Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 5 (3): 428-436, 2005
ISSN 1812-5654

Environmental Disamenities Produced by Particulate and Gaseous Emissions from Ewekoro Cement Kilns on Some Strata of Aquatic and Terrestrial Ecosystems

[1]V.F. Olaleye, [2]E.A. Oluyemi and [3]O.A. Akinyemiju
[1]Department of Zoology, [2]Department of Chemistry, [3]Department of Plant Science,
Obafemi Awolowo, University Ile-Ife, Nigeria

Abstract: Disamenities caused by emissions from Ewekoro cement Kilns were monitored at some terrestrial and aquatic receptor locations. High levels of total suspended particulates (TSP) and atmospheric deposition rates (ADR) were recorded within the factory compared to auxiliary locations outside the factory. The TSP and ADR levels which are location dependent were significantly higher ($p<0.05$) during the dry periods than in the wet season. Irrespective of seasonal variations the key elements in the emissions were Ca^{2+} and Fe^{2+}. The concentrations of Zn^{2+}, Mn^{2+} and Pb^{+} which were trace elements were significantly higher ($p<0.05$) in the deposited than in the airborne particulates. An extensive vegetation structure overlap was recorded at the various sites studied. The most abundant flora belongs to the family: Poaceae with nine (9) identified species. Also, prominent at the study sites with four (4) species each was the family: Cyperaceae and Asteraceae. The planktonic flora and fauna of the river systems draining the area were poor with 16 phytoplanktonic and 9 zooplanktonic species. Numerically, the phytoplanktons were dominated by diatoms (Bacillariophyta) with *Synedra* sp. being the most abundant species. The zooplanktonic fauna dominated by rotifers had *Lecane curvicornis* as a regular occurrence in all the three catchment rivers. The physico-chemical parameters assayed were significantly higher ($p<0.05$) in the factory effluent discharges than in water samples from each of the catchment rivers. Seasonal variations inclusive, HCO_3^-, CO_3^{2-}, Ca^{2+} and Mg^{2+} constituted the ionic component of water samples analysed irrespective of location. Alaguntan river which receives effluents directly from the factory had significantly higher levels ($p<0.05$) of the assayed ions than the other two rivers draining the cement factory catchment area.

Key words: Particulate emission, gaseous emission, aquatic ecosystem, terrestrial ecosystem, Ewekoro cement kilns

INTRODUCTION

Wet and semi-wet clinker production technology has been adopted by Ewekoro plant of the West African Portland Cement (WAPC Plc) since its inception in 1959[1]. By-products from the process include gaseous and particulate emissions from the kilns and effluent discharges from the slurry basins. Akeredolu[2] reported that kiln stack losses from the Ewekoro plant mostly ranged between 1 and 4% of the clinker produced. Mean atmospheric deposition rate from the factory in the early 1990s within 5 km radius was estimated to be in the neighbourhood of 67 tones km^{-2} $month^{-1}$[3]. The authors also reported the average dustfall rates even at a distance greater than 5 km from the factory ranged between 13-16 tones km^{-2} $month^{-1}$.

Depositions and discharges from Ewekoro cement plant would have had an unquantifiable negative impacts on the riparian ecosystem after over 40 years of continuous cement manufacture. Dustfall not only contaminate the soil[2] it also form encrustations on plant leaves thereby reducing the chlorophyll content, impairing carbon dioxide exchange and ultimately the plant photosynthetic rate[4]. The toxic elemental composition in the atmospheric deposition from the cement plant operations not only endanger the soil quality[5] but also affect the flora and fauna composition[6]. Although, Adejumo *et al.*[3] reported that cement marker element, Ca, decreased exponentially with increasing distance from the factory, some toxic heavy metals like As, Pb, Ni, Co, Zn, Cu, Cr, as well as S, P were found highly enriched in the neighbourhood compared to the control sites.

Facilitating environmental sustainability of Ewekoro cement plant for future challenges requires reduction of the emission levels from the kilns to acceptable levels

Corresponding Author: Dr. V.F. Olaleye, Department of Zoology, Obafemi Awolowo, University Ile-Ife, Nigeria
E-mail: olafoluwa_59@yahoo.com

prescribed for the Nigerian environment[7]. In a bid to mitigate the effects of cement dusts and other particulates on the riparian environment, WAPC Plc. initiated some environmental control and abatement programmes to the tune of \$7.0 million (USD)[1]. The company has also phased-out completely the wet and semi-wet clinker line and replaced it with an environmentally amenable new dry clinker line which is expected to come on stream soon.

Intermediate disturbance hypothesis on evolution on a disturbed community[8] predicted that continuous low level impact from atmospheric deposition of long duration is expected to cause significant alteration in the ecosystem. Flora and fauna in such an ecosystem are expected to be variously adapted to the induced environmental variability[9]. The primary objective of the current investigation was to characterize the vegetation types, document the planktonic quality and some susceptible water quality parameters of Ewekoro cement factory catchment area. The data collected is expected to serve as a baseline for monitoring the environmental impact of the new dry clinker line on Ewekoro factory catchment area.

MATERIALS AND METHODS

Study site: Ewekoro cement production facility located five kilometers North of Ewekoro town (6°55'N 3°12'E) is within the tropical rainforest belt of Nigeria. Farming settlements such as Olapeleke (West), Itori (North), Elebute and Alaguntan (East) which predate the factory are located within 10 km radius of the production facility. The settlements are perennially drained by Itori, Elebute and Alaguntan Rivers. Only Alaguntan River receives waste water directly from the cement plant. However, the water quality of other catchment rivers are primarily influenced by non-point pollutants from run-offs and atmospheric depositions.

Cement dust and other particulate depositions are facilitated by an average wind speed of 1.0 and 0.72 m s^{-1}, respectively 10 m above the ground during the dry (January-March) and wet periods (May-November) (IITA, 2000). Other significant prevailing climatic conditions over the cement plant catchment area include an average relative humidity of 65±10% and an average annual rainfall of 1500±120 mm[10].

Based on the locations up-wind and down-wind of the cement factory various sites were adjudged suitable for sample collection. The selected locations for water quality and planktonic studies were the After Work Discharge Channel (AWDC), Alaguntan, Itori and Elebute Rivers. For air quality and vegetation studies within the factory area, sites selected include the main gate, the new factory site and the current overburden. Outside the factory, the Junior Staff Quarters (JSQ) (1.1 km South), Olapeleke (1.0 km West), Itori (4.8 km North), Wasinmi (9.5 km North) and Alaguntan settlements (1.5 km East) were selected as sampling points.

Air and water quality, planktonic composition and the vegetation of some strata of Ewekoro cement plant catchment area were investigated between November, 1997 and August, 2000. Monthly samplings which were carried out on the selected strata accommodated the primary influence of the prevailing dry and wet tropical rainforest climatic conditions[10].

Air quality studies

Sample collection and analyses: An Aztec Twin-flow sampler fitted with a pre-weighed Whatman cellulose acetate filter paper was used to collect the air particulate samples. The sampler pump operated at a flow rate of 12 L min^{-1} for a period of 3-4 h sucked the air particulates unto the pre-weighed filter paper. After the mandatory sampling period, the filters were retrieved and re-weighed to determine the amount of air particulates collected.

Particulate matter deposition rates (wet and dry) within and outside Ewekoro factory were measured using strategically placed dustfall collectors designed to receive descending particles[3]. Open space configuration devoid of any shielding in conjunction with gradient from the point source; the prevailing meteorological considerations and an elevation of about 4-5 m above the ground level determined the dustfall collector placements. The dust collectors were appropriately filtered. The amount of dust deposited was then determined gravimetrically.

Aerosol-loaded filter papers collected during the sample collection were digested in a concentrated nitric and perchloric acid mixtures (5:3). The resultant residue obtained after boiling the excess acid off was redissolved in 1 mL conc. HNO_3 and 10 mL distilled water with gentle warming. The concentrations of Ca, Fe, Mn, Zn and Pb in the resultant solution diluted to 25 cm^3 were by analyzing with Atomic Absorption Spectrophotometer (Chemtech Analytical, UK) at the Centre for Energy Research, Obafemi Awolowo University, Ile-Ife. The data was retrieved from Gateway PC 2000 system using Alphastar software and then subjected to Analyses of Variance (ANOVA).

Vegetation studies: A permanent belt transect of 25x25 m sampling plot was established in each location after visual assessment based on the stage of growth and development of the vegetation. Across each plot, a line transect was laid. One meter square quadrat was randomly laid at 1 m interval to ensure adequate data collection.

Where counting of individuals was not possible as in situation of grasses, herbs and creeping plants, cover was measured according to Greig-Smith[11]. Woody plant species within each transect were also identified to species level. Samples of unidentified plant species were collected, pressed and preserved for proper identification in the herbarium[12]. Means of number of plant encountered across season were used in computation of vegetation abundance. Seasonal comparison of the vegetation manifestations at the various locations was done using Analyses of Variance (ANOVA). Seasonal diversity indices was calculated using Shannon-Weiner Diversity Index[13].

Water quality and planktonic analyses: Duplicate sub-surface water samples were collected at designated points on sampling days with a Friedinger water sampler. A multi-probe HACH portable water laboratory was used to determine the water pH *in situ*. Collected water were field preserved to retard chemical changes prior to laboratory analyses[14].

The preserved water samples were analysed for the HCO_3^-, $S_1O_2^{2-}$ NO_3^- and PO_4^{2-} contents using standard methods[14]. Na^+ and K^+ concentrations were determined using flame photometry[15], while the Ca^{2+}, Mg^{2+} P^{3+}, Cr^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Fe^{2+} concentrations were determined by Zeeman Flameless Atomic Absorption Spectrophotometer.

Water samples from designated locations were evaluated for the planktonic composition. Collected water sample (30 L) which was concentrated to 20 mL by filtering through 45 μ plankton net was preserved in Lugol solution. Each preserved concentrated sample was examined through an Olympus BH2 Microscope in a Sedwick-Rafter counting chamber. Planktonic identification and enumeration were done where possible to specific level according to Adeniyi[16] and APHA *et al.*[14]. Planktonic species richness and diversity were calculated according to Washington[13]. Collected water and planktonic quality data were subjected to Analysis of Variance (ANOVA).

RESULTS

Air quality: The mean TSP values and ADR were higher within the factory premises than within the factory catchment areas irrespective of seasonal variations (Table 1). The mean TSP values during the wet season within the factory which ranged between 182.80 and 315 $\mu g\ m^{-3}$ were comparatively lower than the corresponding dry period values of between 465.12 and 857.40 $\mu g\ m^{-3}$ during the wet periods. Inclusive of seasonal variations, the Junior Staff Quarters (JSQ) located up-wind of the factory had the least mean TSP value (18.44 $\mu g\ m^{-3}$ during the wet season and 79.43 $\mu g\ m^{-3}$ during the dry season).

Dry season particulate deposition in most cases doubled the amount of wet season deposition in and outside the factory during the period of study (Table 1). Particulate deposition was also found to be location dependent. Relatively lower particulate deposition occurred in Wasinmi (the farthest sampling point) and at the JSQ which is an up-wind location. Wasinmi and JSQ had a dry season ADR of 17.27±1.8 and 25.43±7.1 tones km^{-2} $month^{-1}$ and a wet seasonal deposition rate of 5.34±2.7 and 10.35±3.5 tones km^{-2}. $month^{-1}$, respectively.

Elemental assay of the airborne particulate collected across seasons at the factory and the auxiliary neighbourhood during the period of study showed that Ca and Fe were the key elements in the emitted particulates (Table 2). Base on their concentration, Zn, Mn and Pb which could be regarded as trace elements had significantly higher levels ($p<0.05$) in the particles deposited than in the airborne particulates. In most cases the concentration of the assayed elements were higher in the dry season depositions than during the wet period though not significantly ($p>0.05$).

The vegetation: The composition of the flora of the study area made-up of eight (8) families exhibited a high level of overlap either within the factory premises or in the auxiliary areas (Table 3). The family Ceasalpiniaceae represented by *Cassia hirsuta* was absent on the current overburden (within the factory) and in the sampled catchment areas of Alaguntan and Olapeleke villages during the period of study. *Diplazium sammatii* (Athyriaceae) and *Anailema beniniense* (Commelinaceae) were also absent in the flora of the Junior Staff Quarters (JSQ) during the same period.

About 20 species were recorded at each location during the dry period with Diversity Indices (H′) ranging between 2.81 and 2.99. The floristic species richness during the wet season within the study area ranged from between 21 and 23 species with Diversity Indices (H′) ranging between 3.01 and 3.06. In all the sampled locations, the plant population was higher during the wet periods than during the corresponding dry season (Table 3).

The Family Poaceae represented by nine species which are mostly perennial in nature were found to be most abundant during the period of study irrespective of the sampling season and location. Prominent members of the family include *Paspalum polystachion* which is a

Table 1: Seasonal variations in the atmospheric deposition rates and total suspended particulates during the period of study

	Mean ADR (tones km^{-2} $month^{-1}$)		Mean TSP concentration (μg m^{-3})	
Location	Wet	Dry	Wet	Dry
Factory site				
Main gate	95.67±9.5	230.16±11.4	315.30±21.8	857.40±36.5
Kiln back end	118.42±13.5	145.63±18.3	182.80±41.1	465.12±34.7
Factory catchment area				
Alaguntan	23.51±11.9	40.18±6.3	122.81±63.1	138.80±21.7
Itori	27.89±6.6	38.18±2.7	162.80±13.4	211.63±17.6
JSQ	10.35±3.5	25.43±7.1	18.44±3.5	79.43±6.1
Olapeleke	15.84±2.4	28.64±8.7	190.45±15.6	245.71±18.1
Wasinmi	5.34±2.7	17.27±1.8	66.71±11.2	214.11±6.7

ADR-Atmospheric deposition rate, TSP-Total suspended particulate, JSQ-Junior staff quarters

Table 2: Seasonal variation in mean concentrations (μg g^{-1}) (Standard deviation) of some selected elements in the suspended air particulates and in particulates deposited during the period of study

	Ca		Fe		Zn		Mn		Pb	
	W	D	W	D	W	D	W	D	W	D
Suspended air particulates										
Factory location										
Packaging plant	75.67	95.43	2.17	2.34	0.92	0.96	0.80	0.42	<0.10	<0.10
	(10.4)	(15.1)	(1.1)	(1.6)	(0.8)	(1.0)	(1.0)	(0.8)	(0.1)	(0.1)
Main gate	7.01	10.91	3.81	4.73	0.99	2.16	0.30	0.20	<0.10	<0.10
	(3.1)	(2.7)	(1.8)	(3.8)	(1.1)	(1.4)	(1.0)	(0.4)	(0.1)	(0.1)
Factory catchment area										
Alaguntan	10.53	11.65	1.28	1.33	1.78	1.25	0.23	0.21	0.14	<0.10
	(4.2)	(2.4)	(1.1)	(0.9)	(0.8)	(1.1)	(0.8)	(0.4)	(0.11)	(0.1)
Itori	12.84	17.03	1.16	1.61	1.58	1.59	1.02	1.16	0.16	<0.10
	(5.2)	(3.8)	(0.8)	(1.2)	(1.0)	(1.3)	(1.0)	(0.8)	(0.2)	(0.1)
JSQ	10.83	12.40	3.16	3.38	1.51	1.55	0.20	0.25	0.13	0.10
	(2.2)	(1.8)	(1.2)	(1.8)	(1.0)	(0.9)	(0.2)	(0.1)	(0.1)	(0.12)
Olapeleke	10.11	13.27	1.27	1.36	1.67	1.78	0.10	0.13	<0.10	0.13
	(2.6)	(3.1)	(0.9)	(1.0)	(1.3)	(1.0)	(0.2)	(0.1)	(0.1)	(0.11)
Wasinmi	13.67	18.51	1.44	2.60	2.87	3.67	0.18	0.10	<0.10	<0.10
	(4.5)	(5.1)	(0.7)	(1.3)	(1.2)	(1.4)	(0.4)	(0.3)	(0.1)	(0.1)
Particulates deposited										
Factory location										
Packaging plant	3064.11	3639.47	841.41	865.38	219.02	241.41	64.66	75.18	18.16	12.11
	(95.4)	(70.4)	(141.5)	(102.3)	(41.1)	(62.4)	(16.3)	(15.2)	(14.2)	(6.5)
Main gate	4147.91	4244.41	322.17	312.65	175.87	201.65	14.66	15.88	11.24	10.17
	(120.3)	(181.6)	(100.1)	(60.1)	(30.1)	(51.8)	(5.8)	(4.9)	(3.2)	(4.1)
Factory catchment area										
Alaguntan	2698.11	2842.61	784.31	795.93	191.50	220.57	17.95	17.68	17.95	12.61
	(101.7)	(58.6)	(100.2)	(87.6)	(49.7)	(63.4)	(6.6)	(10.4)	(4.3)	(6.1)
Itori	3004.18	2962.14	807.35	816.11	289.53	301.11	100.22	78.67	35.08	41.11
	(62.4)	(71.7)	(65.4)	(78.6)	(91.1)	(112.8)	(19.7)	(15.4)	(7.2)	(9.3)
JSQ	2177.78	2444.41	716.05	732.17	375.31	383.42	44.44	51.28	10.37	9.81
	(96.6)	(68.8)	(43.4)	(62.7)	(36.4)	(51.8)	(4.3)	(12.1)	(3.3)	(6.1)
Olapeleke	2861.14	2329.06	775.54	801.28	178.97	181.47	67.11	59.81	25.34	21.18
	(151.3)	(117.4)	(101.1)	(114.1)	(22.4)	(35.7)	(13.1)	(18.2)	(7.1)	(9.3)
Wasinimi	2612.07	2698.4	1274.66	1184.43	341.11	330.71	37.94	51.81	56.15	41.11
	(117.4)	(171.4)	(67.8)	(73.2)	(22.1)	(18.8)	(6.7)	(11.2)	(10.8)	(12.1)

W-Wet season, D-Dry season, JSQ-Junior staff quarters

coarse perennial plant with thick creeping stem and *Dactyloctenium aegyptium* which is a loosely tufted short-lived perennial grass. Less prominent members of the family in the area include: *Axonopus compresus* (glabrous perennial grass with prostrate stem), *Panicum maximum* (a robust and densely tudted grass) and *Sacciolepis africana* (a short-lived perennial grass).

The sedges (family Cyperaceae) and the family Asteraceae with four species each were also well represented in the flora of Ewekoro Cement Factory and its auxiliary environment. Dominant species belonging to the family cyperacea include *Mariscus alternifolius*, *M. flabelliformis* and *Kyllingia erecta*. Dominant species from the family Asteraceae in the study area were *Chromolaena odorata* and *Tridax procumben*. *Sida acuta* (Malvaceae) which is a small perennial shrub and *Polygonum lannigerum* (Polygonaceae) an erect or sometimes scrambling herb were also recorded in the area irrespective of the period of sampling and location.

Table 3: Plant coverage (per meter squared) in the areas sampled during the period of study. 0 = no plant; 1 = sparsely populated (1-5 plants). 2 = fairly populated (6-12 plants). 3-4 = densely populated (13-20 plants). 5 = very densely populated (>25 plants)

		Factory site						Catchment areas					
		Overburden		N.F.S.		JSQ		Alaguntan		Olapeleke		Itori	
Plant species	Plant longevity	D	W	D	W	D	W	D	W	D	W	D	W
Asteraceae													
Aspilia africana Per.	(A)	0	1	1	3	1	2	1	2	1	3	2	3
Chromolaena odorata (L) Schau.	(P)	1	2	2	4	1	4	2	4	1	3	2	3
Synedrella nodiflora Gaertn	(A)	0	1	0	1	1	1	1	1	0	1	0	1
Tridax procumbent L.	(A)	1	1	1	3	1	3	1	2	1	2	1	3
Caesalpiniaceae													
Cassia hirsuta L.	(P)	0	0	1	1	1	1	0	0	0	0	1	1
Athyriaceae													
Diplazium sammatii (Kuhn)	(P)	1	1	0	1	0	0	1	1	1	1	1	1
Commelinaceae													
Anailema beniniense (P. Beauv.)	(P)	1	1	1	1	0	0	1	1	1	1	1	1
Commelina benghalensis (L.) Morton	(A/P)	1	2	1	2	0	1	0	1	1	1	1	1
Cyperaceae													
Cyperus esculentus (L.)	(P)	1	1	0	1	2	3	2	2	1	1	1	1
Kyllingia erecta (Schum.)	(A/P)	1	2	1	1	2	3	2	3	1	1	0	1
Mariscus alternifolius (Vahl.)	(P)	1	2	2	2	2	2	2	3	2	3	1	2
M. flabelliformis (Kunth)	(P)	2	2	1	2	2	2	2	3	1	2	2	2
Poaceae													
Axonopus compersus (SW)	(P)	2	2	2	3	3	4	2	3	2	3	2	3
Chloris pilosa (Schum.)	(A)	1	3	0	2	1	3	1	3	0	2	1	2
Dactyloctenium aegyptium L.	(A/P)	2	3	3	3	3	4	3	3	3	3	2	3
Echinochloa colona L.	(A)	1	3	1	2	1	3	1	3	1	3	1	2
Imperata cylindrical (Anderss.)	(P)	2	2	1	1	1	2	2	3	1	2	2	3
Paspalum polystachyum (L.) Schult.	(P)	3	3	2	3	3	3	3	3	4	5	2	2
Pennisetum polystachion (L.) Schult.	(A/P)	1	2	1	2	1	2	1	3	1	2	1	2
Panicum maximum (Jacq.)	(P)	1	2	1	2	2	4	2	3	1	1	2	3
Sacciolepis africana Hubb. & Snow.	(A/P)	2	3	2	3	1	3	1	3	1	2	1	2
Polygonaceae													
Polygonum lannigerum L.	(A)	1	2	1	2	1	3	1	3	1	2	1	2
Malvaceae													
Sida acuta Brum. E.	(P)	1	1	2	3	3	3	3	3	3	3	2	3
Species Richness		20	22	19	23	20	21	21	22	20	22	21	23
Diversity Index (H')		2.90	3.02	2.87	3.06	2.88	3.05	2.95	3.06	2.81	3.01	2.99	3.06

N.F.S= New factory site J.S.Q. = Junior staff quarters A = Annual P = Perennial D = Dry season W = Wet season

Water and planktonic quality: Qualitatively, the discharged factory effluents had comparatively significantly higher ($p<0.05$) levels of assayed ions, suspended and dissolved solid loads than samples collected from each of the catchment rivers (Table 4). Also, the factory effluent and water samples from Alaguntan River had pH in the alkaline range compared to the slightly acidic nature of Elebute and Itori River samples irrespective of season of collection. Location-wise and seasonal variations inclusive, the bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), calcium (Ca^{2+}) and magnesium (Mg^{2+}) constituted the major dissolved solid components of water samples collected (Table 4). The level of each of the parameter determined was also shown to be relatively higher (though, not significantly, $p>0.05$) during the wet than during the corresponding dry periods. Comparatively, the assayed ionic concentrations, were however significantly higher ($p<0.05$) in samples from Alaguntan River than in corresponding samples from Elebute and Itori River during the period of study.

The Planktonic flora and fauna of the sampled river systems in the Ewekoro Cement Plant catchment area were qualitatively and quantitatively poor consisting of 16 phytoplankton and nine zooplankton species (Table 5). The phytoplankton flora consist of two blue green, nine green algal species and five diatomic species. The zooplankton fauna was largely made-up of rotifers (7 species) and copepods (2 species). The factory effluents had only one (1) blue green alga (*Oscillatoria brevis*) four diatomic species (*Bacillaria* sp., *Diatoma* sp., *Navicula pelliculosa* and *Synedra* sp.) and no zooplanktonic species.

The river systems within the catchment area with similar planktonic assemblages had a species richness ranging between 17 and 23 species during the dry period with Diversity Indices (H′) of between 1.68 and 1.99. During the wet period, 23 plankters with Diversity Indices (H′) between 1.86 and 2.13 were recorded in the three catchment rivers sampled. Numerically, the diatomic species were dominant irrespective of the period of sample collection with *Synedra* species being the most abundant in the catchment river systems. The most frequently encountered green algal species in the study area were *Closterium kuctzingu, Cosmarium turgidum,*

Table 4: Mean±SD of physico-chemical parameters determined in the factory effluent and in the riparian rivers impacted by cement production activities

			Investigated rivers					
	Effluent outside factory		Elebute		Alaguntan		Itori	
Physico-chemical parameters	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Dissolved Oxygen (DO) (mg L^{-1})	2.60±1.04	3.80±1.12	3.05±1.16	4.80±2.10	5.80±1.88	6.10±2.16	3.10±1.04	4.50±2.65
pH	7.06±0.85	7.18±0.55	6.61±1.15	6.80 ±3.92	7.72±0.92	7.90±1.55	6.80±.087	6.90±1.31
Suspended solids (mg L^{-1})	135.26±23.18	160.49±11.41	20.18±1.72	27.06±3.92	10.45±3.46	15.60±2.92	40.7±6.52	55.1±2.28
Organic matter (mg L^{-1})	1.76±0.44	3.88±1.04	2.56±0.88	4.68 ±1.25	2.18±0.94	4.88±1.02	3.48±0.86	5.24±1.16
CO_3^{2-} (mg L^{-1})	45.62 ±5.16	90.53±10.12	6.98±1.12	18.04±2.65	83.10±10.12	99.66±14.16	18.62±2.10	25.38±5.64
HCO_3^- (mg L^{-1})	92.64±12.04	182.84±14.16	14.06±2.19	32.62±4.83	188.91±21.10	202.30±17.86	37.82±5.11	42.64±4.26
Ca^{2+} (mg L^{-1})	23.10±4.21	12.05±3.18	7.74±2.46	10.41±3.22	10.76±1.88	17.06±2.24	12.36±1.18	16.56±4.67
Mg^{2+} (mg L^{-1})	30.89±5.66	25.16±7.24	8.50±3.72	4.82±2.84	50.18±6.68	42.44±10.12	3.14±1.12	3.55±1.36
Na^+ (mg L^{-1})	3.96±1.06	4.20±0.88	1.63±0.96	2.08±1.04	3.82±1.11	3.94±1.41	1.82 ±1.08	1.89±1.18
K^+ (mg L^{-1})	2.94±1.18	2.18±0.96	1.28±1.10	1.09±0.65	3.46±1.06	3.91±1.21	2.44±0.88	2.88±1.16
Fe^{2+} (mg L^{-1})	2.85±1.03	1.63±2.14	1.70±0.88	1.80±1.02	2.70±1.06	3.11±1.02	1.14±0.68	2.07±1.15
Cu^{2+} (mg L^{-1})	1.13±0.64	0.82±0.12	0.16 ±0.04	0.12±0.08	0.41±0.03	0.74±0.05	0.73±0.10	0.61±0.14
Pb^+ (mg L^{-1})	0.45±0.12	0.56±0.28	0.03±0.04	0.05±0.01	0.11±0.06	0.28±0.05	0.10±0.02	0.06±0.01
Zn^{2+}	0.66±0.04	0.19±0.10	0.14±0.06	0.23±0.04	0.30±0.04	0.50±0.04	0.70±0.05	0.35±0.05

Table 5: Planktonic flora and fauna of some waterbodies within Ewekoro cement plant catchment areas

	Effluent outside factory		Elebute River		Alaguntan River		Itori River	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Phytoplanktons (cellx10^3/M^3)								
Cyanophyta (Blue green algae)								
Clastidium rivulare	0	0	0	10	0	25	15	40
Oscillatoria brevis	20	10	511	410	71	145	110	175
Chlorophyta (Green algae)								
Closterium acerosum	0	0	15	40	0	5	52	65
C. balmacarense	0	0	0	5	0	10	13	50
C. elongatum	0	0	40	70	0	5	31	65
C. kuctzingu	0	0	15	10	160	52	47	80
Cosmarium turgidum	0	0	410	200	10	65	210	115
Micrasterias truncata	0	0	110	40	41	50	72	100
Scenedesmus quadricauda	0	0	41	125	60	110	21	200
Volvox rousseletii	0	0	20	60	40	25	30	22
Bacillariophyta (Diatoms)								
Bacillaria sp.	15	10	111	180	140	160	510	300
Diatoma sp.	10	0	230	400	483	680	674	600
Navicula pelliculosa	40	15	104	210	262	240	118	210
Pinnularia viridis	0	0	16	45	111	80	281	135
Synedra sp.	115	200	1803	1950	1674	1730	1935	1840
Zooplanktons (Cellx10^3/M^3)								
Rotifera (Rotifers)								
Argonotholca sp.	0	0	0	8	0	0	9	10
Asplancha sp.	0	0	0	10	0	8	0	11
Brachionus caudatus	0	0	14	20	41	35	48	40
Keratella tropica	0	0	51	32	17	41	46	40
Lecane curviconis	0	0	38	60	13	73	16	45
Notholca sp.	0	0	0	6	4	0	18	20
Testudinella patina	0	0	0	0	0	0	6	0
Copepoda (Copepods)								
Acartia tonsa	0	0	17	10	10	22	30	33
Thermocyclops neglectus	0	0	18	32	8	28	15	25
Species Richness	5	4	18	23	17	21	23	23
Diversity Index (H')	0.34	0.33	1.68	1.86	1.46	1.67	1.99	2.13

Micrasterias truncata and *Scenedesmus quadricauda*. The zooplanktonic assemblages were quantitatively poor in the catchment rivers with *Brachionus caudatus*, *Keratella tropica* and *Lecane curvicornis* being a regular occurrence. *Acartia tonsa* and *Thermocyclops neglectus* were the two copepods recorded in Elebute, Alaguntan and Itori Rivers during the period of study.

DISCUSSION

Particulate matter deposition constituted major atmospheric pollution problem in Ewekoro Cement Plant immediate and auxiliary environment. The very high mean Atmospheric Deposition Rate (ADR) and Total Suspended Particulates (TSP) within the factory area could be attributed to kiln stack losses which Akeredolu[2] estimated to range between 1 and 4% of the clinker produced. Other sources of contamination within the factory include dust re-moblisation from vehicular traffic on unpaved and unswept paved road[5]. Fugitive emission from wind erosion of large open air piles of clinker and winnowing of clinker fine particles while being fed by a band of conveyor[2] are also identified source of atmospheric pollution within the factory.

Location and distance from the cement factory dictated the amount of particulate deposition within the factory auxiliary area. The farther the location, the less the amount of particulate deposited. Wind direction also plays a major role in particulate deposition. Locations down-wind had higher amount of deposition than locations up-wind. Differential deposition rate occurred due to differing lifetime of aerosols with different particle size in the air.

Adejumo *et al.*[3] reported that particles in the range of 0.08-1.0 μm could be airborne for a long distance from the point of origin. Large particles with diameter greater than 1.0 μm on the other hand have a life time of minutes to days. Based on such findings, locations within 1-10 km radius down-wind of the cement factory would likely be inundated with coarse cement particles[17] whose diameters are = 1 μm.

The concentration of the selected elements assayed in the suspended and deposited particulates confirmed that cement dustfall were enriched with toxic heavy metals[3] although an exponential fall-off in concentration occurred with increasing distance from the factory[5]. The TSP and ADR coupled with the concentration of element assayed in the particulates which was higher during the dry periods was probably due to the influence of harmattan haze. Oguntoyinbo *et al.*[10] reported that harmattan dust haze constitutes the largest source of particulate matter over Nigeria between the months of November and March. Simoneit *et al.*[18] estimated the total harmattan particle loading over Nigeria to range between 300,000 and 600,000 ta^{-1}. The harmattan dust particles most probably amplified the effects of the emissions from the cement plant hence the high ADR and TSP during the dry period.

Sources of water for the three catchment rivers in the vicinity of the cement plant are groundwater discharges from opened-up confined aquifers and vertical flow from fractures and joints within the floor of the quarry[19]. The physico-chemistry of water from the catchment Rivers therefore is primarily dependent on the soil characteristics[20], secondarily on the enriched cement dust-falls[3] and run-offs[21]. The enhanced nutrient status of Alaguntan River was probably due to potential impact from direct effluent recipient from the cement Plant.

The poor planktonic composition as well as the vegetation species richness in Ewekoro Cement Factory catchment area could be related to the damaging effects of exposure of the flora and fauna to the toxic heavy metals enriched cement particulate deposition. Using internationally prescribed standards for comparison[17], the deposition rates obtained for the factory were higher. Adejumo *et al.* [3] calculated the Toxicity Potential (TP) which is used to estimate the relative damaging effects of deposition from some cement factories in Nigeria (on flora and fauna) to range between 11-33 (0-1 km); 3.5-15.7 (1-5 km) and 1.1-1.3 (for distances greater than 9 km). By USEPA standards, TP values greater than 1.0 indicates potentially toxic depositions at receptor locations[22]. By inference, the factory premises and the catchment areas within 5 km of the factory which primarily act as receptors to the emitted air pollutants could be regarded as being environmentally contaminated.

Anthropogenic disturbances like emissions from the cement plant will generate high frequency or intermediate disturbance which will likely lead to evolution of disturbed community[23,24]. Disamenities created over the last 42 years by the operations of Ewekoro Cement Factory would have modified the dynamics of the riparian ecosystems unquantifiable. However, the seasonal differences observed in the vegetation standing crop during the study could be attributed to natural variations associated with hydrological conditions[25] and photoperiod prevalent over the area[10].

Planktonic community composition and dynamics are known to be influenced by physiologico-ecological factors such as nutrient availability and physical variables[26] and biological interactions[9]. Profound relationship has also been established between anthropogenic perturbations which directly influence water quality and the frequency of flora[27]. As a result of their short life cycles, plankters respond quickly to perceived environmental changes and hence their standing crop and species composition are more likely to indicate the quality of a water mass[28]. The slightly turbid nature of the effluent discharge from the Cement Plant coupled with rapid water turn-over was probably responsible for the absence of the chlorophytes and zooplanktons. Water from the limestone belt such as Ewekoro[19] perpetually rich in calcium, carbonate and bicarbonate ions with a pH range of between 6.8-9.6 are known to be characterized by alkalophilic diatomic flora[29]. The dominance of *Bacillaria* sp., *Diatoma* sp., *Navicula* sp., *Pinnularia* sp. and *Synedra* sp. in the three catchment rivers could therefore be attributable to the water chemistry. The zooplanktonic assemblages on the other hand were probably influenced by biological interactions such as competition, grazing and food availability[9].

ACKNOWLEDGMENTS

The authors wish to acknowledge the West African Portland Cement (WAPC) Plc, Ewekoro and the Management of ABC Agricultural and Environmental Systems Ltd., Ikeja, Lagos for the support granted to facilitate the study.

REFERENCES

1. WAPC., 2001. Environmental impact assessment of the proposed clinker line of the West African Portland Cement (WAPC) Plc at Ewekoro. Submitted to the Federal Ministry of Environment, Abuja by the West African Portland Cement, Plc, Elephant House, Alausa, Ikeja, Lagos, Nigeria, pp: 1-160.
2. Akeredolu, F., 1989. Atmospheric environment problems in Nigeria-An overview. Atmosph. Environ., 23: 783-792.
3. Adejumo, J.A., I.B. Obioh, O.J. Ogunsola, F.A. Akeredolu, H.B. Olaniyi, O.I. Asubiojo, A.F. Oluwole, O.A. Akanle and N.M. Spyrou, 1994. The atmospheric deposition of major, minor and trace elements within and around three cement factories. J. Radioanal. Nucl. Chem., 179: 195-204.
4. Shukla, J., V. Pandey, S.N. Singh, M. Yunus, N. Singh and K.J. Ahmod, 1990. Effect of cement dust on the growth and yield of *Brassia campestris* L. Environ. Pollut., 66: 81-88.
5. Asubiojo, O.I., P.O. Aina, A.F. Oluwole, W. Arshed, O.A. Akanle and N.M. Spyrou, 1991. Effects of cement production of the elemental composition of soils in the neighbourhood of two cement factories. Water Air, Soil Pollut., 5758: 819-828.
6. Borka, G., 1980. The effect of cement dust pollution on growth and metabolism of Helianthus annus. Environ. Pollut. Ser. A., 22: 75-79.
7. FEPA., 1991. Federal Environmental Protection Agency. National Interim Guidelines and Standards for Industrial Effluent, Gaseous Emissions and Hazardous Wastes in Nigeria.(Abuja: Government Press), pp: 1-42.
8. Soule, M.E. and M.A. Sanjayan, 1998. Conservation targets: do they help? Science, 279: 2060-2061.
9. Reynolds, C.S., 1984. Phytoplankton periodicity: the interaction of form, function and environmental variability. Freshwater Biol., 14: 111-142.
10. Oguntoyinbo, J.S., O.O. Areola and M. Filani, 1983. A Geography of Nigerian Development, 2nd Edn., Ibadan: Heinemann Educational Books (Nig) Ltd., pp: 45-70.
11. Greg-Smith, P., 1983. Quantitative Plant Ecology. 3rd Edn. Blackwell Scientific Publication, Oxford.
12. Hutchison, J. and J.M. Dalziel, 1954-72. Flora of West Tropical Africa (Revised by Keay, R.W.J. and F.N. Hepper) London: Crown Agents.
13. Washington, H.G., 1984. Review-diversity, biotic and similarity indices. Water Res., 18: 653-694.
14. APHA, AWWA and WEF., 1992. Standard Methods for Examination of Water and Waste Waters. 18th Edn. Prepared and published by American Public Health Association, American Water Works Association and Water Environment Federation, New York, pp: 3-9, 4-134.
15. Golferman, H.L., R.S. Oymo and M.A.M. Onhastad, 1978. Method for Physical and Chemical Analysis of Freshwater. IBP Handbook No 8. Oxford: Blackwell Scientific Publication, pp: 38-56.
16. Adeniyi, I.F., 1978. Studies on the physico-chemical factors and the planktonic algae of Lake Kainji, Nigeria. Ph.D. Thesis, University of Ife. Ile-Ife, Nigeria, pp: 1-587.
17. Fergusson, J.E., 1990. The Heavy Elements: Chemistry, Environmental Impact and Health Effects. New York. Pergamon Press, pp: 85-241.
18. Simoneit, B.T.R., R.E. Cox and L.J. Standley, 1988. Organic matter of the troposphere-IV Lipids in harmattan aerosols of Nigeria. Atmosph. Environ., 22: 983-1004.
19. WAPC., 2000. Environmental Audit Report of the West African Portland Cement Plc Ewekoro and Shagamu Quarries, Submitted to the Federal Ministry of Environment, Abuja by the West African Portland Cement Plc, Elephant House, Alausa, Ikeja, Lagos, Nigeria, pp: 1-155.
20. Omatsola, M.E. and O.S. Adegoke, 1981. Tectonic and cretaceous stratigraphy of the Dahomey Basin. J. Mining Geol., 18: 130-137.
21. Bowen, H.J.M., 1966. Trace Elements in Biochemistry. New York: U.S. Academy Press, pp: 111-138.
22. USEPA., 1990. National Air Quality and Emission Trends Report, 1988. Office of Air Quality Planning and Standards, Technical support Division, Research Triangle Park, NC 27711, USA.

23. Reynold, C.S., 1988. Functional Morphology and the Adaptive Strategies of Freshwater Phytoplanktons In: Growth and Reproductive Strategies of Freshwater Plankton. (Sangen, C.D., Ed.) (Cambridge: Cambridge University Press), pp: 388-433.
24. Padisak, J., F.A.R. Barbosa, G. Borbely, B.I. Chorus, E.L.G. Espindola, R. Heinze, O. Rocha, A.K. Torokne and G. Vasas, 2000. Phytoplankton Compoistion, biodiversity and a pilot survey of toxic cynoprokaryotes in a large cascading reservoir system (Tiete basin, Brazil. Verh. Intl. Verin. Limnol., 27: 2734-2742.
25. Charrier, C., C. Brunet, H. Delcambre and C. Touzeau, 2000. Effects of rapidly varying nutritional conditions on the dynamics of an algal population. Verh. Intl. Verein. Limnol., 27: 3086-3091.
26. Dos Santos, A.C.A. and M.C. Calijuri, 1997. Phytoplankton communities of a short period of time, in the Barra Bonita Reservoir (State of Sao Paulo, Brazil): Microcosm experiments. Verh. Intl. Verein. Limnol., 26: 468-471.
27. Hildrew, A.G. and P.S. Giller, 1994. Patchiness, Species Interaction and Disturbance in the Stream Benthos. In: Aquatic Ecology: Scale, Pattern and Process (Giller, P.S., A.G. Hildrew and D.G. Raffaelli, Eds.)(Oxford: Blackwell), pp: 21-62.
28. Sephton, D.H. and G.P. Harris, 1984. Physical variability and phytoplankton communities: VI. Day to day changes in primary productivity and species abundance. Arch. Hydrobiol., 102: 155-175.
29. Kalff, J. and R. Knoechel, 1978. Phytoplankton and their dynamics in oligotrophic and eutrophic lakes. Ann. Rev. Ecol. Syst., 9: 475-95.