

INVESTIGATING THE POTENCY OF *GMELINA ARBOREA* MORPHOLOGICAL CHARACTERIZATION AS A PHYTOREMEDIATOR IN HEAVY METAL CONTAMINATED SOIL TOWARDS SUSTAINABLE NATIONAL DEVELOPMENT

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Abstract

This study investigated the phytoremediation potential of Gmelina arborea seedling grown on soil contaminated with spent engine oil in quest of eco-friendly measures for sustainable national development. Environmental degradation is one of the current challenges of national development thus the need to seek remedies. This study examined the potency of Gmelina arborea in remediation of soil contaminated through mindless deposits of spent engine oil. The study was guided by two research questions. The experiment design was a 4 factorial in Completely Randomized Design (CRD) carried out in 15 replicates. Ripe fruits of Gmelina arborea were collected from the ground besides standing trees inside University of Nigeria, Nsukka campus. The fruits were depulped mechanically and viable seeds were soaked for 24 hours in water at room temperature. Top garden and compost soil samples were obtained at 10 cm depth from the new Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. Soil was taken for analysis in the Department of Soil Science of the same university. Soil was further mixed with poultry manure at a ratio of 6:2 and was watered daily for two weeks. Experimental plants were categorized into four groups: A, control (Ctrl), B, slight pollution, C, moderate pollution and D, severe pollution. Each of these treatments had fifteen pots. To simulate spillage, each of the 15 soil bags in groups B, C, and D was polluted with 10mls, 50mls, 100mls, of spent engine oil. The control (group A) had no spent engine oil. The plantlets were transplanted after forty-three days of germination into polythene bags each containing 20 kg of the amended soil. Pollution was repeated 57 days after planting (DAP) with 20 mls, 100 mls, 650 mls in groups B, C, and D which made it a total of 30mls, 150 mls and 750 mls of spent engine oil respectively. This was done when it was observed that the transplanted plants were stable. The comparisons of the mean of morphological characterization were observed at 57 DAP and 163 DAP. The results showed that there was significant difference ($p > 0.05$) in the Gmelina arborea morphological characterization of soil polluted with spent engine oil between 57DAP and 164DAP. The result therefore showed that G. arborea has the ability to phytoremediate soil contaminated with spent engine oil.

Key words: *Gmelina arborea*, phytoremediation, spent engine oil, DAP(days after planting).

Introduction

Sustainable national development requires an environment devoid of pollution or in reduced quantity. In part, eco-friendly environment is foundational in terms of national development because it is indispensable for the healthy growth of plants used for pharmaceutical, dietary,

aesthetic and economic purposes, all of which are essential for national development. It is also crucial for the health of human beings who constitute critical capital for national development. Notwithstanding the above, human activities such as industrialization, urbanization, farming, and waste disposal practices have resulted in the large-scale contamination of soil and water with organic compounds and heavy metals, with detrimental effects on ecosystem and human health. Conventional soil remediation methods are expensive and often involve the storage of soil in designated areas, postponing rather than solving the problem. In the last decade, the pressing need to find alternative methods has highlighted the scientific and economic benefits of plant and their associated microorganisms, which can be used for the reclamation of polluted soil and water (Meagher, 2000). This is an elegant and low-cost approach for the decontamination of polluted sites and has been greeted with a high degree of public acceptance, therefore prompting research into the use of phytoremediation technology to address the large areas of land and water currently affected (Krämer, 2005; Vangronsveld, Herzig, Weyens, Boulet, Adriaensen and (&) Ruttens, 2009; Lee, 2013). Land and water are precious natural resources on which rely the sustainability of agriculture and the civilization of mankind. Unfortunately, they have been subjected to maximum exploitation and severely degraded or polluted due to anthropogenic activities.

When engine oil is used in automobile, it picks up a number of additional compounds from engine wear. These include iron, steel, copper, zinc, lead, barium, cadmium, sulfur, dirt and ash etc. Because of the additives and contaminants, used motor oil disposal can be more environmentally damaging than crude oil pollution. These additives and contaminants may cause both short and long term effect if they are allowed to enter the environment through water ways or soil. Once engine oil is drained off an engine, it is no longer clean because it has picked up materials, dirt particles, and other chemicals during engine operation, thus such lubricating oil is now classified as Spent Engine Oil (Uchendu & Ogwo, 2014).

The disposal of spent engine oil (SEO) into gutters, water drains, open vacant plots, and farms which is a source of metal contamination is a common practice in Nigeria especially by automobile and power generator mechanics. This oil, also called spent lubricant or waste engine oil, is usually obtained after servicing and subsequently draining of expired oil from automobile and generator engines (Anoliefo & Vwioko, 2001). Most of the time, the artisans discard the spent engine oil by pouring much of it into the soil. Plants growing in soil contaminated with such oil usually experience difficulty due to poor water penetration into the soil as a result of hydrophobicity nature of oil as reported by Ajuziogu, Abu, Aino, Ideyi, Udoh, and Ojua, (2019).

Due to the effects of metal contamination of the soil, there is need for cleaning up the soil. Several methods are already being used to clean up the environment from these kinds of contaminants, but most of them are costly and difficult to get for optimum results (Bieby, Siti, Abdullah, Mushrifah, Nurina & Muhammad, 2011). This study aims at investigating the potency of *Gmelina arborea* morphological characterization in remediating soil contamination with spent engine oil which is a source of metal contamination to the soil.

Literature Review

Gmelina arborea

Gmelina arborea belongs to the family Verbenaceae, is commonly known as 'Gamhar'. *Gmelina* is one of the important genera of the family, consisting of about 33 species. It is a beautiful fast growing deciduous tree, which is a vital ingredient of the "dasamula". It is one of the herbs mentioned in all ancient scriptures of Ayurveda. It is known to have been used in traditional Indian medicine. The whole plant is medicinally very important.

Gmelina arborea as a fast-growing exotic deciduous tree grows naturally throughout India (Keay, Onochie, and Stanfield, (1989). It was introduced in Nigeria in 1924 and since then has been widely cultivated in the country (Tewari, 1995). *G. arborea* covers a total land area of 0.11million hectares representing about 59.3% of the total plantation area in Nigeria (Ekukudo, 2000). It attains a height moderate to large up to 30m with a girth of 1.2-4.5m with a clear bole of 9-15m.

Ekukudo (2000), maintained that *G. arborea* is among the trees recommended for quick vegetal cover of erosion sites. The leaves are harvested for fodder for animals and silkworms (Agbogidi, Eruotor & Akparobi, 2006a). Agbogidi, Dolor and Okechukwu, (2007a), reported the *G. arborea* displays a lot of multipurpose uses even at the peak of the dry season thereby ensuring an all-year supply of foliage and fodder.

The word "phytoremediation" derives from the Greek «phyton», meaning "plant", and Latin «remedium», which means "to remedy" or "to correct". Phytoremediation can be understood as the use of plants (trees, shrubs, grasses, and aquatic plants) and their associated microorganisms in order to remove, degrade or isolate toxic substances from the environment as an eco-friendly approach Dickinson, Baker, Doronila, Laidlaw and Reeves,(2009).With the development of industrialization and urbanization, the abundance of heavy metals in the environment has increased enormously during the past decades, which raised significant concerns throughout the world (Ashraf, 2017).

Statement of the Problem

This study has become crucial due to the environmental degradation caused by spent engine oil in our environments, as its spread takes place immediately. Environmental pollution from oil activities in major oil-producing countries such as Nigeria is inevitable. Agbogidi, Eruotor and Akparobi, (2006).

The disposition of soil contaminated with heavy metals is one of the most difficult tasks, especially on a large scale. Various studies have shown that plants accumulate heavy metals in different sites where spent engine oil is being spilt. These heavy metals are toxic to plants and may affect seed germination, plant growth, and crop yields and eventually affect human health. When these affected crops are consumed by animals and humans, the heavy metals might adversely affect some specific tissues, reproduction, and development Monisha, Tenzin, Naresh, Blessy, and Krishnamurthy, (2014).

Purpose of the Study

1. To investigate the potency of *Gmelina arborea* morphological characterization in remediating soil contaminated with spent engine oil in oil spillage environment.

2. To investigate the effect of different concentrations of spent engine on the morphological characterization of *Gmelina arborea*.

Research Questions

- i. To what extent does *Gmelina arborea* morphological characterization remediate spent engine oil polluted soil in an oil spillage environment?
- ii. What are the effects of different concentrations of spent engine oil on morphological characterization of *Gmelina arborea*?

Area of Study

This study was carried out in the Botanic Garden at the University of Nigeria Nsukka in Enugu State, located between longitude 7.39° E and latitude 6.86° N with elevation of 456m above sea level (Chicago, 2015). Nsukka annual rainfall ranges from 1845mm to 2000mm. The climate of Enugu is tropical with two major seasons, wet (April - October) and dry (November – March) seasons. Nsukka is a commercial and agricultural town *Gmelina arborea* grows there.

Methods

Mature fruits of *Gmelina arborea* used for this study were collected from the ground beside the trees around Faculty of Biological Sciences University of Nigeria Nsukka. The fruits were de-pulped mechanically. Seed pre-treatment was not necessary, though, for quick germination, the seeds were soaked between 6 - 24 hours in cold water. The seeds germinated within 20 - 50 days under ideal conditions; it met the average germination rate of 60% for a healthy seed lot. More plants were easily raised by transplanting, which was carried out in the rainy season and watering was done in the early hours of the morning when there was delay in rainfall.

Ten (10) centimeters depth of top garden and humus soil samples were obtained from the new Botanical Garden of the Department of Plant Science and Biotechnology, University of Nigeria, Nsukka. Soil was taken for analysis in the Department of Soil Science UNN to check for physical and chemical contents of the soil, both for pre and post-analysis. Poultry manure was collected at Nelo farm, Odoru phase 11 Nsukka. The soils were further mixed with poultry manure at a ratio of 6:2 and were watered for two weeks with adequate turning. 60 polythene bags were filled with 20kg of the mixture of soil. The polythene bags were perforated underneath which prevented water logging and allowed water drainage during the entire experiment. Up to ten seeds of *Gmelina arborea* were sown in each bag. The polythene bags were observed daily, for seedling emergence. The days on which the first seedling emerged were expressed as days to initial germination according to Sadat, Babalola, Shonubi and Olubukanala,(2014).

The experiment was carried out in 4 factorial in a Completely Randomized Design (CRD) and replicated 15 times. The bags were watered and kept under the sun and rain-fed since the experiment was carried out during the rainy season. Experimental plants were categorized into four groups: A, control (Ctrl), B, slight pollution, C, moderate pollution, and D, severe pollution. Each of these treatments had fifteen bags. To simulate, spillage, each of the 15 soil bags in group B, C, and D was polluted with 10 ml, 50 ml, and 100 ml, of spent engine oil respectively. Group A served as control and therefore was not polluted.

The plantlets were transplanted forty-three days after germination into some of the polythene bags each containing 20kg of the amended soil. The transplanting was done in the evening to

avoid excessive effect of transpiration on the plantlets. The plants were irrigated with tap water at an interval of two days for two weeks for the plantlets to stabilize before the application of spent engine oil. When transplanted plants were stable, (14 days later) that is 57 days after planting (DAP) pollution was repeated with 20 ml, 100 ml, and 650 ml, which gave a total number of T0, T1, T2, and T3 respectively of spent engine oil. The control had no spent engine oil.

Data Collection/Determination of Morphological Characterization of *Gmelina arborea*

The morphological characterization of the plant such as plant height, stem length, number of leaves per plant, petiole height, leaf length, leaf width, stem circumference, number of roots, root length, and root diameter were determined on the 57 days after planting (DAP). After pollution, the same vegetative parameters mentioned above were still taken, that is 57 days (initial parameter) and 106 days (final parameter) which was at 163 DAP. The various means of the observations were recorded.

Plant Height: The plant height was measured with the aid of a meter rule from the soil level to the plant apex and recorded in centimeters (cm).

Stem Length: The stem length was measured with the aid of a meter rule from the soil level to the end of the stem before topmost leaves and recorded in centimeters (cm).

Stem Girth/Diameter: This was determined by winding a thread around the main stem and strengthening it on a ruler and measurement was recorded in centimeters (cm).

Number of Leaves: The number of leaves was determined visually by counting. The leaf scars from fallen leaves were included.

Petiole Length: This was determined by measuring the length of the petiole with a thread starting from the point it is attached to the node to the leaf base and then placing it on a ruler to ascertain the length in centimeters (cm).

Leaf Length: This was done by measuring the length of two selected largest leaves in a *G. arborea* plant starting from the base to the tip of the leaf using a ruler. Values were recorded in centimeters (cm).

Leaf Diameter: This was done by measuring the broadest parts of the largest leaf samples in *G. arborea* with a meter rule. Values were recorded in centimeters (cm).

Results

The morphological characterizations presented in table 1 shows the mean comparisons of the plant height, stem height, leaf length, leaf diameter, number of leaves, root number, petiole, root length and root diameter of *Gmelina arborea* grown on soil polluted with varying volumes of spent engine oil (SEO). The study shows that the heavy metals increased in their concentrations as the spent engine oil (SEO) increased.

Table 1: Comparisons of the Means of Morphological characterization

		Control	T1	T2	T3	LSD
Plant Height (cm)	57 DAP	110.09 ± 11.28 ^a	101.60 ± 8.68 ^a	79.08 ± 7.36 ^a	91.71 ± 5.98 ^a	NS
	163 DAP	224.20 ± 6.60 ^a	194.93 ± 4.98 ^b	143.61 ± 7.56 ^c	34.97 ± 5.11 ^d	17.44
Stem Length (cm)	57 DAP	104.97 ± 11.29 ^a	97.54 ± 8.64 ^a	74.13 ± 7.35 ^a	86.44 ± 5.98 ^a	NS
	163 DAP	222.13 ± 6.60 ^a	186.32 ± 4.96 ^b	138.95 ± 7.73 ^c	33.17 ± 5.06 ^d	17.55
Stem Diameter (cm)	57 DAP	2.50 ± 0.32 ^a	2.31 ± 0.25 ^a	1.73 ± 0.20 ^a	2.27 ± 0.14 ^a	NS
	163 DAP	5.13 ± 0.39 ^b	4.35 ± 0.31 ^b	4.49 ± 0.51 ^b	13.07 ± 3.53 ^a	5.11
No. of Leaves	57 DAP	39.87 ± 5.40 ^a	35.33 ± 4.82 ^{ab}	22.33 ± 3.79 ^c	24.60 ± 4.09 ^{bc}	12.94
	163 DAP	129.80 ± 33.79 ^a	98.87 ± 18.63 ^b	24.63 ± 2.71 ^c	3.09 ± 0.72 ^c	54.80
Petiole Length (cm)	57 DAP	26.85 ± 3.97 ^a	18.83 ± 1.71 ^b	15.50 ± 1.80 ^b	17.52 ± 1.43 ^b	6.94
	163 DAP	17.59 ± 0.60 ^a	17.07 ± 0.69 ^a	14.38 ± 1.16 ^b	6.35 ± 1.04 ^c	2.56
Leaf Length (cm)	57 DAP	46.50 ± 7.16 ^a	34.63 ± 2.49 ^b	28.29 ± 2.46 ^b	34.33 ± 1.83 ^b	11.58
	163 DAP	22.04 ± 0.87 ^a	21.95 ± 0.72 ^a	19.47 ± 0.65 ^b	5.52 ± 1.01 ^c	2.34
Leaf Diameter (cm)	57 DAP	44.83 ± 7.20 ^a	34.74 ± 2.32 ^a	29.42 ± 2.47 ^a	34.76 ± 1.99 ^a	NS
	163 DAP	20.96 ± 0.83 ^a	20.33 ± 0.78 ^a	18.97 ± 0.60 ^a	1.59 ± 0.23 ^b	4.15

Data are presented with mean ± standard error. Means with different alphabet superscripts along each row represents significant differences across treatments separated using LSD- least significant difference at $P < 0.05$; NS- not significant.

1.1. Effect of Spent Engine Oil (SEO) on Height of *Gmelina arborea*

The mean analysis of plant height showed that there was no significant difference ($p < 0.05$) in height of the plants in all the treatments which were recorded 57 DAP. But at 163 DAP, there was a significant difference ($p < 0.05$) in height of *Gmelina arborea* among the treatments. The tallest plant was observed in control (224.2 cm) which was followed by treatment with T1 of spent engine oil (194.93 cm). The control was not significantly different ($p < 0.05$) from T1 treatment but was significantly different ($p < 0.05$) from T2 and T3 treatments. However, the latter two treatments (T2 and T3) were also significantly different ($p < 0.05$) in comparison (Table 1).

1.2. Effect of Spent Engine Oil (SEO) on Stem Length of *Gmelina arborea*

The control produced the highest mean stem length in 163 DAP (222.13 cm) followed by T1 and T2 treatments. The least was that of T3 treatment. There was no significant difference ($p < 0.05$) between control and T1 treatment, but when compared with T2 and T3 there was an observed significant difference ($p < 0.05$), as well as between T2 and T3 treatments. There was no significant difference ($p < 0.05$) in lengths of stems in 57 DAP (Table 1).

1.3. Effect of Spent Engine Oil (SEO) on Stem Diameter of *Gmelina arborea*

Results of the stem diameter of *G. arborea* at 57 DAP showed that there was no significant difference ($p < 0.05$) among all the treatments (control, T1, T2 and T3). Table 5 showed that the control had the highest diameter of 2.50 and were not significant at ($P < 0.05$), when compared to those of other treatments within the same DAP. More so, at 163 DAP, plants polluted with T3 of SEO showed the highest stem girth of 13.07cm, followed by the control at 5.13 cm. T1 and T2 of SEO had almost the same value of 4.35 cm and 4.49 cm respectively. The highest value was obtained from the plant polluted with T3 of SEO, which was significantly different ($p < 0.05$) from the rest of the treatments. However, there was no significant difference ($p < 0.05$) among the rest of the treatments (Table 1).

1.4. Effect of Spent Engine Oil (SEO) on Number of Leaves of *Gmelina arborea*

At 57 DAP, the mean of the number of leaves of *G. arborea* in the control did not differ significantly ($p < 0.05$) from those of the rest of the treatments. However, there were significant difference ($p < 0.05$) between the mean number of leaves at T1 and T2 treatments, but there was no significant difference ($p < 0.05$) between those of T2 and T3. At 163 DAP the highest mean value was observed in the control (129.80). This was followed by that of T1 and T2 respectively. The least number of leaves was that of T3 treatment (3.09). There was significant difference ($p < 0.05$) between the control and T1 pollution but when compared with the T2 and T3 treatments, there was no significant difference ($p < 0.05$). There was also a significant difference ($p < 0.05$) between the T1 and T2 treatments as well as T3 (Table 1).

1.5. Effect of Spent Engine Oil (SEO) on Petiole of *Gmelina arborea*

Results showed that the control, with the longest petiole, (26.85 cm) was significantly different ($p < 0.05$) from the rest of the treatments at 57 DAP. Meanwhile, at 163 DAP, control was not significantly different ($p < 0.05$) from that of T1 treatments, but differed significantly ($p < 0.05$) from those of T2 and T3 treatments respectively. In the same vein, there was a significant difference between the mean lengths of the petioles in T2 and T3 treatments (Table 1).

1.6. Effect of Spent Engine Oil (SEO) on Leaf Length of *Gmelina arborea*

At 57 DAP, control recorded the highest leaf length of 46.50 cm, showing a significant difference ($p < 0.05$) with T1 and T3 treatments. However, the T2 treatment significantly differed ($p < 0.05$) when compared with the other two treatments. Meanwhile, at 163 DAP there was no significant difference ($p < 0.05$) between control and T1. But there was between control, T2, and T3 treatments. A significance difference ($p < 0.05$) also existed between T2 and T3 treatments (Table 1).

1.7. Effect of Spent Engine Oil (SEO) on Leaf Diameter of *Gmelina arborea*

The result showed that at 57 DAP, there was no significant difference ($p < 0.05$) among the treatments. However, at 163 DAP, there was no significant difference in the mean leaf diameter of the control, T1 and T2 treatments. That of T3 treatment differed significantly ($p < 0.05$) from all other treatments (Table 1).

Discussion

According to the study's findings, most of the morphological characterization were not significantly different at 57 DAP but were significantly different at 163 DAP, either in terms of a drop in or an increase in the morphological data. Spent engine oil, when clearly visible, greatly decreased the plant height, stem height, leaf length, leaf diameter, number of leaves, number of roots, petiole, root length, and root diameter of *Gmelina arborea* with increase in maturity time. The decrease in plants height was in line with Nwachukwu, Azorji, Adjero, Green, Igwe and Nnadozie, (2020) who reported that high concentration of SEO noticeably decreased the height of plants. The decrease in plant height could be attributed to the high oil concentration in the soil (Oyedeji, Kayode, Besenyei and Fullen, 2015; Njoku, Akinola and Busari, 2012). There was plant inhibition of growth and performances as a result of its exposure to SEO pollution (Njoku, Akinola and Busari, 2012). There was an exceptional increment in the growth of the morphological characterizations of the stem diameter with increment in SEO concentration. This is comparable to the findings of Ogbuehi, Ezeibekwe & Ejiogu, (2011) who found that *Arachis hypogea* plants' height, number of leaves, percentage of germination, and leaf area all significantly decreased as a result of exposure to used engine oil. Agbogidi and Eruotor, (2012) also noted decreases in the plant height, leaf area, and quantity of *Jatropha curcas* leaves that were contaminated with used motor oil. *Telfairia occidentalis* and *Zea mays* planted on soil contaminated with used motor oil experienced a decrease in the number of leaves and a suppression of radicle and plumule growth during early seedling growth. According to Otunne and Kinako, (2010), *Abelmoschus esculentus* (L.) Monech also saw a decline in height, petiole length, and leaf area with an increase in the concentration of wasted engine oil pollution, according to (Okon and Mbong, 2013). With an increase in the concentration of applied waste engine oil, the height and petiole length both dropped. This outcome is comparable to that of

Otunne and Kinako (2010), who showed that seedlings of *Telfaria occidentalis* and *Zea mays* experienced greater growth inhibition as used engine oil concentration increased. This present finding supports the reports of Osawuru and Abioye (2012) on their work on *Abelmoschus esculentus* where the control plants grew better than plants sowed in soils treated with spent oil. The significant increase seen 163 DAP demonstrated that used motor oil, in addition to extending the maturation period, increased stem diameter after pollution. More so, the leaf area of the plants exposed to greater concentrations of SEO were usually smaller than the control plants. This investigation made by Olanranton, Stewart and Traiperm (2020) who pointed that plants in soil with low water concentration frequently show reduction in leaf areas techniques of balancing their water content available in their tissue. Plants growing in soil contaminated with oil usually experience difficulty in water penetrating the soil because of hydrophobicity nature of oil as reported by Ajuziogu, Abu, Aino, Ideyi, Udoh and Ojua (2019). Some of the leaves of plants in the heavily polluted soils curled upwards from their tips and

withered, resulting to death of such plants. This suggests that apart from the level of pollution, the age of plant has much influence on the survival of plants to oil pollution. As suggested by Agbogidi, Dolor and Okechukwu (2007) the higher resistance of the older plants to spent oil pollution may be due to the presence of already cutinised tissues in such plants.

Conclusion

With the growing human population and improving quality of life, there will be an inevitable increase in the amount of land pollution released into the environment. Disposal of spent engine oil indiscriminately as a common practice in Nigeria have adversely affected the soil, water etc. When SEO are impacted on the land at a higher concentration, it alters some changes on the plants found there. *G. arborea* is a fast-growing exotic deciduous tree that occurs naturally in so many regions. It is known for its quick vegetal cover of erosion sites, medicinal uses, good timber etc.

This study assessed the impact of used engine oil on the *Gmelina arborea* morphological characterizations. The different mean comparisons of the different DAP, between 57 and 163, of the plant to the pollutant were often dose-dependent. With the exception of the stem diameter, which increased gradually, a reduction in the different morphological characterizations metrics was clearly seen at the 163 DAP. The results of the current investigation have demonstrated that soil contaminated with used engine oil significantly reduces nearly all the morphological characterizations of the *Gmelina arborea* plant. It should therefore be the concern of all and sundry to guard against spent engine oil pollution in our environment to satisfy our quest for sustainable national development.

Recommendations

The following recommendations are made based on the findings of this study:

- Public enlighten on the need for sustainable natural resources / national development and exploitation should be intensified in our environment to raise the level of awareness of the local community on the effect of SOE on the soil.
- There is need for good and adequate measures such as afforestation with *G. arborea*, reafforestation, good land planning in our environment as preventive and remedial measures against stresson vegetation by natural hydrocarbon seepage.
- Such plant species should be grown in polluted cities, road sides, around industrial areas in order to create a sort of 'shield or curtain' that will absorb pollutants and screen the environment from such effects.

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