Environmental Impacts of Cement Production on Surface Water Quality, Vegetation and Workers' Health

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Abstract

The present study investigated environmental impacts of cement production on surface water quality and vegetation around the vicinity of the industry. A two-year study was conducted covering both wet and dry seasons. Water samples were collected from Akinbo River where the Cement industry discharges its liquid waste/effluents. Samples were analysed for physical and chemical parameters using standard procedures. The vegetation around the factory was studied for chlorophyll, plant density, basal areas and heights of woody species. The study also assessed the health impacts of cement production activities on the workers and the residents around the factory. The health assessment was based on the hospital information obtained from two clinics in the nearby villages. The water quality results revealed high concentrations of Ca and Fe. All the trees sampled around the study area had small basal areas and short heights. There was also a significant reduction in the chlorophyll contents of vegetations around the cement factory. The health study showed a high incidence of upper respiratory tract infections, cardiovascular diseases, arthritis, and dermatitis among the cement factory workers. The present study suggests an upward review of the dust-suppressing system in use by the industry for the protection of public health.

Introduction

Up until about a decade ago, about 8 million tonnes of cement were produced yearly in Nigeria from the eight operating companies (Africa.com, 2008; Ademola and Oluseyi, 2013). Currently, the aggregate installed capacity stands at 47.8 million metric tonnes (MMT). The cement manufacturing companies vary both in technology and status. Cement companies in Nigeria are either independently owned and operated locally as joint venture companies or are state operated. Cement production is a particle-generating operation connected with many processes including crushing and extraction of mined rocks, milling activities, and kiln operations. Cement production releases solid waste substances and gaseous pollutants such as NOx, SO_2 and CO_2 into the environment (Huntzinger et al., 2009; Lei et al., 2011; Voicu et al., 2020). Contaminants such as heavy and trace elements and organic compounds like dioxins and furans are associated with cement kilns (Van-Oss and Padovani, Arfala et al., 2018).

Regular discharge of dust from the kiln stack releases fine particulate matter into the environment. These dust particles are blown by prevailing winds to the adjoining villages where they could initiate many health problems. Exposure to cement dust has been reported to cause respiratory symptoms and lung diseases in the exposed workers (Al-Neaimi et al., 2001; Meo et al., 2001; Merenu et al., 2007). The severity of the respiratory problems is a function of years of exposure (Alakija et al., 1990). A study by Merenu et al. (2007) at a cement factory in Sokoto, Nigeria reported lung function impairment in subjects exposed to cement dust over a long time. Liquid waste/effluent generated by the quarry, press house and milling operations during cement production can also have detrimental effects on the different environmental media at the study site. The noise generated from the quarry, cement and raw mills may pose detrimental effects on human health.

Many studies have been conducted at the Ewekoro cement factory when the system of production was operating on a wet system of cement manufacture (Asubiojo et al., 1991; Adejumo et al., 1994; Salami et al., 2002; Olaleye, 2005). Salami et al. (2002) investigated the effect of cement production on the vegetation around the Ewekoro cement factory and concluded that cement dust deposition affected the vegetation parameters studied up to 5 km from the factory. Also, Olaleye (2005) reported the effect of Ewekoro cement dusts on the aquatic and terrestrial ecosystems. The aim of the present study is to evaluate the impacts of the dry system of cement manufacture on the surface water quality, vegetation and human health.

Materials And Methods

Study area

The WAPCO cement factory is located at Kilometer 64 on Lagos-Abeokuta Road in Ewekoro Local Government Area of Ogun State on latitude 6º 54′ N – 6º 55′ N and longitude 3º 12′ E – 3º 13 ′ E (Figure 1). The abundance of limestone deposit informed the location of the Cement Plant in Ewekoro. There is a linear settlement pattern in the area around the cement factory. The present vegetation may be described as derived savanna and most part of the area is subjected to annual bush burning. The WAPCO cement industry produces about 1.8 million tonnes of cement per annum (IDRC, 2004). The technologies of production in Ewekoro factory began with a semi-wet system in 1960 to wet in 1978 and purely dry in 2002. Consequently, varying degrees of environmental pollution can be attributed to each of these systems.

Sample Collection and Analysis

Surface water collection and analysis

Watersamples were collected along Akinbo River, the only river the cement factory discharges its waste water into at an interval of 500 m. Akinbo River takes its source from Ewekoro River and discharges into Alagutan River about 10 km from the factory. Water samples were collected at 5 sites for a period of two years from 2005 to 2006 covering both the dry and rainy seasons. A total of 72 surface water samples were collected during the period of the study. Each sample was analyzed for temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), hardness, dissolved oxygen (DO), metals (K, Na, Ca, Mg, Cr, Cu, Pb, Mn, Fe and Zn). Control water samples were collected from a River in Obada Oko, about 22 km from the factory.

Water parameters were determined using the standard methods (APHA, 2005). Temperature, DO, pH and conductivity were determined on site for accuracy. Temperature, pH and Conductivity were determined using a battery-operated electronic Hanna multipurpose meter. The meter was calibrated with standard buffer solutions each time prior to sampling. DO was measured using Jenway 9071 battery operated DO meter with values in mg L^{-1}. TDS and TSS were determined by gravimetric method while Total hardness was determined by titrimetric method using EDTA solution (APHA, 2005). Water samples for metal determination were digested with concentrated nitric acid (10 mL acid + 100 mL water sample) on a hot plate for 30 minutes. The digested samples were filtered and made up to the mark with distilled water into 100 mL bottles. Na and K were determined using the Flame photometer (Jenway PFP7), while Ca, Mg, Zn, Cr, Pb, Fe, Cu and Mn were determined using the Atomic Absorption Spectrophotometer (AAS, model 210 VGP).

Sampling and analysis of vegetation

Plants (Cassava, *Manihot esculenta*) and sugar cane, *Saccharum officinarum* around the vicinity of the industry were collected and analyed for chlorophyll, plant density, basal areas and heights of woody species. Plant density and leaf abundance were obtained from field enumeration and counting.Five stands of each plant were randomly picked and all the leaves counted. Cassava (dicot plant), and sugarcane (monocot plant) were selected for chlorophyll analysis. Chlorophyll was determined using the method of Lancaster et al. (1997). The leaves were washed in distilled water to remove dust particles and weighed. For each species, a known weight of fresh leaf was collected and ground in 20 mL of 80% acetone. It was filtered through Whatman filter paper. The filtrate was then made up to 25 mL with 80% acetone. The absorbance of filtrate was measured at 663 nm and 645 nm using UV-visible spectrophotometer. Chlorophyll content was then calculated according to the method of Lancaster et al. (1997).

Tree basal areas were calculated from the girth measurement and their density obtained from field enumeration. For the purpose of this study, a tree was considered as a woody plant having one erect perennial stem (trunk) and at least fifteen centimeter in diameter at a point 1.3 m above the ground, a definitely formed crown of foliage, and a height of at least 5 m. Tree Basal Area (TBA) is the cross-sectional area (over the back) at breast height (1.3 m above the ground) measured in meters squared (m^2). TBA was calculated from breast height (Diameter at Breast Height, DBH) in centimeter using an equation based on the formula for determining the area of a circle as:

Tree Basal Area (TBA) $m^2 = \pi r^2 = 3.142 \times (DBH/200)^2$

Where, r is equal to radius (i.e., DBH/2) and π is a constant = 3.142.

Tree heights were measured using the Haga Altimeter.

Health data collection

Medical records of the prevalent diseases and ailments amongst the Cement factory workers, the neighbouring inhabitants and residents of Obada Oko (the control area) were collected between 2003 and 2006 from the factory clinic, the State General hospital located at Itori, and the Medical Center in Obada Oko. Common ailments recorded included Upper Respiratory Tract Infections, Gastro-intestinal Disorders, Cardio-vascular diseases, Dermatitis, Carbuncle, Conjunctivitis, Malaria, Measles, Insomnia, Cuts, Colds, General body malaise, abdominal pains, road traffic accidents, loss of appetites, Bites of different types, malnutrition and many others. All these were eventually sorted and reduced to ailments whose causes can be related to particulate matter. The divergence and peculiarity of these diseases vis-à-vis the activities of the inhabitants in the two locations were discussed.

Results And Discussion

Water quality

The results of the water parameters of Akinbo River for the period of two-year sampling covering dry and wet seasons are shown in Figure 2. The variation in temperature observed at different distances of sampling from the factory may be attributed to prevailing climatic conditions. The mean values for the wet season (26.02 - 27.02 ^oC) and for the dry season (26.58 - 29.77 ^oC) were still within the range for tropical climate. The significantly higher temperature for the dry season in this work actually reflected the environmental conditions prevalent in the dry season and the results are similar to that obtained by Jaji et al. (2007) for Ogun River. The mean pH values of the Akinbo River varied from 6.87 to 7.35 in the wet season and 6.43 to 7.41 in the dry season, indicating slight acidic to neutral conditions. All the pH values were within the WHO guideline range of 6.5 to 8.5 (WHO, 2017a).

The season seemed to have little or no effects on the stream pH value. Fabbri et al. (2000) reported a range of water pH of 7.0 to 8.5 for surface water around the Southdown Portland Cement factory in Lyons, Colorado, while Olaleye (2005) reported a range of 6.63 to 7.73 (wet season) and 6.21 to 7.91 (dry season) in the effluents around Ewekoro cement factory. Dissolved oxygen (DO) values did not show any significant difference with sampling distances from the factory. However, the DO values were slightly higher during the dry season than wet season. The DO value range for the dry season was from 6.56 to 7.0 mg L^{-1} and for the wet season 6.16 to 6.7 mg L^{-1}, which were within the acceptable limit of 4.0 mg L^{-1} set by the Nigeria Federal Ministry of Water Resources as the permissible level for surface water quality criteria for public supplies (FRN, 2000).

Total dissolved solids (TDS), total suspended solids (TSS) and total solids (TS) values also did not show any significant difference with sampling distances from the factory. EC did not vary between the two seasons but showed higher values at the factory effluent discharge point on the stream. Total hardness (TH) followed similar trend like EC, Ca and Mg concentrations of the River. A notable rise in total hardness was measured at the sampling points immediately after the factory effluents discharge point. The concentrations of K, Na, Mg and Ca were a reflection of their natural occurrence in the surface water despite higher values at the discharge point downstream. The values of these parameters were similar with those reported for the same neighbourhood by Olaleye (2005). However, the higher concentrations of K and Mg observed during the wet season might probably be linked to influx of erosion water.

The Pb values of the stream were below the WHO guideline value of 0.05 mg L^{-1} (WHO, 2017a), except at the discharge point of the factory effluent during the dry season. Cu and Zn concentrations were also lower than the respective guideline values of 1.0 mg L^{-1} and 5.0 mg L^{-1} (WHO, 2017a). At some sampling sites, Mn, Cr and Fe have values slightly higher than the WHO guideline values of 0.1 mg L^{-1}, 0.005 mg L^{-1} and 0.3 mg L^{-1}, respectively (WHO, 2017a). The heavy metals data (Cr, Cu, Pb, Mn, Fe and Zn) were generally low with no seasonal significance, except for Fe. Many of these metals are emitted from anthropogenic activities such as traffic, industries, incineration and combustion of fossil fuel (Taiwo et al., 2014); however, their low occurrence in Akinbo stream indicated minimal inputs from the cement factory.

The Pearson correlation coefficients of water parameters are presented in Table 1 of the supplementary information. There existed a strong positive correlation between EC and TH (r^2 = 0.997; p<0.01), which indicates probable influence from salts of Mg and Ca, which are essential constituents of cement dust. A strong positive relationship was also observed between Ca and Mg (r^2 = 0.841; p<0.05). Ca is a major tracer element for cement [23]. A high significant correlation between Zn and Cu (r^2 = 0.878; p<0.05), Zn and Mn (r^2 = 0.899; p<0.05) might indicate a common source of emission, probably from other anthropogenic activity aside cement production, since these metals were anti-correlated with Ca and Mg. Previous studies have adopted Zn and Cu as fingerprints for traffic pollution (Taiwo et al., 2014; Taiwo *et al.*, 2017).

Vegetation

The results of vegetation parameters in relation to sampling distance from the cement factory are presented in Tables 2 and 3. The number of trees increased significantly from 48 to 148 trees per hectare up till 3 km away from the factory, where another dust-generating activity (Clay factory) was located. This can be attributed partly to the effect of the cement dust on the vegetation and/or partly due to deforestation work done around the factory site during the construction of the new factory in 2001. The land areas around the factory were generally touched during the construction work as industrialization always goes with deforestation. The areas farther away fall outside the factory acquired land and are thus protected.

In the work of Salami et al. (2002) around Ewekoro factory, a gradual increment in the number of trees was also observed from 38 to 218 trees per hectare, but became insignificant after 6 km away from the factory location, where the highest density was found. The average tree diameter at breast height followed the same pattern as the number of trees; although with fewer trees at 0 km. One of the trees was very big having been shielded from farmers' aggression and thereby increase the diameter value at this plot.

Table 1: Pearson Correlation Coefficients for water parameters

	Temp	pH	DO	EC	TDS	TSS	TS	TH	K	Na	Ca	Mg	Cr	Cu	Pb	Mn	[illegible]
Temp	1																
pH	.862*	1															
DO	.555	.363	1														
EC	.824*	.990**	.426	1													
TDS	-.662	-.940**	-.309	.961**	1												
TSS	-.914*	-.798	-.813*	-.813*	.659	1											
TS	-.850*	-.961**	-.585	-.982**	.930**	.889*	1										
TH	.827*	.980**	.478	.997**	-.949**	-.842*	-.989**	1									
K	-.597	-.534	.188	-.429	.397	.247	.362	-.382	1								
Na	.437	.657	.610	.725	-.754	-.651	-.776	.739	.178	1							
Ca	.779	.982**	.260	.981**	-.949**	-.719	-.929**	.972**	-.484	.626	1						
Mg	.655	.930**	.363	.960**	-.972**	-.699	-.933**	.955**	-.245	.841*	.941**	1					
Cr	-.137	.262	-.225	.282	-.421	.094	-.210	.253	.203	.599	.304	.517	1				
Cu	-.246	-.293	.411	-.247	.214	-.004	.128	-.228	.614	.441	-.388	-.093	.372	1			
Pb	.629	.740	.148	.702	-.625	-.556	-.652	.683	-.268	.624	.708	.736	.609	.085	1		
Mn	-.618	-.596	.304	-.491	.394	.274	.374	-.450	.851*	.153	-.599	-.338	.041	.708	-.529	1	
Fe	-.830*	-.989**	-.398	-.996**	.944**	.810	.970**	-.994**	.438	-.679	-.989**	-.945**	-.246	.312	-.696	.532	[illegible]
Zn	-.614	-.529	.163	-.455	.319	.343	.362	-.439	.738	.264	-.561	-.251	.361	.878*	-.271	.899*	[illegible]

Table 2: Vegetation parameters in relation to distance from dust pollution source for wet seasons 2005 and 2006

Distance from factory (km)	No of Trees in 25x25m plot	No of Trees per hect	Mean DBH/plot (cm)	Mean DBH /hect	Mean TBA/plot (m^2/hec) $\pi D^2/4$	Mean TBA/hect(m^2/hec) $\pi D^2/4$	Mean tree height/plot (m)	Mean Tree height/hectare (m)	Leaf Abundance/plant (Average of 10 stalks)		Comme on Vegetat
									Cassava	Sugar cane	
0	3.0±0.0^{d}	48^{d}	40.67 ± 22.20^{a}	650.72^{a}	0.17 ± 0.17^{a}	2.70^{a}	11.73 ± 4.79^{a}	187.68^{a}	36.25 ±1.27^{e}	11.4 ±1.66^{d}	Dusty le yellowis patches the leaf surface folding edges.
1	7.0±0.0^{b}	112^{b}	24.64 ± 14.54^{d}	394.24^{d}	0.07 ± 0.08^{d}	1.04^{d}	7.91 ± 3.40^{b}	126.56^{b}	48.75 ± 9.21^{d}	12.5 ±0.77^{c}	Improve surface and nur of leave leaves r greenish
2	8.0±0.0^{a}	128^{a}	27.90 ± 15.53^{c}	464.40^{c}	0.08 ± 0.08^{c}	1.28^{c}	6.95 ± 2.88^{c}	111.20^{c}	70.00 ±10.11^{c}	13.0 ±1.53^{b}	Leaves cassava more, fr wider ar less dus
3	4.5±0.5^{c}	80^{c}	18.32 ± 5.03^{e}	293.12^{e}	0.03 ± 0.01^{e}	0.45^{e}	7.32 ± 1.50^{c}	117.12^{c}	82.75 ± 8.77^{b}	13.0 ±0.85^{b}	Number leaves c cassava more apprecia but not sugarca Ogun St Clay bric factory to 3 km Ewekoro
Control Site 22 km	7.0±0.0^{b}	112^{b}	38.56 ± 11.55^{b}	616.96^{b}	0.13 ± 0.07^{b}	2.03^{b}	7.83 ± 1.08^{b}	125.28^{b}	125.00 ± 12.01^{a}	14.0 ±1.10^{a}	Fresher leaves, v surface dust impregr no yello patches Leaves mostly abunda the stalk

Means with similar alphabets (in superscript) along the rows are not significantly different at $p > 0.05$. DBH-Diameter at breast height, TBA-Tree basal area, hect-hectare

Table 3: Chlorophyll content of Cassava and Sugarcane (mg g^{-1}) compared for 2005 and 2006 sampling in relation to distance from cement factory

Distance (km)	Plant	2005	2006 (mg g^{-1})	Mean
0	Cassava	2.10	2.97	$2.53±0.43^{b}$
	Sugar cane	1.18	1.69	$1.44±0.25^{b}$
1	Cassava	3.17	3.64	$3.40±0.24^{ab}$
	Sugar cane	2.99	2.77	$2.88±0.11^{a}$
2	Cassava	4.18	4.67	$4.42±0.24^{a}$
	Sugar cane	2.07	2.79	$2.43±0.36^{ab}$
3	Cassava	2.75	4.08	$3.41±0.66^{ab}$
	Sugar cane	1.63	3.01	$2.32±0.69^{ab}$
Control site 22 km away	Cassava	3.88	3.71	$3.79±0.09^{a}$
	Sugar cane	1.38	1.73	$1.56±0.18^{b}$

Means with similar alphabets (in superscript) along the columns are not significantly different at $p > 0.05$.

A significant increase was noticed while moving away from the factory up till 3 km. Basal area values calculated from these breast height measurements were generally small and similar to the past study (Salami et al., 2002). It was observed that tree species were less than 40 years old and that cement dust pollution did not prevent the appearance and growth of these tree species, although it might have affected their growth rate. This suggested that the impact of land use, especially farming system in the area had reinforced the effect of the factory pollution on the vegetation in the area; which is similar to the findings of Du et al. (1998) and Saravanan and Appavu (1998). A wide variety of tree species have been studied for their response to dust. Dust may cause physical injury to tree leaves and bark, reduced fruit setting and a general reduction in growth. Details of injuries to a range of tree species from cement kiln dust has been described elsewhere in Lepeduš et al. (2003). The dust forms a hard crystalline crust on the leaf surface, which dissolves releasing solution of calcium hydroxide into the intercellular spaces. This causes cell plasmolysis and death. Cement dust deposition can lead to growth reduction for many species (Iqbal and Shafig, 2001; Sett, 2017).

The quantity of dust that affects trees is much more difficult to ascertain than for crops. Brandt and Rhoades (1972) measured cement/lime dust deposition rate that could affect trees and found out that the rate was high in comparison to those of many crops earlier studied. The study concluded that it was not possible to give a critical level of deposition that could start to cause the effects described for crops. It is also not certain how long some of the physiological responses could affect the health of trees. Flückiger et al. (1979) found that, while 1 mg cm^{-2} of dust was necessary to cause a decrease in stomatal diffusive resistance in *Popolus tremula,* only 0.5 mg cm^{-2} was necessary to cause an increase in leaf temperature.

Following similar pattern as the trees data, leaf abundance and chlorophyll contents of cassava (*Manihot esculenta*) and sugarcane (*Saccharum officinarum*) increased significantly up to 3 km away from the factory. The most positive result was observed for the leaf abundance at the control site, 22 km away from the factory. Some of the chlorophyll content values of plants around the study area insignificantly exceeded those from the control site; which is similar to the results reported by Prasad and Inamdar (1990) and Iqbal and Shafig (2001). This may have negative effects on crop yields and consequently affect the agricultural activities within the vicinity of the factory. Raajasubramanian et al. (2011) reported that cement dust caused reduction in growth and yield of groundnuts (*Arachis hypogaea L.*).

The variations in the chlorophyll contents of cassava and sugarcane as reported in this study can therefore be explained by their different susceptibilities to pollutants. Plant response to pollutants varied between species of a given genus and between varieties within a given species (Yu et al., 2011). Plants do not necessarily show similar susceptibility to different pollutants. The presence of heavy metals in cement dust could also have played a significant role in the various metabolic processes of plants (Abdel-Rahman and Ibrahim, 2011; Mutlu et al., 2013).

Health assessment

Tables 4 and 5 show the prevalent ailments data among the factory workers, the neighbouring villagers (in Itori) and the residents of Obada Oko (which was selected as the control site). Records of the ailments were extracted from the record books of the selected clinics in Itori and Obada Oko towns. Itori is about 2 km from the factory plant, while Obada Oko is around 10 km away from the Ewekoro cement plant.

The prevalence of upper respiratory tract infections (URT), which include cough, catarrh, tonsillitis, bronchitis and asthma, dermatitis and eye problems were observed highest (90%) among the factory workers compared to the neighbouring villages (2%) and the control site at Obada Oko (8%). The high prevalence of URT among the factory workers may be directly linked to exposure to cement dust (Vestbo and Rasmussen, 1990). URT infections among the factory workers dropped from 90% in 2003 to 85 % in 2006. The decrease in the occurrence of URT infections and other dust-inducing ailments among the factory workers can be attributed to many factors.

These factors might include (1) better campaign and awareness on the use of personal protective equipment (PPE), (2) introduction of new technology of production as reflected in the new dry system plant, (3) better clinic attention and retirement of old staff who have spent long years of service with greater exposure to dust and, (4) better environmental management system in the plant as reflected in the certification of the factory to NIS ISO 14001:2004 in the late 2006.

Table 4: Health data of reported URT, Malaria and GIT disorders in the selected areas

		URT Infections			Malaria Infections			GIT Disorders		
Year		FW	Obada	NV	FW	Obada	NV	FW	Obada	NV
2003	Frequency	1611	34	148	1486	43	630	514	22	117
	Percent	90%	2%	8%	69%	2%	29%	79%	3%	18%
2004	Frequency	1278	50	165	1782	48	625	540	25	95
	Percent	86%	3%	11%	73%	2%	25%	82%	4%	14%
2005	Frequency	1300	79	142	1710	54	693	670	26	73
	Percent	85%	5%	9%	70%	2%	28%	87%	3%	9%
2006	Frequency	1381	45	190	1813	56	607	475	32	148
	Percent	85%	3%	12%	73%	2%	25%	73%	5%	23%

URT - Upper Respiratory Tract Infection (Cough, Catarrh, Tonsillitis, Bronchitis, Asthma); GIT - Gastro-Intestinal Tract Disorders (Peptic ulcer, Typhoid, Gastroenteritis, and dysentery); FW: Factory Workers; NV: Neighbouring Villagers

Table 5: Health Data of Reported CVD, Arthritis and Dermatitis in the selected Areas

		CVDs			Arthritis patients			Dermatitis infections		
Year		FW	Obada	NV	FW	Obada	NV	FW	Obada	NV
2003	Frequency	71	12	45	763	1	12	453	10	8
	Percent	55%	9%	35%	98%	0%	2%	96%	2%	2%
2004	Frequency	65	9	33	684	8	10	268	11	11
	Percent	61%	8%	31%	97%	1%	1%	92%	4%	4%
2005	Frequency	41	11	44	565	10		172	9	
	Percent	43%	11%	46%	98%	2%	0%	95%	5%	0%
2006	Frequency	25	6	47	415	9	14	182	20	6
	Percent	32%	8%	60%	95%	2%	3%	88%	10%	3%

CVD: Cardio-Vascular Diseases: Hypertension, Angina pain, Palpitation; Arthritis: Muscular and joints

pains; FW: Factory Workers NV: Neighbouring Villagers; Dermatitis: Contact and infectious skin diseases,

nail infections (paronychia); FW: Factory Workers; NV: Neighbouring Villagers

Similarly, malaria and gastro intestinal tract (GIT) disorder cases were also most prevalent among the factory workers. Malaria is a common disease in the tropics and may not be attributable to exposure to cement dust. However, GIT disorder may be related to exposure to cement dust through inhalation. Koh et al. (2011) had linked exposure to cement dust with gasto-intestinal cancer.

Cases of cardio-vascular diseases (CVDs), arthritis and dermatitis were also prevalent among the factory workers. However, the CVD cases were prevalent among the residents of neighbouring villages in 2005 and 2006. The latter may be related to risk factors such as unhealthy diet, physical inactivity, tobacco use and harmful use of alcohol (WHO, 2017b). Globally, CVD is the leading killer disease, which has also been linked to air pollution (Rajagopalan *et al.*, 2018). Data had shown that 17.9 million people died from CVDs in 2016, thus representing 31% of all global deaths (WHO, 2017b).

The 2006 data for factory workers revealed general reduction in the cases of URT (90-85%), GIT (79-73%), CVD (55-32%), arthritis (98-95%) and dermatitis (96-88%). Among these dust related diseases, only CVD has shown drastic decline, probably due to the mitigating measures highlighted earlier, most especially the use of PPE and better environmental management system (NIS ISO 14001:2004).

Conclusion

This study assessed the environmental impacts of Portland cement factory in Ewekoro on surface water (Akinbo River), vegetation and health status of workers and neighbouring communities. The surface water samples were found to be rich in calcium carbonate and bicarbonate ions showing a pH range of 6.87 to 7.35 in the wet season, and 6.43 to 7.41 in the dry season. The physical and chemical parameters of surface water were not hugely affected by the activities of the cement industry. This was reflected in strong correlations of some water parameters with calcium. Heavy metals values from Akinbo River were generally low with minimal impacts from the cement factory. The plants' growth and chlorophyll contents of cassava and sugarcane were affected by cement dust, which might be due to the presence of different toxic pollutants in cement dust. The presence of another dust generating factory less than 3 km away, the State-owned Gateway Brick Company might have additional effects on the vegetation growth in the area. Almost all the tree species measured in this study have small basal areas and heights.

The numbers of ailment cases reported in this study showed the effects of cement dust on the exposed workers as well as the neighbouring villagers around the industry. Despite the fact that cases of CVD, arthritis and dermatitis dropped between 2003 and 2006; yet there is a need for improvement in dust control mechanisms by the factory. The cases of URT diseases which are mainly attached to cement dust are still high despite decreasing by 5%. This therefore suggests a review of the dust suppressing system being used by the industry for the protection of public health.

Declarations

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Dedication

This paper is dedicated to the memory of the first author, Dr. Orisunmibare Taiwo Agbede who died in November 2014, four years after completing his Ph.D programme.

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Authors' contributions

OTA and TAA conceptualized and designed the study. TAA, COA and MTA supervised the study. OTA collected and analysed the samples. AMT analysed the data. TAA and AMT drafted the manuscript. All the authors read and approved the manuscript.

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Figures

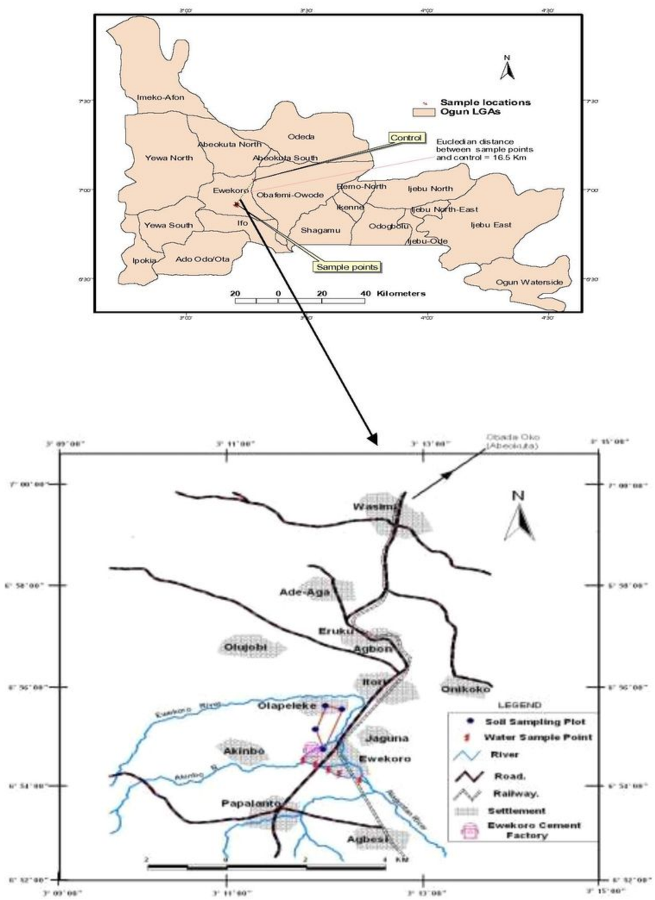

Figure 1

Map of Ogun State of Nigeria showing the study and control sites located with Ewekoro Local Government Area of the State

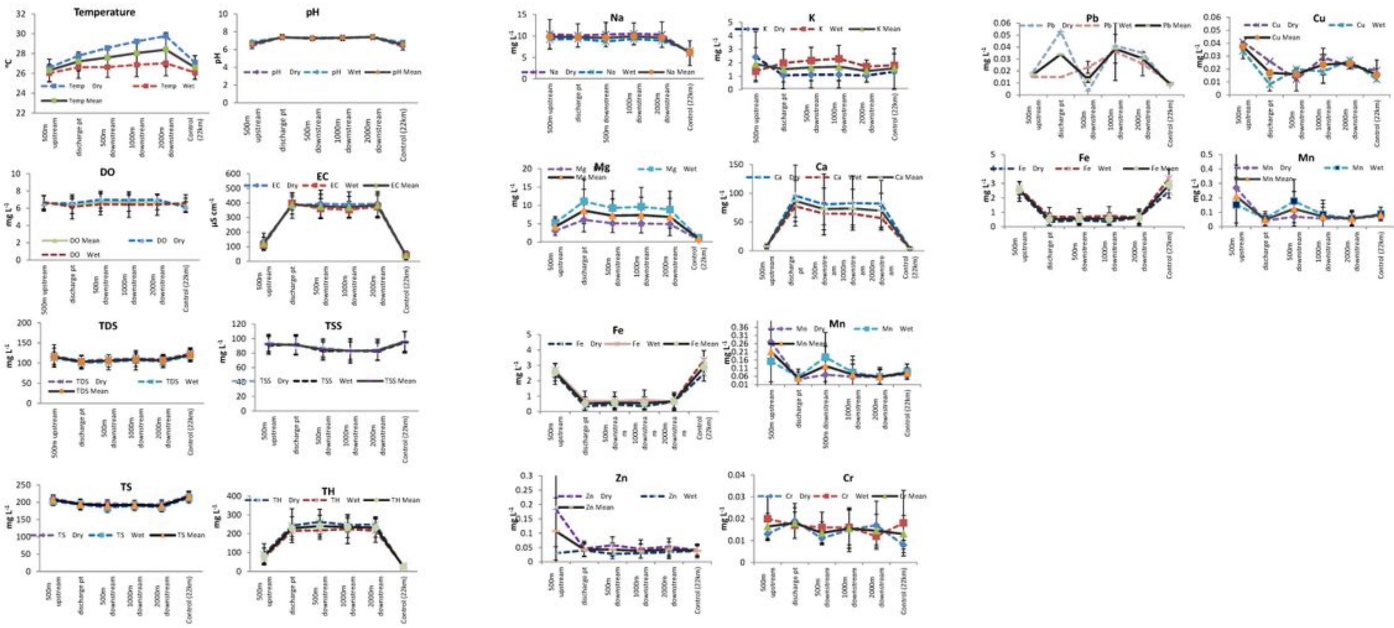

Figure 2

Seasonal variations of Akinbo River water parameters between 2005 and 2006. Discharge pt-discharge point (Point at which the cement effluents are discharged into the receiving River). The whiskers in the plots represent the standard deviations.