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Coal-fired Power Plants and Their Impact on Ecosystems Health

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Coal-fired power plants emit greenhouse gases (GHG) that cause global warming. Coal, being one of the most important fossil fuel, emits three times as much GHG as natural gas. The combustion of coal (fossil fuels at large) discharge different kinds of chemical substances that affect ecosystems and human health. Some of the most important by-products include Nitrous oxides, Sulfur oxides, Carbon dioxide, Fly ash and Mercury. Various studies have confirmed that fly ash contains high levels of carcinogens causing more incidences of cancer, albeit data on ecosystems health is scanty and little is understood. The Author designed a greenhouse study to investigate the effects of coal by-products on the health of immediate ecosystems by growing tomatoes in potted soils collected from two coal-fired power plants. The first site (Chalk Point generating station), is located in Prince George's County (MD) while the second one (Brandon Shore generating Station) is located in Anne Arundel County near Curtis Bay (MD). Three replicate samples were taken within 1 mile and 4 miles radius of these coal-fired power plants. Measurements were made on the soils physico-chemical (pH, soil texture) and plant morphological (leaf-area-index, color, stalk diameter and height) characteristics. Results of the analysis show that plants growing in close proximity to the coal-fired power plants exhibit a very low leaf-area-index, stunted growth and overall low performance. The study concluded that coal-fired power plants do exert undesirable ecological impacts and in the long-run can have a detrimental effect on the health of ecosystems.

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1. INTRODUCTION

Coal-fired power plants emit more than 60 different hazardous air pollutants. Yet, despite billions of dollars of investment, scientists are unable to completely remove harmful emissions from plants. Coal mining involves excavation of the earthly bound coal by removing overburdens using mechanical devices. This process is associated with release of large quantities of mine spoil and dust particles [1]. Pollution from coal-fired power stations is released in four main ways; (i) fly ash from the smoke stack, (ii) bottom ash which stays at the bottom after the coal is burned, (iii) waste gases from the scrubber units (which are chemical processes used to remove some pollutants) and (iv) gas released into the air [2].

The large scale burning of coal contributes to global climate change and regional air pollution [3]. Coal mining and combustion are associated with social injustices in local communities. These include environmental harms and health impacts on both minor and major scales [4]. There are a number of by-products that are released by coal burning; among these the most important are sulfur dioxide, nitrogen oxides, carbon dioxide and mercury. Sulfur dioxide has been associated with acid rain and the increased occurrence of respiratory disease. Another chemical that has been associated with acid rain is nitrogen oxide, which is also linked to photochemical smog and to the depletion of the Earth's ozone layer. Mercury is another by-product that is associated with both neurological and developmental damage in human beings and animals [5].

In the United States alone, air pollution from power plants contributes to an estimated 30,000 premature deaths, hundreds of thousands of asthma attacks, and tens of thousands of hospitalizations for respiratory and cardiovascular illnesses each year. Studies show that people living in coal mining with no direct contact with the mines themselves were at higher risk for kidney disease and chronic lung and heart diseases. They were found to be 70 times as likely to develop kidney disease, 64 times as likely to develop chronic lung diseases such as emphysema, and 30 percent more likely to develop high blood pressure [6]. Coal dust has been shown to stimulate release of cytokines that are important in lung inflammation and fibrosis [7]. Death rates in coal mining communities are higher than in other parts of the country, even among non-mine workers. Fine matter pollution from U.S. power plants leads to more than 24,000 deaths each year. Power plant pollution is responsible for 38,200 non-fatal heart attacks per year [8].

Ecosystems are also strongly impacted by coal-fired power plants. Mining operations rip apart ecosystems and reform the landscape. As forests are replaced with non-native grasslands, soils become compressed and streams polluted. In the United States there are over 156 coal-fired power plants that store ash in surface ponds similar to the one that collapsed in the coal incident in Tennessee [9]. Records specify that Indiana, Ohio, Kentucky, Georgia and Alabama store the most ash in their ponds. The impacts of these ponds on water resources and the surrounding fauna and flora are not fully studied [8]. The negative health effects of these coal-fired power plants on the nearby human population, plant life, and wildlife have been hard to quantify precisely and thoroughly [10]. Another study indicated that the long-standing health crisis in coal mining communities requires a multidisciplinary approach [11].

The current study attempted to examine the local ecosystems impacts of power generating plants in an experiment that was carried out in a greenhouse using tomatoes as an indicator plant on soils collected from two coal-fired coal plants in Maryland. The objectives of the study were to examine the impacts of the by-products on select soil properties and morphological characteristics of the indicator crop.

2. MATERIALS AND METHODS

2.1 Study Sites

In 2016, approximately 37.1% of all energy produced in Maryland came from coal. Out of the nine major coal-fired power plants, we selected two for this study. Fig. 1 shows Brandon shore and Chalk point power generating stations. Chalk point power generating station is located in Prince George's County (MD) whereas Brandon shores power generating station is located in Anne Arundel County (MD).

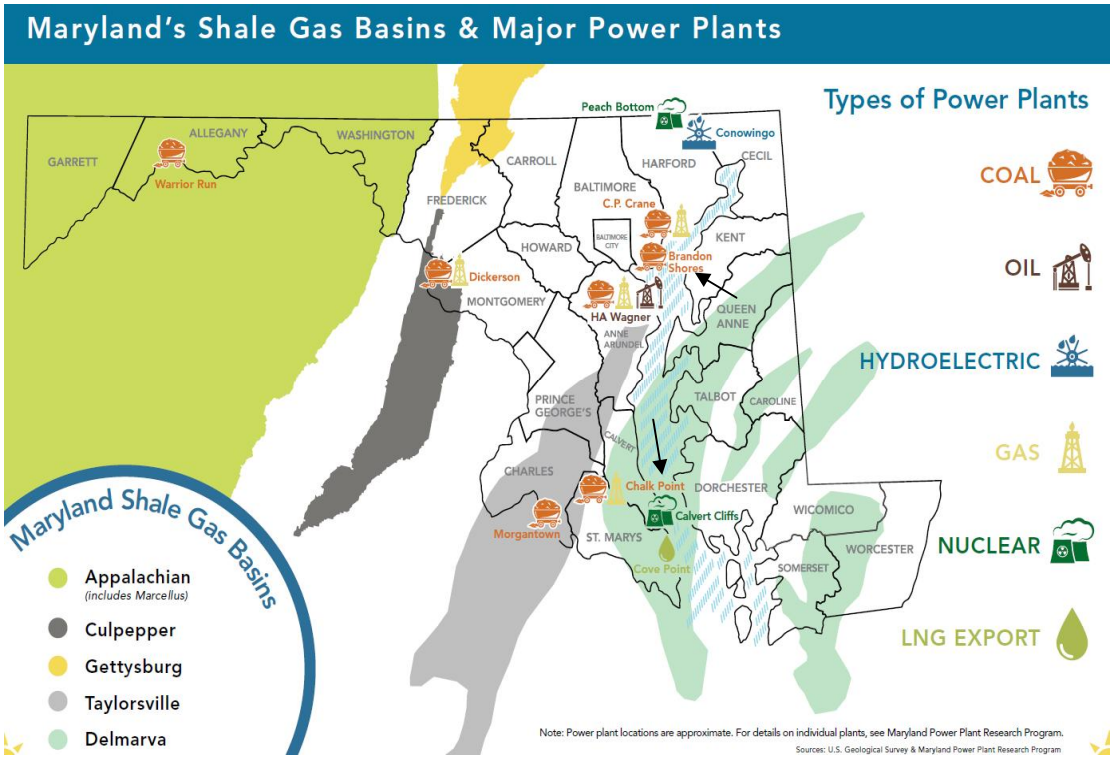

Fig. 1. Map showing the study sites (Black arrows indicating Brandon shore and Chalk point power generating stations)

Soil samples were collected within 1 mile and 4 miles radius of the study sites. Three replicate samples were collected from each radius to ensure complete representation of the study sites. As a control, garden soil (with no chemical by-products) was used to investigate the impacts of the by-products on soil properties and plant morphological characteristics.

2.2 Experimental Design

Each site had three treatments (1 mile, 4 miles and control) and the pots were filled with equal mass of soil. All pots were watered at the same frequency and depth using a sprinkler system. Tomato seeds were germinated on a seedling bed before transplanted into the pots. The seeds took over 14 days to have the minimum number of leaves (4) required for transplanting.

2.3 Soil Analysis

Once soil samples were brought to the lab, analysis was made on select physico-chemical characteristics following standard procedures. The analysis included soil pH and particle size distribution.

2.4 Monitoring Plant Morphological Characteristics

Periodic measurements were made on important morphological characteristics of the indicator crop (tomatoes), including plant height, leaf area index, stalk diameter, leaf color, and flowering and overall growth rate.

3. RESULTS AND DISCUSSION

3.1 Soil Characterization

3.1.1 Soil texture

Particle size analysis of the experimental soils (Table 1) shows that Brandon shore has a silt loam texture whereas Chalk point has a sandy clay loam. The control (garden soil) was classified as clay loam texture.

3.1.2 Soil pH

Soil pH was measured for all treatments and their replications and the result is presented in Table 2.

Table 1. Soil texture analysis of the study sites

Particle size	Value	Soil type	Methods
Brandon shore			
Sand (%)	32.7	Silty loam	Pipette method
Silt (%)	52.2		
Clay (%)	15.1		
Chalk point			
Sand (%)	46.1	Sandy clay loam	Pipette method
Silt (%)	26.3		
Clay (%)	27.6		
Control			
Sand (%)	33.7	Clay loam	Pipette method
Silt (%)	34.2		
Clay (%)	32.1		

As can be seen from the table, Brandon shore is more acidic (average pH 5.6) closer to the power plant (1 mile radius) than further away (4 miles radius) from it (average pH 7.32). On the other hand, Chalk point gets more alkaline as one goes further away from the power plant (4 miles). The Author believes the acidity of Brandon shore soil is the result of by-products from the power plant. The pH is an important indicator of soil's productivity and plants performance [12]. A similar study in China demonstrated a high concentration of combustion by-products that affected ecosystems sustainability [13].

3.2 Plant Morphological Characteristics

The study used plant height, leaf diameter, color and stalk diameter to compare the different treatments. Fig. 2 (a, b and C) is an example to show the difference in the rates of growth (after 8 weeks of planting) at 1 mile, 4 mile and control samples for Brandon shore power generating plant. Leaves of the control sample had deeper green color while leaves within 1 mile radius revealed lighter green colors showing some level of stress.

Fig. 2(a). Brandon shore (4 mi)

Fig. 2(b). Brandon shore (1 mi)

Fig. 2(c). Control sample

The Author observed the same pattern for Chalk point where tomatoes planted on samples collected from 4 miles showed a better morphological performance compared to 1 mile radius (Fig. 3). This difference could be explained by the fact that concentration of the byproducts decrease as one goes further away from the power plants.

Similar studies on the impacts of coal-fired power plants on water quality have shown that Acid Mine Drainage (AMD), which refers to distinctive types of waste bodies that originate from the weathering and leaching of sulphide minerals, present contamination of drinking water and disrupted growth and reproduction of aquatic plants and animals [2]. Effects of AMD related to water pollution include the killing of fish and loss of aquatic life and corrosion of mining equipment and structures such as bridges and concrete materials.

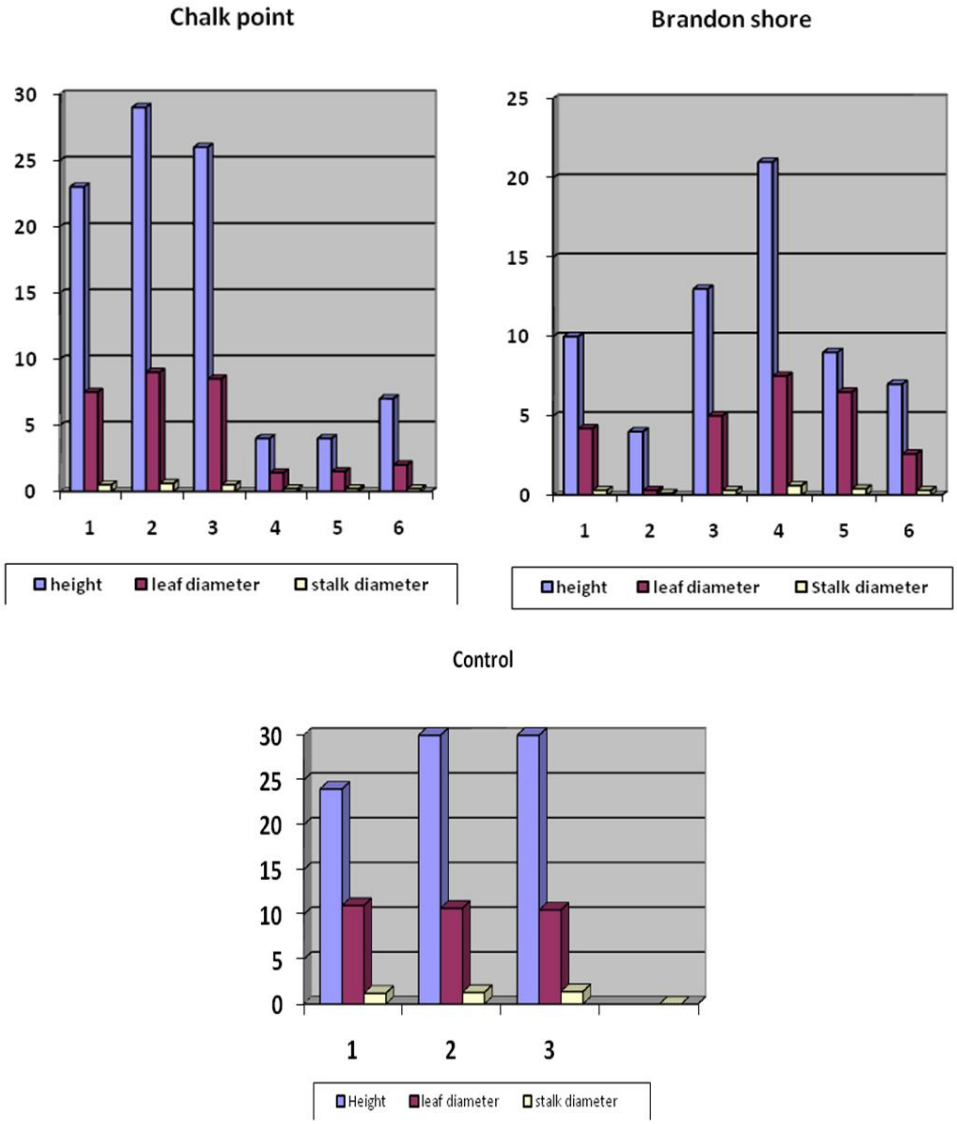

Fig. 3. Morphological measurements (in cm) after 8 weeks of planting. For Chalk Point, 1- 3 indicate samples within 4 miles and 4-6 show samples within 1 mile radius. For Brandon Shore 1-3 indicate within 1 mile and 4-6 indicate within 4 miles radius

Table 2. Measurement of soil pH for the study sites and control sample

Soil pH	Value	Soil pH	Value
Brandon shore (1 mi)	5.27	**Brandon Shore (4 mi)**	7.10
REP 1	5.53	REP 1	7.46
REP 2	6.02	REP 2	7.39
REP 3		REP 3	
Chalk point (1 mi)	7.23	**Chalk Point (4 mi)**	7.99
REP 1	7.08	REP 1	7.56
REP 2	7.01	REP 2	8.00
REP 3		REP 3	
Control			
REP 1	7.20		
REP 2	7.14		
REP 3	7.00		

4. CONCLUSION

The trace elements contained in coal are a large group of diverse pollutants with a number of health and environmental effects. These elements are a public health concern because at sufficient exposure levels they adversely affect human health. Some are known to cause cancer, others impair reproduction and the normal development of children, and still others damage the nervous and immune systems. Many are also respiratory irritants that can worsen respiratory conditions such as asthma. They are also an environmental concern because they damage ecosystems. Power plants also emit large quantities of carbon dioxide (CO_2), the "greenhouse gas" largely responsible for climate change [14]. The health and environmental impacts caused by power plant emissions may vary over time and space, from short-term episodes of coal dust blown from a passing train to the long-term global dispersion of mercury, to climate change. Because of different factors like geology, demographics and climate, impacts will also vary from place to place [15].

In order to better understand the local ecological impacts of coal-fired plants, a greenhouse experiment was conducted on soils sampled from two power plants, using tomatoes as an indicator crop. Soils collected close to the power plants have higher acidity (as evidenced by pH measurements). Tomatoes that were grown on soil sample taken within 1 mile radius of the power plants showed poor performance in all morphological characteristics. Future study should consider more treatments (closer proximity to the power generating stations) and add more replications to have a comprehensive understanding on the impacts of coal-fired power plants.

In summary, there is nothing clean about coal and the health of our ecosystem is constantly being threatened by it. Coal-fired power plants cause a host of environmental harms; promoting increased reliance on coal without additional environmental safeguards is certain to increase those harms. One of those safeguard measures would be to locate these coal-fired power plants far from urban ecosystems so that their impacts on animal and plant habitats could be minimized [16]. Another option is to focus on renewable technologies as optimal use of these resources minimize environmental impacts, produce minimum secondary wastes and are sustainable based on current and future economic and social societal needs [17].

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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