Scientific and technical journal
«Technogenic and Ecological Safety»

RESEARCH ARTICLE
OPEN ACCESS

STUDYING THE EFFECT OF CEMENT DUST ON PHOTOSYNTHETIC PIGMENTS OF PLANTS ON THE EXAMPLE EWEKORO CEMENT INDUSTRY, NIGERIA

A. E. Farinmade[1], A. L. Ogunyebi[1*], K. O. Omoyajowo[1]
[1]University of Lagos, Akoka, Lagos, Nigeria
*Corresponding email: logunyebi@unilag.edu.ng

UDC 504.06: 628.511
DOI: 10.5281/zenodo.2413063
Received: 6 November 2018
Accepted: 17 December 2018

Cite as: Farinmade, A. E., Ogunyebi, A. L., Omoyajowo, K. O. (2019). Studying the effect of cement dust on photosynthetic pigments of plants on the example Ewekoro cement industry, Nigeria. Technogenic and ecological safety, 5(1/2019), 22–30. doi: 10.5281/zenodo.2413063

Abstract

Most technogenic human activities in quest for industrialization and civilization interfere with ecological safety and biodiversity − all of which are deleterious to the continual existence of life on Earth. This study examined the effect of cement dust from Ewekoro cement industry, Nigeria on the photosynthetic pigments of *Ocimum gratissimum*, *Mangifera indica*, *Terminalia catappa*, *Jatropha curcas* and *Carica papaya*. Samples of these endemic plant species were taken at 500 m, 1000 m, 1500 m, 2000 m and 6000 m away from the cement industry. Supernatants taken during Laboratory analysis was used for absorbance readings, using UV-VIS spectrophotometer at 662, 645, 470, 435 and 415 nm wavelength to determine the concentrations of chlorophyll A, chlorophyll B and carotenoids. Results show that chlorophyll A, B, total chlorophyll and carotenoids were reduced in all the plants species exposed to cement dust compared to the control site. The rate of degradation of photosynthetic pigments was high in all the investigated species but significantly higher in *Ocimum gratissimum* and *Mangifera indica*. All the plant species except *Terminalia catappa* showed a decline in carotenoid content. Specifically, *Mangifera indica* had the highest reduction of chlorophyll (91.03 %), followed by *Ocimum gratissimum* (77.40 %) among other plant species investigated at 500 m away from the factory site. The lowest reduction in percentage of chlorophyll was observed in *Carica papaya*. This study infers that cement dust pollution could possibly cause a decline in photosynthetic pigments of leaf extracts and hence, affects plant productivity. Future research should exhaustively examine and perhaps predict the concentration and effect of cement dust on the environment (including both fauna and flora) in 20 years to come via appropriate toxicokinetic models and also they should consider the impact of cement dust on nutritive value of plants. If these prospective studies are conducted, then this will help to choose and apply the organizational measures and technical means to protect the components of nature.

Keywords: environmental sustainability; photosynthetic pigments; cement industry.

1. Problem statement and Analysis of the recent researches and publications

Environmental sustainability could be a stark reality provided that adequate knowledge about all components of the ecosphere especially their possible interactions with anthropogenic activities are considered and thoroughly managed. Though industrialization is critical to human civilization and development but this often comes with some inimical environmental consequences such as ozone layer depletion [1], heavy metal contamination [2, 3] etc. [4]. All of which are deleterious to the continual existence of life on Earth. In the study [5] reported that rapid industrialization and interaction with toxic substances in the environment are chiefly responsible for ecosystem degradation.

The rapid rise of cement industries in Nigeria is economically remarkable but there seems to be dearth of information regarding its impacts on the ecosystem. Indeed the presence of cement industries contributes significantly to poor environmental quality by producing air pollution hazards [5]. Cement dust and metals such as mercury, cadmium, iron, calcium and potassium are released into the atmosphere during cement production [6, 7]. The dust escaping from the cement factories is often transported by wind and deposited in areas close and far away from the factory. These potentially impacted areas do not excise agricultural lands, natural vegetation, towns and villages. Such depositions of particulate matter and other pollutants could interfere with normal metabolic activities of plants, causing direct injury and impairment of growth and quality and may ultimately lead to decrease in plant yield.

Cement dust and their constituent gases such as SO_2, CO_2, CO, and SiO_2 could adversely alter the balance of chemicals and nutrients in drinking water resources like wells, ponds and mine pits [8] and consequently affects human health. Due to immobility of higher plants, they are often the primary target among other living component of the ecosystem of the impacts of the cement dust and all activities of industrialization generally. Ambient level of air pollution has been demonstrated to affecting stomata conductance, photosynthesis and root morphology of young beech [9].

The technogenic effect of cement dust particles on chlorophyll accumulation in leaves has been exhaustively described by several researchers while the most common environmental stressor is dust accumulation, a factor which provokes severe damage in the photosynthetic apparatus [10]. Wind erosion suspends large quantities of dust in the atmosphere that settle back to the earth's surface and hence are deposited on plant leaves when wind velocities decrease [11]. Increased concentrations of the cement dust can cause progressive reduction in the photosynthetic ability of leaves, closure of leaf stomata and, mainly, a reduction in growth and productivity of plants [8]. The absence of light rays could interfere with the pigment formation process and this would retard chlorophyll synthesis in the leaves, leading to premature leaf yellowing and subsequent dropping of the stem. Chlorophyll biosynthesis is a good indicator of plant productivity and it represents the plants' potential in food manufacture. The use of plants as tools to assess the impact of pollution on the ecosystem cannot be overemphasised. They have played a crucial role in helping us to understand complex biological processes (for example plant productivity), specie richness, and communities' resilience and to assess the quality of the environment and how it changes over time [12].

Taken together, this study is poised to critically examine the effect of cement dust on the photosynthetic pigments of five endemic plant species – *Ocimum gratissimum* (*O. gratissimum*), *Mangifera indica* (*M. indica*), *Terminalia catappa* (*T. catappa*), *Jatropha curcas* (*J. curcas*) and *Carica papaya* (*C. papaya*) around Ewekoro cement industry.

2. Statement of the problem and its solution.
2.1. Materials and methods.
Description of study area.

The study was carried out in Ewekoro, where the West African Portland Cement Company (WAPCCO) factory is located. Ewekoro is one of the villages along Sango-Ifo-Abeokuta expressway of Ogun State of Nigeria. Ewekoro borders Papalanto in the west, Abeokuta in the East and numerous villages along the northern and southern axis. The WAPCCO commenced manufacturing in Nigeria with the commission of its first work at Ewekoro, Southwestern part of the country in 1960 [13].

The climate is not different from that of these towns and villages earlier mentioned and adjoining towns such as Ifo, Sagamu and others. The area lies between Latitudes 7º 10' N and 6º 40' N and Longitudes 3º 05' E and 3º 26' E. Ewekoro local government is one of the 21 local government Areas in Ogun State. The local government area is bounded in the North by Abeokuta 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. Ewekoro is located on latitude 6º 53' N and longitude 3º 11' N. It has a land area of about 631.5 km^2, with a population of 55,093.

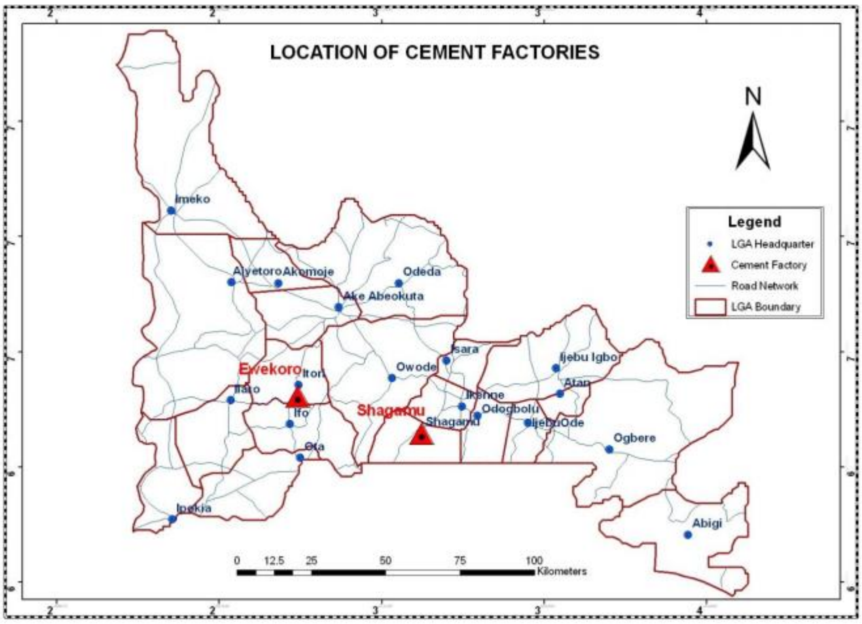

Figure 1 – Location of the cement company in Ewekoro Local Government area [14]

Sample Collection. This present study considered *O. gratissimum*, *M. indica*, *T. catappa*, *J. curcas* and *C. papaya* and the choice of these five plants were majorly based on clinical and economical importance, dominance in the area with special regards to the ability in growing under natural conditions. The plants were selected at different locations around cement factory at 500 m intervals except the control which were selected at 5500…6000 m far away from the factory. The comprehensive detail of the distances between the sample locations is shown in table 1.

Table 1 – Description of the study area

Sampling Site	Distance from Cement Production Unit (metres)	Category
Site 1	0 – 500	Cement Industry area
Site 2	1000	Cement Industry area
Site 3	1500	Cement Industry area
Site 4	2000	Cement Industry area
Site 5	5000 – 6000	Control

Sample Pre-treatment. Selected plant species were collected randomly from the different locations covering study area in the late rainy season. The tissue samples larger than the tissue needed for analysis were cut from the plant washed with water and immediately placed in aluminum foil. The leaves were carefully removed from the bark, using a snapper blade and washed with water to remove the dust on the surface of the leaf samples. The samples were then labeled, placed in a resalable plastic bag, and kept in refrigerator. The samples were kept in a darkened environment to prevent chlorophyll degradation.

Sample Preparation. In the laboratory experiment, 1g of each of the samples were ground into small pieces in a mortar ground while a pinch of quartz sand and a total of 10 ml of absolute acetone were added subsequently. A small amount of acetone was initially added to begin the grinding process. The extract was poured into a 15 ml centrifuge tube and centrifuge in the bench top centrifuge at 5000 rpm for 5 minutes. The extract was poured to a 10 ml graduated cylinder using Pasteur pipette. An aliquot of the clear leaf extract (supernatant) was transferred with a pipette to a 1 cm pathlength cuvettes.

Photosynthetic Measurements. Photosynthetic pigments are the substances with very different chemical structure; they are present in the form of porphyrin pigments (chlorophyll A, B and C), carotenoids, anthocyanins and flavones [15–17]. Pigment content assay chlorophyll A, chlorophyll B and carotenoid content assays were performed according to [18]. Supernatants taken was used for absorbance readings using UV-VIS spectrophotometer at 662, 645, 470, 435 and 415 nm wavelength to determine the concentrations of chlorophyll A, chlorophyll B and carotenoids using the formula given by [19]. The ratio of absorbance 435 nm to 415 nm is the parameter for chlorophyll degradation in the experiment [20]. Total chlorophyll in each of the sample was calculated by finding the sum of chlorophyll A and B according to [21].

Measuring chlorophyll A. Chlorophyll A is found in all green plants. Its concentration was measured in all the samples. The absorbance reading for chlorophyll A was calculated with the equation below [18]:

$$\text{Chl A } (\mu g/ml) = 12.25\ (A_{663.6}) - 2.55\ (A_{646.6}).$$

Three replicates were taken for each of the sample site and mean average was generated.

Measuring chlorophyll B. Chlorophyll B is also found in all green plants. Hence, its concentration was also measured in all the samples. The absorbance reading for chlorophyll B was calculated with the equation below [18]:

$$\text{Chl B } (\mu g/ml) = 20.31\ (A_{646.6}) - 4.91\ (A_{663.6}).$$

Three replicates were taken for each of the sample and average mean was generated.

Measuring Total chlorophyll. Total chlorophyll for each of the sample was calculated using the equation below [18]:

$$\text{Total Chl } (\mu g/ml) = 17.76\ (A_{646.6}) + 7.34\ (A_{663.6}).$$

Three replicates were also taken and average mean value was generated for all the samples.

Measuring Carotenoids. Carotenoid content was calculated using the equation that given in [18]

$$\text{Carotenoids } (\mu g/ml) = \frac{1000 \cdot A_{470} - 3.27[\text{Chl A}] - 104[\text{Chl B}]}{227}.$$

Three replicates were also taken and mean average value was taken.

Statistical Analysis. Mean data from three replicates were statistically analyzed using analysis of variance and correlation via Graph pad prism 7.01. Two ways analysis of variance (ANOVA) was used to check for significance at 5 % level of significance in mean evaluated.

2.2. Results.

2.2.1. Changes of chlorophyll A in investigated plants.

Table 2 shows the percentage of reduction in chlorophyll A in all the plants investigated. In all the plant species investigated, there was a reduction in percentage of chlorophyll A for all the samples taken from the polluted sites compared with the control. In all the samples, the site closest to the factory (500 m), showed the highest reduction of chlorophyll compared to the sites far away from the factory (1500 m and 2000 m). For each of the plant species investigated, there was a decrease in percentage of reduction of chlorophyll A as the distance increases away from the factory. For all the plant species investigated at the same distance (500 m away from the factory site), *M. indica* had the highest reduction of chlorophyll (91.03 %), followed by *O. gratissimum* (77.40 %). The lowest reduction in percentage of chlorophyll was observed in *C. papaya*. There was significance difference at 0.05 % level in amount of chlorophyll A in plants species taken at 500 m when compared with control in all the plants. Using 2 way ANOVA (Turkey's multiple comparison test), there is no significance difference in all the sampled plants.

Table 2 – Changes of chlorophyll A in selected plant species due to cement dust pollution

Plant	Control	500 m (% R)	1000 m (% R)	1500 m (% R)	2000 m (% R)
O. gratissimum	4.973 ± 0.203	1.123 ± 0.003 (77.40 %)	3.047 ± 0.026 (38.70 %)	3.146 ± 0.663 (36.70 %)	4.083 ± 0.123 (17.89 %)
M. indica	1.530 ± 0.344	0.133 ± 0.123 (91.03 %)	0.920 ± 0.006 (39.90 %)	0.986 ± 0.776 (35.60 %)	1.497 ± 0.009 (21.60 %)
J. curcas	7.150 ± 0.234	3.003 ± 0.963 (58.00 %)	4.755 ± 0.889 (33.50 %)	5.017 ± 0.124 (29.83 %)	6.014 ± 0.778 (15.88 %)
C. papaya	7.824 ± 0.054	4.055 ± 0.516 (48.20 %)	4.895 ± 0.914 (37.40 %)	5.245 ± 0.009 (33.00 %)	6.016 ± 0.08 (23.11 %)
T. catappa	6.375 ± 0.234	2.390 ± 0.784 (62.50 %)	2.617 ± 0.345 (58.95 %)	5.033 ± 0.893 (21.05 %)	5.805 ± 0.893 (8.94 %)

% R = Percentage of reduction

2.2.2. Changes in chlorophyll B in the investigated plants. Table 3 shows the changes in chlorophyll B in all the investigated plants. In all the plant species investigated, there was a reduction in percentage of chlorophyll B just as it occurred for chlorophyll A for all the samples taken from the polluted sites compared with the control. In all the samples, the site closest to the factory (500 m), showed the highest reduction of chlorophyll compared to the sites far away from the factory (1500 m and 2000 m). For each of the plant species investigated, there was a decrease in percentage of reduction of chlorophyll B as the distance increases away from the factory. For all the plant species investigated at the same distance (500 m away from the factory site), *O. gratissimum* had the highest reduction of chlorophyll (78.04 %), followed by *T. catappa* (55.38 %). The lowest reduction in percentage of chlorophyll was observed in *M. indica*.

2.2.3. Changes in total chlorophyll in the investigated plants. Table 4 shows the changes in total chlorophyll in all the investigated plants. For all the investigated plants, as the distance increases away from the factory site, the percentage of reduction in total chlorophyll decreases. At distance 500 m for all plants, *O. gratissimum* had the greatest percentage of reduction in total chlorophyll (77.89 %) compared to all the other investigated plants. The lowest percentage of reduction in total chlorophyll was observed in *M. indica* at distance of 500 m away from the factory site (38.54 %).

2.2.4. Changes in carotenoids in the investigated plants. Table 5 shows the changes in carotenoid in all the investigated plants. The percentage of reduction in carotenoids for all the sites was calculated against the control. For all plant samples, the sample taken at 500 m had the highest percentage of reduction in carotenoids. *J. curcas* had the highest percentage of reduction of 67.40 % at 500 m while *T. catappa* had the lowest percentage of reduction of 14.95 % at the same distance.

Table 3 – Changes of chlorophyll B in selected plant species due to cement dust pollution

Plant	Control	500 m (% R)	1000 m (% R)	1500 m (% R)	2000 m (% R)
O. gratissimum	7.047 ± 0.023	1.547 ± 0.003 (78.04 %)	4.817 ± 0.023 (31.64 %)	4.267 ± 0.043 (39.45 %)	4.287 ± 0.333 (39.17 %)
M. indica	6.517 ± 0.333	4.817 ± 0.045 (26.08 %)	5.023 ± 0.993 (22.92 %)	5.417 ± 0.435 (16.87 %)	5.833 ± 0.356 (10.49 %)
J. curcas	10.450 ± 0.243	5.885 ± 0.435 (43.68 %)	6.864 ± 0.778 (34.34 %)	7.115 ± 0.044 (31.91 %)	8.295 ± 0.665 (20.62 %)
C. papaya	9.278 ± 0.045	6.123 ± 0.04 (34.01 %)	7.177 ± 0.031 (22.64 %)	7.616 ± 0.023 (17.91 %)	8.295 ± 0.098 (10.59 %)
T. catappa	7.880 ± 0.333	3.516 ± 0.567 (55.38 %)	5.250 ± 0.345 (33.37 %)	6.255 ± 0.003 (20.62 %)	7.455 ± 0.030 (5.39 %)

% R = Percentage of reduction

Table 4 – Changes of total chlorophyll in selected plant species due to cement dust pollution

Plant	Control	500 m (% R)	1000 m (% R)	1500 m (% R)	2000 m (% R)
O. gratissimum	12.030 ± 0.046	2.660 ± 0.003 (77.89 %)	7.867 ± 0.043 (34.61 %)	7.423 ± 0.033 (38.29 %)	8.367 ± 0.567 (30.45 %)
M. indica	8.055 ± 0.887	4.950 ± 0.224 (38.55 %)	5.935 ± 0.453 (26.32 %)	6.410 ± 0.039 (20.42 %)	7.347 ± 0.088 (8.79 %)
J. curcas	17.670 ± 0.003	8.887 ± 0.103 (49.71 %)	11.616 ± 0.873 (34.26 %)	12.127 ± 0.112 (31.36 %)	14.305 ± 0.333 (19.04 %)
C. papaya	17.095 ± 0.003	10.175 ± 0.067 (40.47 %)	12.068 ± 0.054 (29.41 %)	12.850 ± 0.047 (24.83 %)	14.305 ± 0.089 (16.32 %)
T. catappa	14.257 ± 0.053	5.917 ± 0.345 (58.49 %)	7.926 ± 0.445 (49.40 %)	11.287 ± 0.067 (20.83 %)	13.255 ± 0.083 (7.02 %)

% R = Percentage of reduction

Table 5 – Changes of carotenoids in selected plant species due to cement dust pollution

Plant	Control	500 m (% R)	1000 m (% R)	1500 m (% R)	2000 m (% R)
O. gratissimum	1627.000 ± 1.867	638.900 ± 0.026 (60.73 %)	654.900 ± 0.028 (59.75 %)	1300.000 ± 0.525 (20.09 %)	1499.000 ± 0.056 (7.86 %)
M. indica	1221.000 ± 0.033	693.400 ± 0.026 (43.21 %)	914.800 ± 0.073 (25.07 %)	993.350 ± 0.058 (18.64 %)	1169.000 ± 0.141 (4.26 %)
J. curcas	311.400 ± 0.027	101.500 ± 0.003 (67.40 %)	208.900 ± 0.005 (32.92 %)	209.440 ± 0.012 (32.74 %)	309.500 ± 0.052 (0.61 %)
C. papaya	1187.000 ± 0.0334	753.400 ± 0.033 (36.53 %)	914.700 ± 0.007 (22.94 %)	993.400 ± 0.353 (16.31 %)	1168.00 ± 0.084 (1.60 %)
T. catappa	1130.310 ± 0.033	961.300 ± 0.029 (14.95 %)	988.500 ± 0.120 (12.55 %)	1027.000 ± 0.132 (9.14 %)	1084.340 ± 0.065 (4.07 %)

% R = Percentage of reduction

2.2.5. Comparison of degree of change in photosynthetic parameters in O. gratissimum. Figure 2 compared the effect of the cement dust on chlorophyll A, B and total chlorophyll in *O. gratissimum*. For each of the physiological parameters, as the distance from the factory site increases, the concentration of the parameters increases. This shows that as the distance increases away from the factory, the impact of the cement dust reduces. At level of significance (0.05), there is no difference between the control and sample taken at 2000 m for chlorophyll A, B and total chlorophyll. There is significance difference between the control and sample taken at 500 m for chlorophyll A, B and total chlorophyll. There is no significance in samples taken from 500 m compared to other distances (1000 m, 1500 m or 2000 m).

2.2.6. Comparison of degree of change in photosynthetic parameters in M. indica. Figure 3 depicts the effect of the cement dust on chlorophyll A, B and total chlorophyll in *M. indica*. The effect is adversely felt by chlorophyll A especially at 500 m the area closest to the factory. Chlorophyll B seems not to be significantly affected by the cement dust.

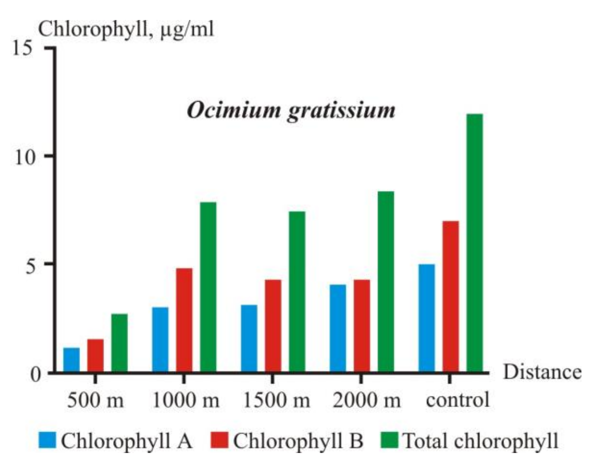

Figure 2 – The means of chlorophyll in *O. gratissimum* at different locations of the study area

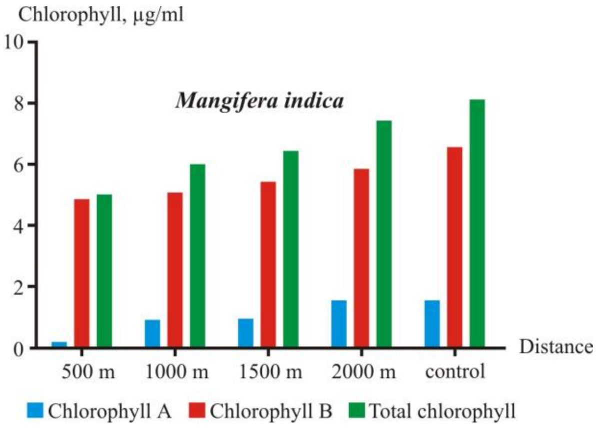

Figure 3 – The means of chlorophyll in *M. indica* at different locations of the study area

2.2.7. Comparison of degree of change in photosynthetic parameters in J. carcus. Figure 4 represents the changes in *J. curcas*. Sample plants taken at 500 m are significantly different from the control at 0.01. No significance difference in the three parameters in all the distances was observed when compared with one another.

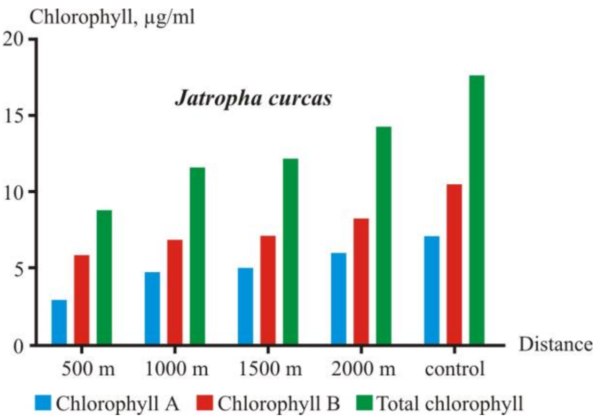

Figure 4 – The means of chlorophyll in *J. curcas* at different locations of the study area

2.2.8. Comparison of degree of change in photosynthetic parameters in C. papaya. Figure 5 is a graph that represents the impacts of the cement on chlorophyll A, B and total chlorophyll in *C. papaya*. There are no much differences in the changes of parameters in this sample species. The only significant difference exists between the samples taken at 500 m and the control.

2.2.9. Comparison of degree of change in photosynthetic parameters in T. catappa. Figure 6 depicts the impact of the cement on chlorophyll A, B and total chlorophyll. As the distance from the factory increases, the concentration of these parameters increases. However, much significance is observed in the sample taken at 500 m and the control. There is a significance difference of 0.01 between the control site and the polluted site one (500 m).

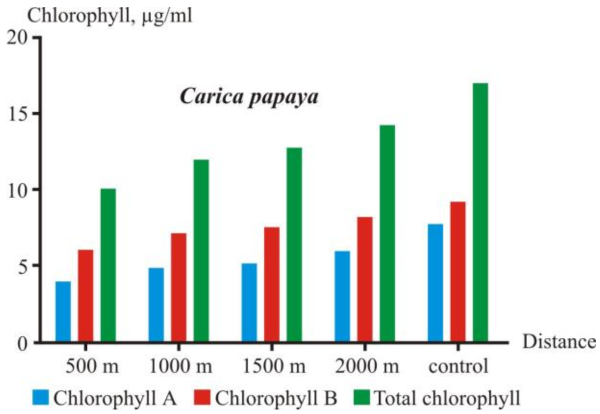

Figure 5 – The means of chlorophyll in *C. papaya* at different locations of the study area

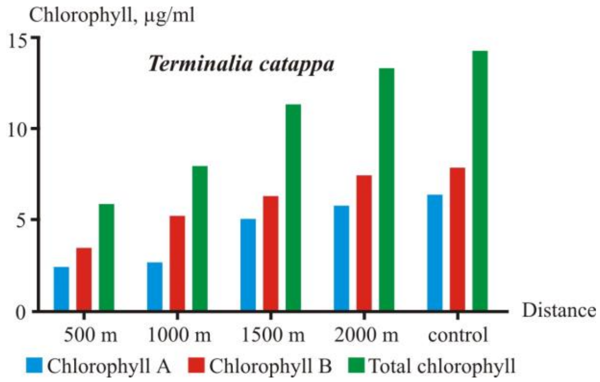

Figure 6 – The means of chlorophyll in *T. catappa* at different locations of the study area

2.3. Discussion.

Measurement of photosynthetic pigments is an important parameter frequently used to evaluate the effects of pollutants on plants because photosynthetic pigments play critical roles in plant metabolism [22]. Several studies have reported a reduction in chlorophyll content in plants subjected to cement dust [23, 24]. The general result of this study supports the claims and the findings of these previous studies that chlorophyll is much affected by the accumulation of the cement dust in plant tissues.

Dust accumulation altered the chlorophyll and carotenoid contents in all plants in the polluted location (near the factory) compared with plants far from the factory in control site. This corroborates with the findings wich were formulated in [25, 26]. Greater decrease in chlorophyll A and B contents was clearly observed in *O. gratissimum* and *M. indica*. For chlorophyll A, It is about 77.40 % and 91.3 % and 78.04 % respectively. A similar pattern of decrease was occurred in *J. curcas* (L) and *C. papaya* (L) but to lower extent (about 58.00 % for chlorophyll A and 48.20 % for chlorophyll B, respectively) which is shown in the table 4 and 5 and figure 1 and 2. For *O. gratissimum*, the plant sample closest to the cement factory (500 m away), had a very great percentage of reduction compared to the ones far away from the factory as shown in table 4 and figure 1. As the distance from the factory increases, the level of chlorophyll A also increases. The low level of chlorophyll A is also observed in the specie of *M. indica* closer to the cement factory as shown in figure 2. While there is a significant difference in the content of chlorophyll A in the samples of *O. gratissimum* and *M. indica* closer to the factory compare to the ones far away from the factory, there is no much significant difference in that *C. papaya*, Jetropha carcus and *T. catappa* using ANOVA at 0.05 level of significance. Using ANOVA and at 0.05 level of significance, the significant difference between the sample taken 500 m away from the factory compared to the one taken 6000 m away from the factory for *O. gratissimum* and *M. indica* is 75 % and 50 % respectively while there is no significant difference in that of *C. papaya*, *J. curcas* and *T. catappa*.

O. gratissimum and *T. catappa* had greater percentage of reduction in chlorophyll B (78.04 % and 55.38 % respectively followed by *J. curcas* which had 43.68 % as shown in table 5. For *C. papaya* and *M. indica*, the percentage of reduction in chlorophyll B is not significant as shown in table 5. *O. gratissimum* and *J. curcas* had greater percentage reduction in carotenoids (60.73 % and 67.40 %) respectively as shown in table 5.

The data gotten from this study indicates that the exposure of plants to dust altered several physiological and biochemical parameters. The most apparent effect of stress induced by dust, described in numerous species, is leaf damage [27]. In the study [28] reported that leaf injury is due to diverse alterations at the sub cellular level. Various studies have shown that the main detrimental effect of dust at the sub cellular level is photo system damage [10, 24]. Moreover, the presented results clearly showed that dust altered several biochemical aspects, such as photosynthetic pigment in leaves. A significant percentage increase in chlorophyll A/B ratio was observed only in *O. gratissimum* which was mainly caused by an increase in chlorophyll A content associated with decrease in chlorophyll B content. On the other hand, a marked percentage decrease in chlorophy A/B ratio was observed in the other four studied plants. The changes in chlorophyll A and B are possibly due to shading and/or photo system damage due to dust accumulation between the petioles or other effects on stomata. Dust from a cement factory seems to cause substantial changes to leaf physiology, possibly leading to reduced plant productivity. This study's results are consistent with [24] who earlier reported that cement dust decreased the leaf total chlorophyll content and chlorophyll A/chlorophyll B ratio. As a result, photosynthetic rate and quantum yield decreased. The decrease in the chlorophyll/carotenoid ratio for stressed plants suggested that these relationships could be used as an indicator of tolerance and physiological status of the plants under these stress conditions.

Conclusion and recommendations.

This study identified cement dust produced by cement manufacturing industry as one of the most hazardous pollutants that may cause a decline in plant productivity. It further suggests that increased concentrations of cement dust could cause progressive loss of the photosynthetic architecture and quality of leaves and hence, may result to reduction in growth and productivity of plants in general. The study thus showed that plants in close proximity with the cement industry are adversely affected by cement dust emissions. Based on the above findings, the following recommendations were made:

1. Future research should exhaustively examine and perhaps predict the concentration and effect of cement dust on the environment (including both fauna and flora) in 20 years to come via appropriate toxicokinetic models.
2. Upon ethical approval, further research should investigate the direct impact of the cement dust on human health especially on the workers and residents of this community.
3. Further work should consider the impact of cement dust on nutritive value of plants.

If these prospective studies are conducted, then this will help to choose and apply the organizational measures and technical means to protect the components of nature.

Acknowledgements.

The authors' team is grateful to the management of the University of Lagos for the opportunity to conduct scientific research, as well as editorial board of the journal and reviewers for the informational support when publishing an article.

Conflicts of Interest.

None of the authors have any potential conflicts of interest associated with this present study.

REFERENCES

1. Vambol, S. O., Kondratenko, O. M. (2017). Calculated substantiation of choice of units of monetary equivalents of complex fuel and ecological criteria components. Technogenic and ecological safety, 2, 53–60. doi: 10.5281/zenodo.1182890.

2. Ziarati, P., Namvar, S., Sawicka, B. (2018). Heavy metals bio-adsorrption by Hibiscus Sabdariffa L. from contaminated weater. Technogenic and ecological safety, 4(2/2018), 22–32. doi: 10.5281/zenodo.1244568.

3. Vambol, S., Koloskov, V., Derkach, Yu. (2017). Assessment of environmental condition of territories adjoined to wastes storage sites based on environmental reserve criterion. Technogenic and ecological safety, 2, 67–72.

4. Balaceanu, C. M., Iordache, G. (2018). Assessment of the air pollution at the industrial stations in metropolitan area of Bucharest. Technogenic and ecological safety, 3(1/2018), 8–15. doi: 10.5281/zenodo.1182485.

5. Sarala, T. D., Saravanakumar, R. (2011). Effect of Cement dust on Photosynthetic pigments of selected plant species. Asian Journal of Environmental Science, 6(2), 161–167.

6. Fukuzaki, N., Tamura, R. Hiramo, Y., Mizushima, Y. (1986). Mercury emission from a cement factory and its influence on the environment. Atmosphere Environment, 20(12), 2291–2299. doi: 10.1016/0004-6981(86)90059-4.

7. Akeredolu, F. A., Olaniyi, H. B., Adejumo, J. A. et al. (1994). Determination of elemental composition of TSP from cement industries in Nigeria using EXDRF techniques. Nuclear Instrument and Methods in Physics Research, 353, 542–545.

8. Koperuncholan, M., Ramesh, V. S., Ahmed, J. (2014). Impact of cement industries dust on selective green plants: a case study in Ariyalur industrial zone. International Journal of Pharmaceutical, Chemical and Biological Sciences, 4(1), 152–158.

9. Taylor, G., Davies, W. J. (1990). Root growth of Fagus sylvatica: impact of air quality and drought at a site in southern Britain. New Phytologist, 166, 457–461. doi: 10.1111/j.1469-8137.1990.tb00531.x.

10. Santosh, K. P., Tripathi, B. D. (2008). Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution. Journal of Environmental Quality, 37, 865–870. doi: 10.2134/jeq2006.0511.

11. Armbrust, D. V. (1986). Effect of particulates (dust) on cotton growth, photosynthesis, and respiration. Agronomy Journal, 78, 1078–1081. doi: 10.2134/agronj1986.00021962007800060027x.

12. Holt, E. A., Miller, S. W. (2011). Bioindicators: using organisms to measure environmental impacts. Nature Education Knowledge, 2(2), 8.

13. Salami, A. T., Farunbi, A. L., Muoghalu, J. I. (2002). Effect of cement production on vegetation in a part of Southwestern Nigeria. Tanzania Journal of Science, 28(2), 69–82. doi: 10.4314/tjs.v28i2.18355.

14. Oluseyi, T., Olayinka, K., Adeleke, I. (2011). Assessment of ground water pollution in the residential areas of Ewekoro and Shagamu due to cement production. African Journal of Environmental Science and Technology, 5(10), 786–794.

15. Britton, G. (1983). The biochemistry of natural pigments. Cambridge University Press, 133–140. ISBN-13: 978-0521105316.

16. Brown, S. B., Houghton, J. D., Hendry, G. A. (1991). Chlorophyll breakdown. In Chlorophylls. Edited by Scheer, H., CRC Press, Boca Raton, 465–489.

17. Costache, M. A., Campeanu, G., Neata, G. (2012). Studies concerning the extraction of chlorophyll and total carotenoids from vegetables. Romanian Biotechnolo. Letters, 17(5), 7702–7708.

18. Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts, polyphenoxidase in beta vulgaris. Plant physiology, 24(1), 1–15. doi: 10.1104/pp.24.1.1.

19. Lichanthaler, H. K. (1987). Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. Methods in Enzymology, 148, 350–382. doi: 10.1016/0076-6879(87)48036-1.

20. Ronen, R., Galun, M. (1984). Pigment extraction from lichens with dimethyl sulfoxide (DMSO) and estimation of chlorophyll degradation. Environmental and Experimental Botany, 24(3), 239–245. doi: 10.1016/0098-8472(84)90004-2.

21. Lichtenthaler, H. R., Wellburn, A. R. (1983). Determinations of total carotenoids and chlorophylls a and b of leaf extract in different solvents. Biochemical Society Transactions, 11(5), 591–592. doi: 10.1042/bst011059.

22. Wagh, N. D., Poonam, V., Shukla, S. et al. (2006). Biological monitoring of road-side plants exposed to vehicular pollution in Jalgaon city. Journal of Environmental Biology, 27(2 Suppl), 419–421.

23. Mandre, M., Tuulmets, L. (1997). Pigment changes in Norway spruce induced by dust pollution. Water Air Soil Pollution, 94(3–4), 247–258. doi: 10.1007/BF02406061.

24. Nanos, G. D., Ilias, I. F. (2007). Effects of inert dust on olive (Olea europaea L.) leaf physiological parameters. Environmental Science and Pollution Research, 14(3), 212–214.

25. Ramanathan, R., Jeyakavitha, T., Jeganathan, M. (2006). Impact of cement dust on Azadirachta indica leaves in and around Ariyalu. Journal of Industrial Pollution Control, 22(2), 285–288.

26. Saravana, K. R., Sarala, T. D. (2012). Effect of cement dust deposition on physiological behaviors of some selected plant species. International Journal of Scientific and Technology Research, 1(12), 1–8.

27. Naidoo, G., Chirkoot, D. (2004). The effects of coal dust on photosynthetic performance of the mangrove, Avicennia marina in Richards Bay, South Africa. Environmental. Pollution, 127, 359–366. doi: 10.1016/j.envpol. 2003.08.018.

28. Health, R. L., Castillo, F. J. (1988). Membrane disturbances in response to air pollutants. In book: Schulte-Hostede S., Darrall, N. M., Blank, L. W., Wellburn, A. R. Air Pollution and Plant Metabolism. Elsevier, London, pp. 53–75.

А. Е. Фаринмад, А. Л. Огунлейе, К. О. Омояжово

ВИВЧЕННЯ ВПЛИВУ ЦЕМЕНТНОГО ПИЛУ НА ФОТОСИНТЕТИЧНІ ПІГМЕНТИ РОСЛИН НА ПРИКЛАДІ ЦЕМЕНТНОЇ ПРОМИСЛОВОСТІ EWEKORO, НІГЕРІЯ

Більшість видів техногенної діяльності людини спрямованої на індустріалізацію призводить до зниження рівня екологічної безпеки та зменшення біорізноманіття, що негативно впливає на безперервне існування життя на Землі. У цьому дослідженні вивчався вплив цементного пилу від цементної промисловості Ewekoro, Нігерія, на фотосинтетичні пігменти рослин *Ocimum gratissimum*, *Mangifera indica*, *Terminalia catappa*, *Jatropha curcas* і *Carica papaya*. Зразки цих ендемічних видів рослин були відібрані на відстані 500, 1000, 1500, 2000 і 6000 м від цементної промисловості. Супернатанти, взяті під час лабораторного аналізу, використовувалися для вимірювання оптичної щільності із застосуванням спектрофотометра UV-VIS при довжині хвилі 662, 645, 470, 435 і 415 нм для визначення концентрацій хлорофілу А, хлорофілу В і каротиноїдів. Результати показують, що концентрації хлорофілу А, В, загального хлорофілу і каротиноїдів були нижче у всіх видів рослин, які зазнали впливу цементного пилу, ніж у рослин з контрольної ділянки. Швидкість деградації фотосинтетичних пігментів була високою у всіх досліджених видів рослин, але найвищою була у *Ocimum gratissimum* і *Mangifera indica*. У всіх видів рослин, крім *Terminalia catappa*, спостерігали зниження вмісту каротиноїдів. Серед усіх видів рослин, досліджених на відстані 500 м від місця розташування виробництва, найбільше зниження вмісту хлорофілу було у *Mangifera indica* (91,03 %), потім у *Otimum gratissimum* (77,40 %). Найменше зниження вмісту хлорофілу спостерігали у *Carica papaya*. За результатами дослідження передбачається, що забруднення цементним пилом може викликати зниження фотосинтетичних пігментів екстрактів листя, а, отже, вплинути на продуктивність рослин. У майбутніх дослідженнях слід ретельно вивчити і, можливо, спрогнозувати із використанням відповідних токсикокінетичних моделей, вплив цементного пилу на довкілля (включаючи фауну і флору) через 20 років, а також розглянути вплив цементного пилу на поживну цінність рослин. Якщо ці перспективні дослідження будуть проведені, то це допоможе обрати і застосувати організаційні заходи та технічні засоби для захисту компонентів природи.

Ключові слова: екологічна стійкість; фотосинтетичні пігменти; цементна промисловість.

ЛІТЕРАТУРА

1. Vambol S. O., Kondratenko O. M. Calculated substantiation of choice of units of monetary equivalents of complex fuel and ecological criteria components // Technogenic and ecological safety. 2017. Vol. 2. P. 53–60. doi: 10.5281/zenodo.1182890.

2. Ziarati P., Namvar S., Sawicka B. Heavy metals bio-adsorrption by Hibiscus Sabdariffa L. from contaminated weater // Technogenic and ecological safety. 2018. Vol. 4(2/2018). P. 22–32. doi: 10.5281/zenodo.1244568.

3. Vambol S., Koloskov V., Derkach Yu. Assessment of environmental condition of territories adjoined to wastes storage sites based on environmental reserve criterion // Technogenic and ecological safety. 2017. Vol. 2. P. 67–72.

4. Balaceanu C. M., Iordache G. Assessment of the air pollution at the industrial stations in metropolitan area of Bucharest // Technogenic and ecological safety. 2018. Vol. 3(1/2018). P. 8–15. doi: 10.5281/zenodo.1182485.

5. Sarala T. D., Saravanakumar R. Effect of Cement dust on Photosynthetic pigments of selected plant species // Asian Journal of Environmental Science. 2011. Vol. 6, Issue 2. P. 161–167.

6. Mercury emission from a cement factory and its influence on the environment / Fukuzaki N., Tamura R. Hiramo Y., Mizushima Y. // Atmosphere Environment. 1986. Vol. 20, Issue 12. P. 2291–2299. doi: 10.1016/0004-6981(86)90059-4.

7. Determination of elemental composition of TSP from cement industries in Nigeria using EXDRF techniques / Akeredolu F. A., Olaniyi H. B., Adejumo J. A. et al. // Nuclear Instrument and Methods in Physics Research. 1994. Vol. 353. P. 542–545.

8. Koperuncholan M., Ramesh V. S., Ahmed J. Impact of cement industries dust on selective green plants: a case study in Ariyalur industrial zone // International Journal of Pharmaceutical, Chemical and Biological Sciences. 2014. Vol. 4, Issue 1. P. 152–158.

9. Taylor G., Davies W. J. Root growth of Fagus sylvatica: impact of air quality and drought at a site in southern Britain // New Phytologist. 1990. Vol. 166. P. 457–461. doi: 10.1111/j.1469-8137.1990.tb00531.x.

10. Santosh K. P., Tripathi B. D. Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution // Journal of Environmental Quality. 2008. Vol. 37. P. 865–870. doi: 10.2134/jeq2006.0511.

11. Armbrust D. V. Effect of particulates (dust) on cotton growth, photosynthesis, and respiration // Agronomy Journal. 1986. Vol. 78. P. 1078–1081. doi: 10.2134/agronj1986.00021962007800060027x.

12. Holt E. A., Miller S. W. Bioindicators: using organisms to measure environmental impacts // Nature Education Knowledge. 2011. Vol. 2, Issue 2. P. 8.

13. Salami A. T., Farunbi A. L., Muoghalu J. I. Effect of cement production on vegetation in a part of Southwestern Nigeria // Tanzania Journal of Science. 2002. Vol. 28, Issue 2. P. 69–82. doi: 10.4314/tjs.v28i2.18355.

14. Oluseyi T., Olayinka K., Adeleke I. Assessment of ground water pollution in the residential areas of Ewekoro and Shagamu due to cement production // African Journal of Environmental Science and Technology. 2011. Vol. 5, Issue 10. P. 786–794.

15. Britton G. The biochemistry of natural pigments // Cambridge University Press. 1983. P. 133–140. ISBN-13: 978-0521105316.

16. Brown S. B., Houghton J. D., Hendry G. A. Chlorophyll breakdown. In Chlorophylls. Edited by Scheer, H., CRC Press, Boca Raton. 1991. P. 465–489.

17. Costache M. A., Campeanu G., Neata G. Studies concerning the extraction of chlorophyll and total carotenoids from vegetables // Romanian Biotechnolo. Letters. 2012. Vol. 17, Issue 5. P. 7702–7708.

18. Arnon D. I. Copper enzymes in isolated chloroplasts, polyphenoxidase in beta vulgaris // Plant physiology. 1949. Vol. 24, Issue 1. P. 1–15. doi: 10.1104/pp.24.1.1.

19. Lichanthaler H. K. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes // Methods in Enzymology. 1987. Vol. 148. P. 350–382. doi: 10.1016/0076-6879(87)48036-1.

20. Ronen R., Galun M. Pigment extraction from lichens with dimethyl sulfoxide (DMSO) and estimation of chlorophyll degradation // Environmental and Experimental Botany. 1984. Vol. 24, Issue 3. P. 239–245. doi: 10.1016/0098-8472(84)90004-2.

21. Lichtenthaler H. R., Wellburn A. R. Determinations of total carotenoids and chlorophylls a and b of leaf extract in different solvents // Biochemical Society Transactions. 1983. Vol. 11, Issue 5. P. 591–592. doi: 10.1042/bst011059.

22. Biological monitoring of road-side plants exposed to vehicular pollution in Jalgaon city / Wagh N. D., Poonam V., Shukla S. et al. // Journal of Environmental Biology. 2006. Vol. 27, Issue 2 Suppl. P. 419–421.

23. Mandre M., Tuulmets L. Pigment changes in Norway spruce induced by dust pollution // Water Air Soil Pollution. 1997. Vol. 94, Issue 3–4. P. 247–258. doi: 10.1007/BF02406061.

24. Nanos G. D., Ilias I. F. Effects of inert dust on olive (Olea europaea L.) leaf physiological parameters // Environmental Science and Pollution Research. 2007. Vol. 14, Issue 3. P. 212–214.

25. Ramanathan R., Jeyakavitha T., Jeganathan M. Impact of cement dust on Azadirachta indica leaves in and around Ariyalu // Journal of Industrial Pollution Control. 2006. Vol. 22, Issue 2. P. 285–288.

26. Saravana K. R., Sarala T. D. Effect of cement dust deposition on physiological behaviors of some selected plant species // International Journal of Scientific and Technology Research. 2012. Vol. 1, Issue 12. P. 1–8.

27. Naidoo G., Chirkoot D. The effects of coal dust on photosynthetic performance of the mangrove, Avicennia marina in Richards Bay, South Africa // Environmental. Pollution. 2004. Vol. 127. P. 359–366. doi: 10.1016/j.envpol. 2003.08.018.

28. Health R. L., Castillo F. J. Membrane disturbances in response to air pollutants. In book: Schulte-Hostede S., Darrall, N. M., Blank, L. W., Wellburn, A. R. Air Pollution and Plant Metabolism. Elsevier, London. 1988. pp. 53–75.

А. Е. Фаринмад, А. Л. Огунлейе, К. О. Омояжово

ИЗУЧЕНИЕ ВЛИЯНИЯ ЦЕМЕНТНОЙ ПЫЛИ НА ФОТОСИНТЕТИЧЕСКИЕ ПИГМЕНТЫ РАСТЕНИЙ НА ПРИМЕРЕ ЦЕМЕНТНОЙ ПРОМЫШЛЕННОСТИ EWEKORO, НИГЕРИЯ

Большинство видов техногенной деятельности человека направленных на индустриализацию приводят к снижению уровня экологической безопасности и уменьшению биоразнообразия, что негативно влияет на непрерывное существование жизни на Земле. В этом исследовании изучалось влияние цементной пыли от цементной промышленности Ewekoro, Нигерия, на фотосинтетические пигменты растений *Ocimum gratissimum, Mangifera indica, Terminalia catappa, Jatropha curcas* и *Carica papaya*. Образцы этих эндемичных видов растений были отобраны на расстоянии 500, 1000, 1500, 2000 и 6000 м от цементной промышленности. Супернатанты, взятые во время лабораторного анализа, использовались для измерения оптической плотности с применением спектрофотометра UV-VIS при длине волны 662, 645, 470, 435 и 415 нм для определения концентраций хлорофилла А, хлорофилла В и каротиноидов. Результаты показывают, что концентрации хлорофилла А, В, общего хлорофилла и каротиноидов были ниже у всех видов растений, подвергшихся воздействию цементной пыли, чем у растений с контрольного участка. Скорость деградации фотосинтетических пигментов была высокой у всех исследованных видов растений, но наибольшей была у *Ocimum gratissimum* и *Mangifera indica*. У всех видов растений, кроме *Terminalia catappa*, наблюдали снижение содержания каротиноидов. Среди всех видов растений, исследованных на расстоянии 500 м от места расположения производства наибольшее снижение содержания хлорофилла было у *Mangifera indica* (91,03 %), затем у *Otimum gratissimum* (77,40 %). Наименьшее снижение содержания хлорофилла наблюдали у *Carica papaya*. По результатам исследования предполагается, что загрязнение цементной пылью может вызвать снижение фотосинтетических пигментов экстрактов листьев, а, следовательно, повлиять на продуктивность растений. В будущих исследованиях следует тщательно изучить и, возможно, спрогнозировать, используя соответствующие токсикокинетические модели, влияние цементной пыли на окружающую среду (включая фауну и флору) через 20 лет, а также рассмотреть влияние цементной пыли на питательную ценность растений. Если эти перспективные исследования будут проведены, то это поможет выбрать и применить организационные меры и технические средства для защиты компонентов природы.

Ключевые слова: экологическая устойчивость; фотосинтетические пигменты; цементная промышленность.