EVALUATING THE IMPACT OF INDUSTRIAL AIR POLLUTION ON THE PROXIMATE DWELLERS OF EWEKORO CEMENT FACTORY: APPLICATION OF PRINCIPAL COMPONENTS ANALYSIS

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ABSTRACT

This research work examined the impact of industrial air pollution on dwellers at Ewekoro area of Ogun State, Southwestern part of Nigeria. Data were gathered from 250 participants who were randomly selected from the study area using Taro Yamani's sample selection approach. The major impacts considered in examining these are ear defects, cardiovascular diseases, high blood pressure, cancer, eroding and corroding of roofs, devaluation of property values and land productivity. The data collected based on these effects were analyzed using principal component analysis technique, so as to determine the most prevalent effects of problems. The results gave rise to the Eigen values and corresponding Eigen vectors of the components, whereby the variance proportion for each is given as 30.962%, 18.309%, 15.882%, 9.872%, 9.510%, 8.980% and 6.486% for ear defects, cardiovascular diseases, high blood pressure, cancer, eroding and corroding of roofs, devaluation of property values and land productivity respectively. Eigen values of PC effects greater or equal to one (1) were considered among estimated eigenvalues. This indicates that first three PC were considered. Empirical analysis of this research study showed that industrial air pollution predominantly affects the dwellers health, as the first three PC constitute the health variables of ear defects, cardiovascular diseases and high blood pressure. The result concluded that remedial action is urgently needed in addition to prior existing actions. It is hereby recommended that industries should unveil and put to practice its collective social obligations to balance industrial development with environmental protection and as well, enact conservative policies that will protect dwellers near the industrial space health and properties.

Keywords: *Air Pollution, Principal Component, Eigen values, Eigen vectors and KMO*

1.0 INTRODUCTION

In the early years of the nineteenth century, Industrialization as a social process creates a modern life style and gave a new pace for massive economic growth and technological development. Thence, all these provide easy life though except for a major concern of our environment being notoriously polluted one day at a time by systematic release of harmful industrial effluents and hazardous substances leading to serious ecological and environmental problems (Singh and Singh, 2006).

Pollution has an extensive assessment reaching its peak during the industrial revolution at the same time as the same time as the first European settlement established in Australia (Lamb, 1995).

In urban regions, the main sources of industrial pollution are power plants, transportation, automotive and residential activities and industry (Houghton, 1997).

Similarly, industrial pollution either affects human being directly or through his physical activities, opportunities for leisure and admiration of nature (Trivedi and Raji, 1992). Atmospheric discharge of quantity and quality of toxic fumes, gases, smoke and mists is a significant problem in industrial areas which possibly have adverse effect on the health of the population (Park and Park, 1985; Trivedi and Raji, 1992).

Since the inception of industrial revolution in 1780s, research have shown that companies were more concern in persistence production and sustainability of profits without any glance into intensive control of the effect of production on the environment. Bio-processing industries like distilleries, pharmaceuticals, diaries and confectionaries may generate strong or weak strength sewage (Ganesh et al., 2007).

Apparently, increase in cement production has transcended beyond 55percent between 1990 and 2000 in developing countries, such as Nigeria. In the nearest future, the demand is expected to be (120-180)percent higher than in 1990, while demand for cement was predicted to have raised by 45percent at 47.9million tones each year (Humphreys and Mahasenan, 2002).

In addition, huge amount of emissions (CO, CO2, SO2, NO2) release in air are varied and industry specific (Metcalf and Eddy, 2003; Sanza et al., 2004).

Nevertheless, both human needs and environmental equilibrium are strongly related to human well-being and public health. This relationship makes it possible to consider human health and sustainability as equivalent concepts (Griffith, 2006).

Over the years, there are multitudes of questions unanswered regarding the causes and effects of industrial pollution on human health because of the unfavourable attitude towards the overall effects of air pollution. Long-term effect, occupational exposure to air pollutants combined with prevalence in urban regions are widely unknown (David, 2015).

Hence, since residents near Ewekoro area of Ogun State are not left out in the industrial air pollution epidemic diseases, it is however, necessary to determine the causative factors contributing to industrial air pollution in the study area and fit a Principal Component model to examine the major effects of the menace on the physical and socio-economic health of the residents.

2.0 REVIEW OF LITERATURE

Most recently, several industrial activities including cement industries are degrading various environmental components like water, air, soil and vegetation in such a concentration that it is defamatory to human health and environment (Dolgner *et al*., 1983; Sai *et al.*, 1987; Mishra, 1991; Murugesan *et al.*, 2004; Kumar *et al*., 2008). On the environment, air Pollutions, falling ground water tables, poor management of waste, loss of forest and biodiversity and soil degradation are one of the primary causes of diseases, health issues and long term livelihood. Nevertheless, by an extent, the most serious environmental effect of air pollution is global warming, which is recognized recently to threaten the existence of human life in the nearest future, especially in the coastal regions. Interest shown about global warming as led to the famous Kyoto Protocol of 1997, through which over 100 countries undertook to reduce their emissions of certain pollutant gases significantly (NRP, 2001; Brasseur and Pszenny, 2001). Considering its effects on man and his environment, industrial air pollution is clearly seen as one of the greatest threats to sustainable development today. Diverse researches have generated significant correlation between industrial air pollution and physical or mental diseases such as mental disorders, nervous system diseases, and arthritis (U.S. Department of Health, 1967; Cropper et al., 860; Medina *et al.*, 2009). And as such, the effects of poor air quality on human health are far reaching, but out-rightly affect the body's respiratory system and the cardiovascular system.

Cement industry as one of the seventeen most polluting industries enlisted by the central pollution control board is a major source of particulate matter; nitrogen oxides (NO_x), sulphur oxides (SO_x), carbon monoxide (CO) emissions which increases risk of chronic respiratory disorder and of developing various types of cancers (Schwartz, 1994; Pope *et al*., 1995; Dockery and Pope, 1994; Hemminki and Pershagen, 1994; Knox and Gilman, 1997; Nyberg et al. 2000).

Aribigbola, Fatusin and Fagbohunka (2012) revealed how industrialization, urbanization in Ewekoro have resulted in several environmental imbalances due to resource exploitation such as; farmlands transformed into quarry sites, deforestation and the likes without respect to standard planning regulations. However, according to Heather, (2003) and Lerman, (1972), prolonged exposure can cause serious irreparable damage to inhabitants within, destroy leaf tissues, reduces chlorophyll, reduce fruit setting. Enhancement levels of other elemental composition (metals and non- metals) in cement dust cause numerous toxic effects on plant whereby result in decrease of yield, seed germination, leaf area and water content of the leaves (Hasan *et al.*, 2011). Hence, all these cause cytogenic as well as mutagenic effects such as decrease in plant growth, decrease in total protein levels, and chromosomal stickiness in meiosis phase, and DNA fragmentation (Abdul, 2010; Ritambhara *et al.*, 2010; Yahaya *et al.*, 2012). Nothing is more important than environmental protection and it should be any nation's top priority (National Green Tribunal).

Within the context of the literatures above, it is therefore becomes imperative to carry out this study in Ewekoro area located in Ogun state, western region of Nigeria. The intent of using this area was due to the cement factory sited whose existence has caused adverse effect on the dwellers. The considered factors influencing industrial air pollution within the studied area were analysed using weighted average technique on a likert scale of five. However, the considered effects of the aforementioned menace are ear defects, cardiovascular diseases, high blood pressure, cancer, eroding and corroding of roofs, devaluation of property values and decrease in land productivity.

Principal component analysis technique shall be employed to fit model for each of the effects in order to determine the most prevalent among them and also create unique equilibrium between environment and sustainable development.

3.0 MATERIAL AND METHOD

3.1 Research Design and Methodology

Ewekoro Local Government is sited in Ogun State. It is one of the Twenty (20) Local Government Areas (LGA), bounded in the North by Abeokuta North Local Government, in the East by Obafemi – Owode, in the West by Yewa South Local Government and in the South by Ado-Odo Ota Local Government with a population of 55,156 as at 2006 census.

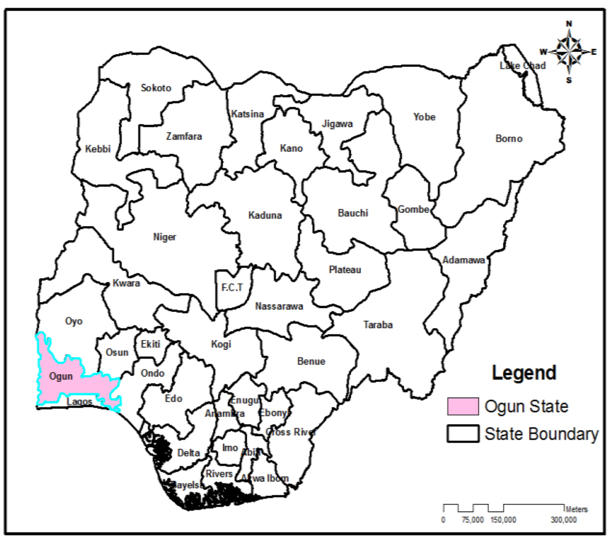

Fig. 1: Map of Nigeria showing Ogun State

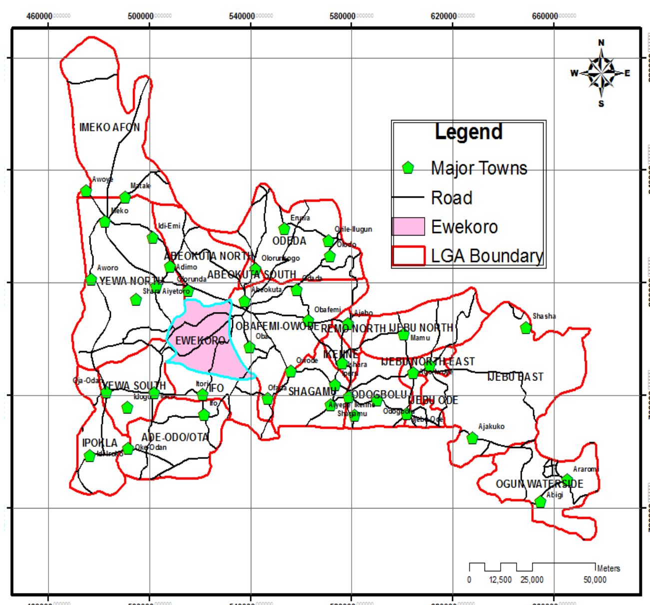

Fig. 2: Administrative Map of Ogun State Showing the Study Area

A sample size of 398 was estimated through Taro Yamane's method of sample selection was randomly selected among focus group of age 18 – 45+. Designed questionnaire was examined on the selected sample size under three (3) different categories. The instrument sought to solicit responses on socio-demographic information of the residents', causative factors influencing industrial air pollution and the effects of industrial air pollution on health and environment. At the end of the survey, 250 of the research instruments were returned. Cronbach's alpha validity test was run on a sample of 20 respondents for reliability measures and the survey was found to be 85.2% reliable.

3.2 Model Identification

The technique adopted in the analysis of these effect variables is a multivariate method known as Principal Component Analysis. Principal Component Analysis (PCA) is one of the oldest and best known of the techniques of multivariate analysis. It was first introduced by Pearson (1901), and developed independently by Hotelling (1933). The basic ideal of principal component analysis is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. It is a mathematical procedure that transforms a number of correlated variables into number of uncorrelated variable.

3.3 Model Specification

Given $X = (X_1, X_2, \dots, X_p)'$ to be a random vector with mean (μ) and covariance (Σ). Then the principal components of X, denoted by $Y_1, \dots, Y_p$, satisfying the conditions; $Y_1, Y_2, \dots, Y_p$, are mutually uncorrelated, $\text{var}(Y_1) \geq \text{var}(Y_2) \geq \dots \geq \text{var}(Y_p)$, and

$$Y_j = \alpha_{1j}X_1 + \alpha_{2j}X_2 + \cdots + \alpha_{pj}X_p = \alpha_j'X, \quad (1)$$

where $\alpha_j = (\alpha_{1j}, \alpha_{2j}, \dots, \alpha_{pj})$ is a vector of constants satisfying

$$\|\alpha_j\|^2 = \alpha_j'\alpha_j = \sum_{k=1}^{p} \alpha_{kj}^2 = 1, \text{ for } j = 1, \dots, p. \quad (2)$$

The principal components are orthogonal because they are the Eigen vectors of the covariance matrix, which is symmetric. The axis can be rotated by multiplying each Y_j by an orthogonal matrix and then obtain

$$Z_i = \alpha Y_j \quad (3)$$

Where α is an orthogonal, $\alpha'\alpha = I$ and the distance to the origin is unchanged. However, sample covariance matrix of $ZSZ = \alpha S \alpha'$ must be diagonal. Suppose we have a 3×3 matrix α, the sample covariance matrix is given as

$$\alpha S \alpha' = \begin{pmatrix} S^2Z_1 & 0 & \dots \\ 0 & S^2Z_1 & \dots \\ 0 & 0 & S^2Z_1 \end{pmatrix} \quad (4)$$

The orthogonal matrix α which diagonalizes S is the transpose of the matrix C

$$\alpha = C' = \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \end{pmatrix} \quad (5)$$

3.4 Model Estimation: Eigenvalues and corresponding Eigenvectors

For every square matrix α, a scalar λ and a nonzero vector X can be found such that

$$\alpha X = \lambda \text{X}. \quad (6)$$

It should be known that λ is called an eigenvalue of $\boldsymbol{\alpha}$, and $\boldsymbol{X}$ is an *eigenvector* of $\boldsymbol{\alpha}$ corresponding to λ. To find λ and $\boldsymbol{X}$, we write the equation as as

$$(\alpha - \lambda I)X = 0. \quad (7)$$

If $|\alpha - \lambda I| = 0$, then $(\alpha - \lambda I)$ has an inverse and X= 0is the only solution.

Hence, in order to obtain nontrivial solutions, we set $|\boldsymbol{\alpha} - \lambda \boldsymbol{I}| = 0$ to find values of λ that can be used to find corresponding values of $\boldsymbol{X}$. Thus, matrix $\boldsymbol{\alpha} - \lambda\mathbf{I}$ must be singular in order to find a solution vector Xthat is not 0. From the 3×3 matrix α with eigenvectors $X = \boldsymbol{x_1}, \boldsymbol{x_2}, \boldsymbol{x_3}$ and eigenvalues' $\lambda = \lambda_1, \lambda_2, \lambda_3$, then,

$$\boldsymbol{\alpha x_1} = \lambda_1 \boldsymbol{x_1} \qquad \boldsymbol{\alpha x_2} = \lambda_2 \boldsymbol{x_2} \qquad \boldsymbol{\alpha x_3} = \lambda_3 \boldsymbol{x_3}$$

$$\boldsymbol{\alpha}(\boldsymbol{x_1} \quad \boldsymbol{x_2} \quad \boldsymbol{x_3}) = (\boldsymbol{x_1} \quad \boldsymbol{x_2} \quad \boldsymbol{x_3}) \begin{pmatrix} \lambda_1 & 0 & \dots \\ 0 & \lambda_2 & \dots \\ 0 & 0 & \lambda_3 \end{pmatrix} \quad (8)$$

The eigenvalues will then be used to compute the variance of the principal components and we can speak of the proportion of variance explained by the first K component.

4.0 RESULTS AND DISCUSSION

It can be seen from the analysis of socio-demographic information of the residents in table 1 that 48% of them were male while 52% were female. Majority of the residents were between age 25-34 Years (29.5%) with minors constituting about 18% of the total sampled residents. Analysis also indicates that 19.2% (minors) were single, 50.8% (majority) were married, 27.6% were divorced while 22.4 with majority (46.4%) of them been educated up till tertiary level. However, frequency and percentage analysis of the residents' occupation depicts that majority (61.4) of them were civil/public servants while the remaining 38.6% fall in the category of artisan, students, retire and unemployed. In addition, it can also be evidenced from the ethnic group that the Yorubas' were found to be most dominant group in the study area accounting for 42.0% of the total residents, others were Igbo and Hausas. Majority of the residents household size were between 1-5(38.4%) with minority constituting above 15 (10%).

Table 1: Frequency and Percentage analysis of Residents Socio-demographic Information (N=250)

Items / Response Level		Frequency	Percentage (%)
Gender	Male	120	48.0
	Female	130	52.0
Age Range	18-24 years	45	18.0
	25-34 years	74	29.6
	35-44 years	71	28.4
	45 years and above	60	24.0
Marital Status	Single	48	19.2
	Married	127	50.8
	Divorced	69	27.6
	Widow/Widower	6	2.4
Educational Qualification	No formal Education	17	6.8
	Primary education	43	17.2
	Secondary education	74	29.6
	Tertiary education	116	46.4
Occupation	Artisan	43	17.2
	Civil/Public servant	111	61.4
	Student	60	24.0
	Retiree	7	2.8
	Unemployed	29	11.6
Ethnic Group	Yoruba	105	42.0
	Igbo	76	30.4
	Hausa	49	19.6
	Others	20	8.0
Household size	1-5	96	38.4
	6-10	70	28.0
	11-15	59	23.6
	Above 15	25	10.0

Source: *Field Survey, October 2018.*

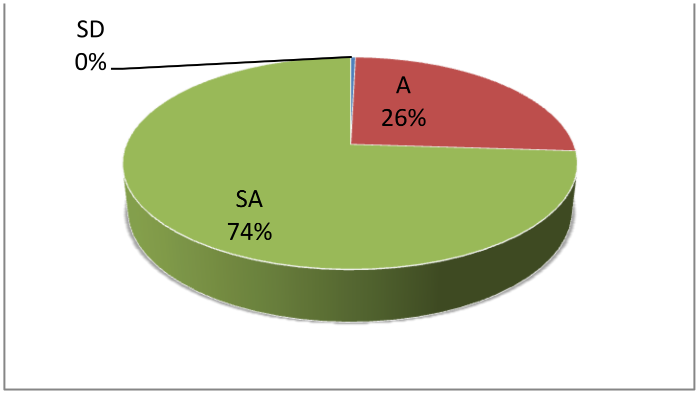

Fig. 1: Observed Perception of residents on Industrial Air Pollution

Figure 1 indicates the perception of residents on industrial air pollution. Empirical analysis of the research study showed that majority of the respondents strongly agreed that the undesirable outcome of emitting of by-products and waste into the environment can be referred as industrial pollution.

Examining the correlation matrix and spotting clusters of high correlations between group of considered variables in table 3, there exist positive degree of relationship between the seven effects considered. However, $\text{effects}_{2.6}$(0.323), $\text{effects}_{4.6}$(0.342), $\text{effects}_{5.6}$(0.304), $\text{effects}_{4.7}$(0.337), and $\text{effects}_{6.7}$(0.437)have estimated correlations above 0.3 coefficients. Norman & Streiner (2001) opined that fewer correlations below 0.3 is a waste of time carrying on with the Principal Components Analysis, clearly such problem is evitable in this report. However, high determinant of 0.405 > 0.0001 also confirmed the acceptance of the correlation matrix for PCA.

Table 2: Correlation Matrix of Effect Variables

Measured Variables	Deafness/ Ear Defects	Cardiovascular diseases	High blood pressure	Cancer	Eroding and Corroding roofs	Devaluation of property values	Land Productivity
Deafness/Ear Defects	1.000						
Cardiovascular diseases	-.103	1.000					
High blood pressure	.038	.233	1.000				
Cancer	.124	.238	.254	1.000			
Eroding and Corroding roofs	.122	.009	-.123	.109	1.000		
Devaluation of property values	-.095	**.323**	.128	**.342**	**.304**	1.000	
Land Productivity	.188	.199	.149	**.337**	.251	**.437**	1.000

a. Determinant = .405

***Source**: Extracted from SPSS Output, Version 20.*

The KMO value of 0.653 depicting measure of sampling adequacy in table 3 indicates that the interrelationship of the variables is poor, but Bartlett's test of sphericity with an associated $p<0.001$ showed that analysis of the research study can also be proceeded upon.

Table 3: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.653**
Bartlett's Test of Sphericity	Approx. Chi-Square	221.961
	Df	21
	Sig.	.000

***Source**: Extracted from SPSS Output, Version 20.*

Table 4 shows the importance of each of the seven principal components. Only the first three with Eigen values 2.167, 1.282 and 1.112 can be attributed in check listing the major effects of environmental air pollution within the study area since the corresponding Eigen values are above the threshold of 1.00. The first three PC together contributes about 65.153% of the total variability among all the effect variables. Major effects determined to be enlisted in the three PC are attributed to cardiovascular diseases, cancer, land productivity and devaluation of property values. This resulted to the conclusion that a three factor solution will probably be sufficient to checkmate the aforementioned effects under study, as evidenced from the scree plot in figure 2. Other four (4) components jointly explained 34.847% of the determinants.

Table 4: Total Variance Explained (*Extraction Method: Principal Component Analysis*)

Component	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	2.167	30.962	30.962	2.167	30.962	30.962	1.856	26.515	26.515
2	1.282	18.309	49.271	1.282	18.309	49.271	1.537	21.962	48.477
3	1.112	15.882	65.153	1.112	15.882	65.153	1.167	16.676	65.153
4	.691	9.872	75.025						
5	.666	9.510	84.534						
6	.629	8.980	93.514						
7	.454	6.486	100.000						

***Source**: Extracted from SPSS Output, Version 20.*

Table 5 shows a section of communality and uniqueness which apportion the diagonals of the correlation matrix into common (explained) and individual (unexplained) components. Therefore, the communalities explained what each variable can be accounted for with their weight(uniqueness). Thus, all the considered effects of industrial air pollution in this research are correlated since the variables were represented from the rotated space of the three PC as evidenced in figure 3.

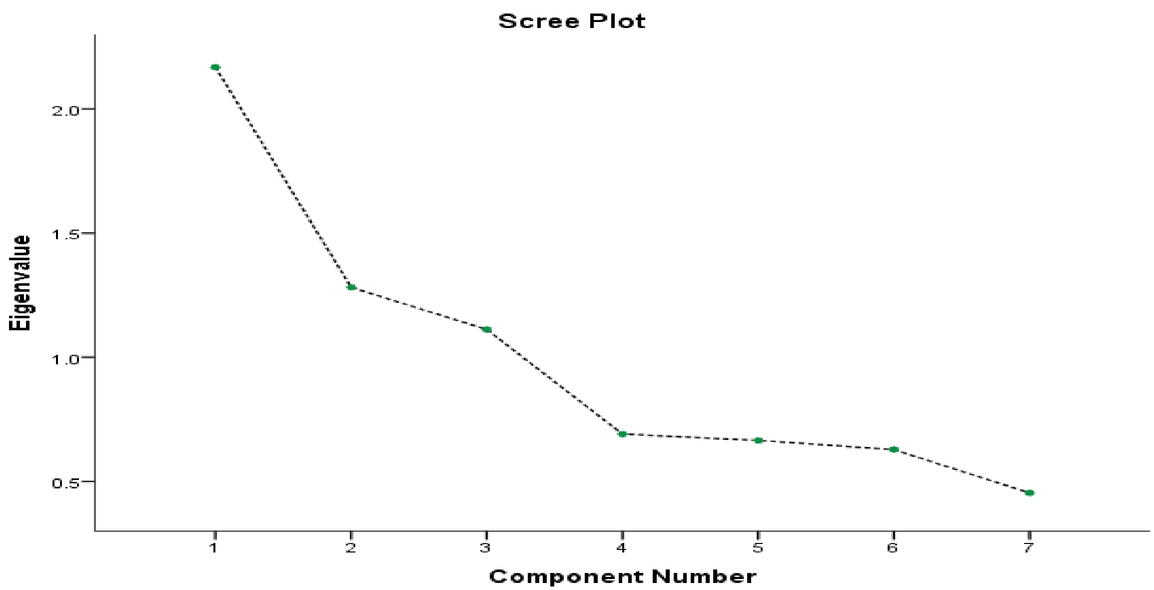

Figure 2: Observed matrix Scree plot

Table 5: Communalities

Measured Variables	Deafness/ Ear Defects	Cardiovascular diseases	High blood pressure	Cancer	Eroding and Corroding roofs	Devaluation of property values	Land Productivity
Initial	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Extraction	0.826	0.552	0.659	0.528	0.686	0.716	0.594

***Source**: Extracted from SPSS Output, Version 20.*

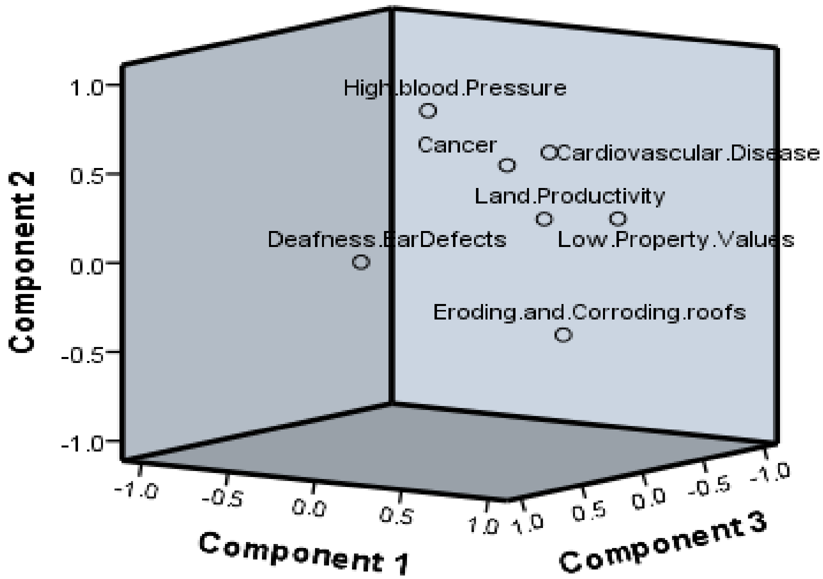

Fig.3: Component plot in Rotated Space

$$PC\ 1 = 0.133ED + 0.540CD + 0.392HBP + 0.676C + 0.392ECR + 0.753DPV + 0.725LP \quad (1)$$

$$PC\ 2 = 0.501ED - 0.474CD - 0.546HBP - 0.085C + 0.662ECR + 0.031DPV + 0.247LP \quad (2)$$

$$PC\ 3 = 0.746ED - 0.187CD + 0.455HBP + 0.251C - 0.307ECR - 0.384DPV + 0.088LP \quad (3)$$

In line with the three equations corresponding to the extracted most relevant PC's in table 7, the first principal component in equation 1 is positively correlated with all the seven original variables. Thus, the first principal component increases with the increase in Ear Defects, Cardiovascular Diseases, High Blood Pressure, Cancer, Eroding and Corroding of Roofs, Devaluation of Property Values and Land Productivity. This suggests that these seven criteria vary together. If one increases, then the remaining six variables also increase. This component can be viewed as a measure of the quality of health and economic effect of industrial air pollution. Furthermore, we see that the first principal component highly correlate with Cancer (0.676), Devaluation of Property Values(0.753) and Land Productivity (0.725) with a moderate correlation coefficient of 0.540 taking effect of

Cardiovascular Diseases into consideration. It would follow that communities with high values would tend to have a lot of effects available around them in terms of the aforementioned seven original variables.

The second principal component in equation 2 also increases with Ear Defects, Eroding and Corroding of Roofs, Devaluation of Property Values and Land Productivity. This component can be viewed as a measure of the degree of Eroding and Corroding of Roofs in the community with high positive value of 0.662 respectively. Thus, industrial air pollution within the studied area quickly deteriorate the structures and devalues such properties

The third principal component in equation 3 is the primary measure of Ear Defects and High Blood Pressure with corresponding values of 0.746 and 0.455. This implies that industrial air pollution affects the ear and blood pressure of the residents Thus, this principal component is the primary measure of ear defects, and high blood pressure which indicates that the duo variables affected residents in the study area due to industrial air pollution released from industries near the area.

Table 6: Component Matrix (Extraction Method: PCA)

	Component		
	1	**2**	**3**
Deafness/Ear Defects	.133	.501	**.746**
Cardiovascular diseases	**.540**	-.474	-.187
High blood pressure	.392	-.546	**.455**
Cancer	**.676**	-.085	.251
Eroding and Corroding roofs	.392	**.662**	-.307
Devaluation of property values	**.753**	.031	-.384
Land Productivity	**.725**	.247	.088

Source: *Extracted from SPSS Output, Version 20.*

5.0 CONCLUSION

This paper empirically based on the principal component analysis (PCA) on the effects of industrial pollution on Ewekoro residents. However, the results of this study has significantly deduced that consistent emission of highly concentrated pollutants from the industries into the environments contribute to a frequent and high number of health challenges faced by the community. In addition, the interaction between the industries and inhabitants is poor, which apparently create gaps in economic sustainability of the Nation. Therefore, investigation based on evidence has shown that remedial action is urgently needed in addition to prior existing actions.

5.1 RECOMMENDATIONS

To change the negative consequences of pollution in the industrial region for positive upturning, we hereby proposed that:

i. the dimension reduction model fitted can be used by policy makers in the environmental protection industry for predicting the prevalent effects of industrial air pollution in the state.
ii. cement industries should unveil and put to practice its collective social obligations to balance industrial development with environmental protection.
iii. conservative policies that will protect the dwellers health should be enacted in order to reduce to barest minimum the adverse effect of industrial air pollution in Nigeria, if not totally eliminated.
iv. ensuring continual renewability of the environmental components such as air,land, water, and other natural resources is important and should be developed for proper economic sustainability in the community and the nation as a whole.
v. industries should ensure continuous practice of corporate social responsibilities that will improve the wellbeing of the people within the industrial space.
vi. risk assessment should be performed regularly and efficiently by the management of the industries.

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