as leading to increased susceptibility to respiratory diseases such as asthma, COPD and lung cancer [2]. A study conducted in southern China on the effects of exposure to ambient particles (PM 10/2.5) associated with COPD concluded that the prevalence of COPD is significantly associated with high levels of particulate matter [3]. Another study of adult asthmatics in six low- and middle-income countries (China, India, Ghana, Mexico, Russia and South Africa) long-term exposure to ambient fine particulate matter associated with asthma has estimated that approximately 5.12% of asthma cases in the study population could be attributed to long-term exposure to PM2.5 [4].

The cement plant is a large producer of these fine particles responsible for respiratory disorders. Cement is used in building and public works to bind hard materials. It is in the form of a fine powder from the grinding of clinker, a material obtained by the calcination at high temperature of a mixture of clay and limestone materials. Most of the cement plant in Benin produces cement with imported clinker. It is a unit for grinding clinker and bagging the cement produced.

The major risk of cement production is dust and noise. The level of dust measured in quarries and cement plants is in the range of 26 to 114mg/m^3. Frequent measurements of the level of dust and noise make it generally clear that the noise level remains within normal limits, but the level of dust constitutes the major risk. We will focus on cement dust risk. In fact, pulmonary diseases represent the most important category of occupational diseases encountered in the cement industry, and they can be attributed to the inhalation of airborne dust and to the macro-climatic and micro-climatic conditions of the workplace. The most common health disorder is chronic bronchitis. The airborne character of cement particles in the air can be source of nuisance to surrounding populations and households.

The aim of the study was to assess the environmental and health impact of the cement activities on the surrounding populations (particularly dusts), with the aim of reducing nuisances, promoting

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Table 1: Socio-demographic and current exposures characteristics.

		Agongo: 1.5km (n=200)	Sekandji: 0.5km (n=200)	p
Age (year) (Mean±SD)		39±14	37±12	0.18
Sex	Female	56%	59%	0.60
	Male	44%	41%	
Domestic exposure to smoke	Wood/coal	96%	95%	0.80
	Gas	4%	5%	
Smoker	Yes	5%	1%	0.09
	No	95%	99%	

Table 2: Assessment of respiratory problems.

		Agongo: 1.5km (n=200)	Sekandji: 0.5km (n=200)	p
Respiratory problems	Frequent	8%	14%	0.01
	Never or rarely	91%	85%	
	Abnormal	1%	1%	

health and safety at work, and local development.

Method

Type of study: It was a cross-sectional and analytical study from January to April 2017 that consisted in assessing two areas, one of which is very close to the production unit and the other a bit farther away.

Target population: The target is made up of the populations, male and female together, who work or live in the vicinity of the cement plant within a radius of approximately 500 meters: Sekandji and Houeyogbe (exposed population) and a comparison population of approximately 1.5km from the cement plant: Agongo (unexposed population). Concerning the particles measurement, we collected particles in the cement factory and in each area study.

The sampling: Based on a sample size calculation, we recruited 400 peoples: 200 people in each area. The sampling technique used was a systematic sampling based on the number of people to be surveyed per household at the ratio of one household/shop/store out of four.

Data collection: For the first part, it was essentially about sending a questionnaire to 200 people at Sekandji and 200 people at Agongo. The data collected mainly concern the respiratory problems encountered in the two localities. The data collection procedure included the information of the different village chiefs and raising awareness of the population through the town crier. It should be noted that all this was done in anonymity i.e. without informing that it was an investigation related to cement factory. After that, the phase of actual data collection followed, and lasted about 2 weeks. For the second part, concerning particles measurement, this consisted in measuring simultaneously the level of fine particles (PM 2.5) at the cement plant, Sekandji and Agongo. Those measurements were made over 24 hours with a measuring station equipped with suitable filters. After the determination of the concentrations (in $\mu g/mm^3$) of the fine particles, the samples of particles collected were analysed by a laboratory of our university. Silica, alumina, calcium, iron, total Polycyclic Aromatic Hydrocarbons (PAHs) were particularly sought after. Total PAHs are controls of combustion so in this work should reflect the level of pollution related to vehicle traffic. The other chemical elements are the constituents of the clinker and should vary in the different sites according to their production at the source which is the cement factory. We did not measure PM10s which, because of their physical characteristics, are not only less able to travel long distances but also cannot penetrate deep into the respiratory tract and reach the terminal and alveolar bronchi.

Data analysis: The data were entered in a database with the software Epi info 7. The analyses were conducted in this Epi info 7 software and also in the SPSS 17 software. In a comparative manner, the risk was evaluated by the odds ratio and a $p \leq 0.05$ based on the chi^2 test, was considered as a significant difference.

Results

1. **Socio demographics characteristics of the population:** There is any difference in the population of the two areas of the study, Table 1.

2. **Overall assessment of respiratory problems**: This involved determining the frequency of respiratory symptoms in a surrounding population of the cement plant compared to a control area. At Sekandji 0.5km far from the cement plant, there are about twice as many participants in the study who report that they "frequently" have respiratory problems compared to Agonglo, 1.5km from the plant, Table 2. Odds ratio has been adjusted over age, sex, exposure to wood smoke and tobacco, medical history. Sekandji residents are 2.4 times more likely to cough than those in Agongo and 3 times to allergic rhinitis; Table 3.

3. **Measurement of dust exposure:** We compared dust levels from the cement plant source to the surroundingstudy areas of the plant, it emerges that the level of production of fine particles is more than 3 times the WHO standard ($25\mu g/m^3$) and that especially the level of PM 2.5 in Sekandji is twice that of Agongo Table 4.

4. **Physico-chemical data on dust samples:** We choose to measure not only the frequent components of clinker but also an indicator of combustion (Polycyclic Aromatic Hydrocarbon: PAH) in this case combustion from the exhaust pipes of vehicles in use. It gives us the results of the analysis in ng/nm^2, that is to say the content

Table 3: Assessment of respiratory diseases in the population.

		Agongo 1.5km (n=200)	Sekandji: 0.5km (n=200)	OR	ORa	p
Wheezing	Yes	6%	5%	1	1	NS
	No	94%	95%			
Asthmaattack	Yes	1%	5%	4.6	4.5	0.1
	No	99%	95%			
Respiratorydiscomfort	Yes	6%	3%	0.5	0.6	NS
	No	94%	97%			
Shortness of breath	Yes	5%	1%	0.2	0.2	NS
	No	95%	99%			
Chroniccough	Yes	5%	11%	2, 3	2.4	0
	No	95%	89%			
Chronicsputum	Yes	4%	8%	1.8	1.7	NS
	No	96%	92%			
Allergicrhinitis	Yes	2%	7%	3.1	3	0
	No	98%	93%			

ORa = OR adjusted; NS = Not significant.

Table 4: Determination of the PM level 2.5 over 24 hours.

Measurement areas	PM 2.5 ($\mu g/m^3$)
At Cement factory	83
At Sekandji (0.5km)	28
At Agongo (1.5km)	14

of chemical constituents per unit area of the filters and also in ng/kg meaning is the content of the chemical constituents per kilogram of particles collected, This chemical analysis confirmed the same concentration gradients in terms of the dispersion of the clinker's chemical components but with some variability found probably due to local measurement conditions at each site. Nevertheless, the overall content of silica and silica oxide recovered at the factory remains constant; silica being one of the main components of clinker, Table 5.

Discussion

Our study aimed to evaluate the environmental and health impact of the activities of CIMBENIN on the surrounding population. This study compared two perfectly similar populations (through socio-demographic characteristics, medical history and lifestyle); though their places of residence are different; the first one is the exposed population who lives within a radius of 500 meters from the factory and the second one is composed of the unexposed population at 1.5km away from the factory. The methodology used took into account the confusion bias and that makes the obtained results fully valid.

The level of concentration of fine particles (PM 2.5) in the cement plant is 83$\mu g/m^3$ in 24 hours, which is three times higher than the WHO standards (25$\mu g/m^3$); which is quite normal considering that cement production emits a lot of dust. Much higher values were found in various countries such as Nigeria with levels of fine particles reaching 249 mg/m^3 [5], Jordan with more than 120$\mu g/m^3$ in 24 hours [6], but production capacities of the factories are not the same because economic contexts and levels of urbanization are different.

The fine particle levels at Sekandji and Agongo are respectively 28 and 14$\mu g/m^3$, and they are below WHO standards. But we should especially note that 500 meters away from the factory, the level of PM 2.5 is twice higher than 1.5km at a greater distance. If our results are similar to those of Nkhama et al., [7] in Zambia with 24.93$\mu g/m^3$ of PM 2.5 in the vicinity of the cement plant against 6.03$\mu g/m^3$ but 18km further; much higher levels have been reported by other authors. This includes kabir et al., [5] in Nigeria with values of 500 to 650$\mu g/m^3$, Chaurasia et al., in India with 526$\mu g/m^3$ [8], by Abdoul et al., [9] in Oman with PM 2.5 levels ranging from 196.19$\mu g/m^3$ to 423.83 $\mu g/m^3$ in the vicinity of the relevant cement plants.

These differences can be linked to several factors: the amount of dust emitted by the plants is not necessarily the same, climatic factors such as wind speed, the season, the degree of humidity also influences

Table 5: Chemical analysis of dust samples.

Parameters	Level			
	Agongo (1.5km) $10^{-14}ng/nm^2$	Sekandji (0.5km) $10^{-14}ng/nm^2$	Cement plant site 1 $10^{-14}ng/nm^2$	Cement plant site 2 $10^{-14}ng/nm^2$
PAH	13.32	26.53	79.29	139.15
Al	1.253	2.67	96.96	123
Al_2O_3	2.37	5.045	183.14	227.4
Si	12.71	26.51	115.53	102.73
SiO_2	21.18	44.19	192.57	171.22
Ca	0.05	1.8	51	5
Fe	0.02	0.3	17.89	1.69

the dispersion of fine particles in nature.

In the study, the inhabitants of Sekandji have 2-3 times more chronic bronchitis or allergic rhinitis than those of Agongo (p=0.04 and OR=2.4 and 3). At Sekandji, there are also twice as many participants who report frequent respiratory problems (p=0.01). Our conclusion is in line with most of the literature [6,10,11,12]. Indeed, several studies have shown a positive link between respiratory symptoms and pollution related to cement dust [6,10,11,12]. Nkhama et al., [7] showed that there was 3 times more cough and respiratory symptoms in the community exposed to cement dust compared to the unexposed population; Mwaiselage et al in Norway [13] achieved a 5-fold increase in chronic bronchitis in dust-exposed individuals compared with those who were not, regardless of tobacco use. But in their study, the focus was the workers of the cement factory while in ours; it is rather the residents nearing the factory who are concerned so the intensity of exposure is not the same. This increased risk of bronchitis and rhinitis is explained by the fact that atmospheric particles, by their size, cross the tracheobronchial tree causing irritation and can penetrate into the alveoli, crossing the alveolar-capillary barrier and cause besides bronchopulmonary problems, cardiovascular diseases [14]. In addition to the selection of study participants, usual factors of confusion such as domestic pollution through the use of firewood for cooking and smoking were taken into account.

Moreover, the physico-chemical analysis of the dust found at the factory, and at the two other sites (Sekandji at 0.5km and Agongo at 1.5km) show that the chemical elements (silica, iron, alumina, calcium) are less present at Agongo than at Sekandji; the ratio is globally 2 for Al, Al_2O_3, Si, SiO_2 and much higher for the other elements. Those chemical elements strongly present in the cement factory are nothing more than the constituents of the clinker. In addition, exposure to PM 2.5 has been shown to increase the risk of cough and rhinitis [15]; which reinforces us in the idea that it is indeed dust emissions from the factory that are causing the recrudescence of bronchial symptoms as observed in local residents; our findings are also the same as those of Tiwari et al [16] in Macron et al., [17]. It should not be forgotten, however, that Polycyclic Aromatic Hydrocarbon (PAH) levels vary with the same gradient in our study at Sekandji and Agongo and denote exposure to a source of combustion, in this case the gases of exhaust from vehicles. Since the measurements at the cement plant were made in the absence of an internal combustion source, the rates found are probably due to pollution caused by road traffic. We must therefore interpret our results with caution and announce that respiratory diseases cannot all be associated solely with dust from the factory because the PAH content, a good indicator of traffic-related pollution, is also high as well at the cement plant as at Sekandji.

Conclusion

There is a production of fine dust at cement plant associated in part with respiratory diseases found in the surrounding population. Findings from this study add to the body of knowledge that even seemingly healthy people are adversely affected due to exposure to PM at low levels. There is a need to strengthen the risk reduction measures of cement dust.

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