PHILIPPINE SCIENCE HIGH SCHOOL WESTERN VISAYAS
Doña Lawaan H. Lopez Campus
Iloilo City

AIR POLLUTION TOLERANCE INDEX OF SOME PLANT SPECIES IN ILOILO CITY

A Research Paper Presented
to the Faculty of the
Philippine Science High School Western Visayas
Iloilo City

In Partial Fulfillment of the Requirements
in Technology Research II

by

Kirsten Ashley Q. Arroyo
Ma. Thea P. Gadong
Johannes M. Magpusao

March 2002

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APPROVAL SHEET

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To Mrs. Josette T. Biyo for extending her scientific knowledge, as we were able to formulate the methodology for our study with the documents she had offered us.

To Mrs. Leilani C. Estilo for her assistance in the conduction of the experiment proper as well as for providing us with the chemicals and equipment needed.

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Abstract

This One-Spot Case Study in a Completely Randomized Design determined the air pollution tolerance index (APTI) of some common plant species in Iloilo City. The study hypothesized that there is no significant difference in the APTI of these plant species among the test areas in the city. Leaf samples were taken from three areas, namely, Jaro Plaza, Bonifacio Drive-Gen. Luna Street, and Philippine Science High School Western Visayas Campus, which was considered as the control test area, having relatively minimal pollutants. These sites had four plant species in common, specifically, talisay (*Terminalia catappa*), papaya (*Carica papaya*), Indian tree (*Polyathia longifolia*), and mahogany (*Swietenia macrophylla*). The APTI value was calculated by the determination of ascorbic acid, relative water content, total chlorophyll, and pH level of mature plant leaf samples. The test solution, standard solution, and blank solution of leaf extract was titrated against the standard dye solution in order

to determine the ascorbic acid content; the fresh, turgid, and dry weights of plants leaf samples were determined as a measure of the relative water content; the spectrophotometric readings of the different leaf extracts at 645 nm and 663 nm against 80% acetone estimated the total chlorophyll content; and the pH of the leaf extracts was measured using a pH meter. The APTI was then calculated from these measurements. Triplicate trials were performed on each plant sample from each test area. The mean and the standard deviation were utilized as descriptive statistical tools. The One-Way Analysis of Variance (ANOVA), both set at 0.05 alpha level of significance, were utilized as inferential statistical tools.

The results of this study showed that mahogany was the best bioindicator since it had the lowest mean APTI value of 5.709422 among the group, followed by Indian tree (5.849522) and talisay (6.470933). Papaya was the least potent bioindicator as it had the highest mean APTI value of 6.895633. This established that mahogany was most sensitive to air pollution among group, while papaya was least sensitive or the plant, which can best tolerate an immense degree of air pollution. The results further showed that the most polluted area among the three sites was Bonifacio Drive-Gen. Luna St. having the lowest APTI values, while the least polluted area was PSHSWVC having the highest APTI values.

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Chapter 1

Introduction to the Study

Background of the Study

Each time we inhale a breath of air, we absorb several liters of gaseous nitrogen and oxygen. If we could breathe fresh air, we would also inhale a small quantity of trace gases, the main ones being carbon dioxide and argon. Unfortunately, we no longer breathe pure air and for most of the time, we inhale air that is polluted with up to 2,800 compounds, most of which comprise exceedingly scarce trace gases. These pollutants are the products of our modern industrialized society. The majority of our air pollutants arise from the burning of fossil fuels --- coal, wood and oil (http://www.strath.ac.uk/Departments/Geography/course_materials/people_and_physical_env/lecture14/ppe_lec_14.htm).

Exhaust gases have both direct and indirect harmful effects on roadside plants. Plant species show a remarkable variation in their sensitivity to air pollution. Since they are immobile and are continuously exposed to pollutants, air pollution injury to plants is proportional to the intensity of pollution. Henceforth, plants are often used as bioindicators for air quality monitoring (http://www.panasia.org.sg/nepalnet/ronast/pollution.htm).

In this study, some local plant species common to the more exposed and less exposed areas in Iloilo City will be used and tested for their bioindicating capabilities based on their air pollution tolerance index (APTI).

The independent variables of this study are the identified test areas in Iloilo City and the common plant species growing in these areas. The dependent variable is the resulting APTI of these plant species in each test area. The relationship between the independent and dependent variables of this study is presented in Figure 1.

Statement of the Problem and the Hypothesis

This study determined the APTI of some growing plants species in Iloilo City. Specifically, this study answered the following questions:

1. What is the APTI of the four plant species, namely, (a) talisay (*Terminalia catappa*), (b) papaya (*Carica papaya*),

(c) Indian tree (*Polyathia longifolia*), and (d) mahogany (*Swietenia macrophylla*), which are common in some areas in the city, namely, (1) Jaro Plaza, (2) Gen. Luna Street, and (3) Philippine Science High School Western Visayas Campus (PSHSWVC)?

2. Compare the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany that are found among the given areas.

3. Is there a significant difference in the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany when compared with other values among the given areas?

4. Which among the plant species, i.e., (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany is considered the best bioindicator of air pollution based on their APTI?

Based on these questions, it is hypothesized that there is no significant difference in the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany when compared with other values among the given areas.

Significance of the Study

It is already established that there is an existence of tolerant plant species to air pollution. The ascorbic acid, relative water content, total chlorophyll, and pH level of plant

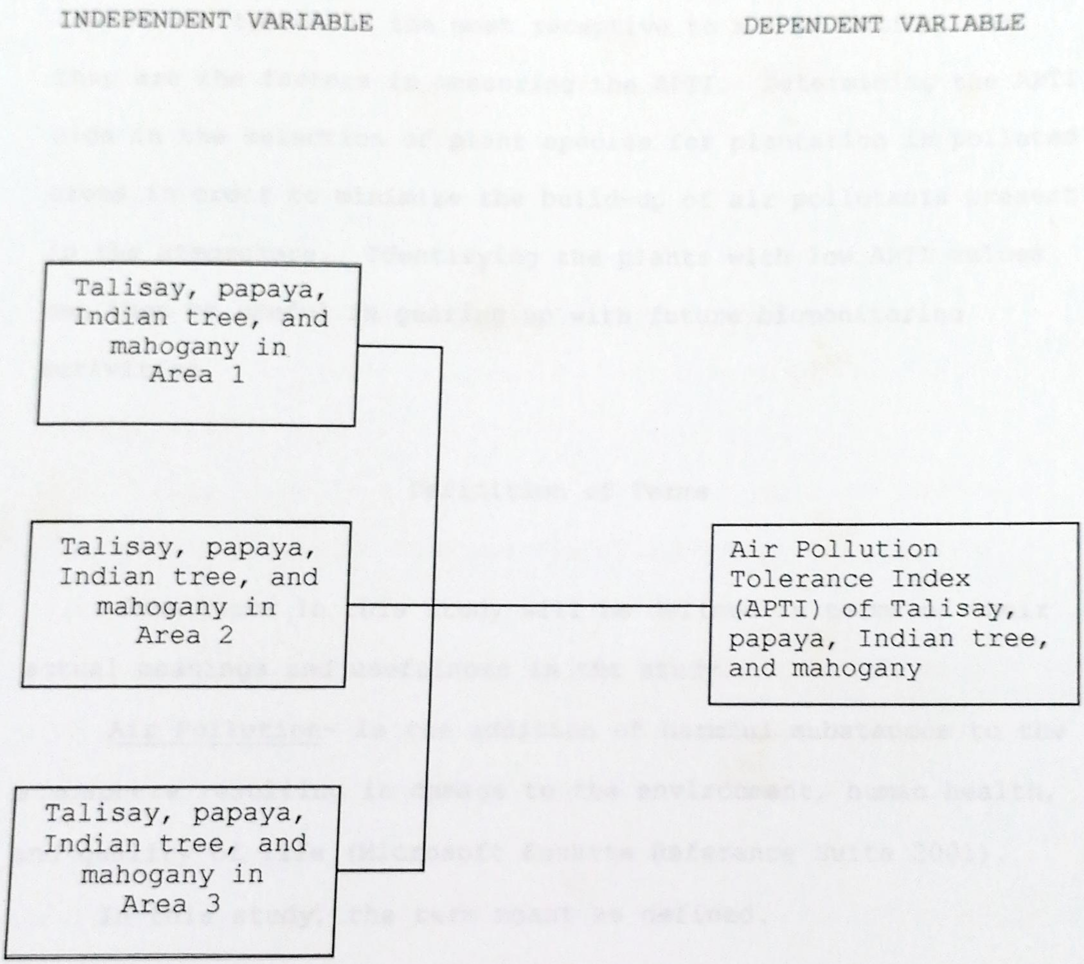

Figure 1. Air Pollution Tolerance Index of talisay (*Terminalia catappa*), papaya (*Carica papaya*), Indian tree (*Polyathia longifolia*), and mahogany (*Swietenia macrophylla*) in three test areas in Iloilo City

leaves are termed as the most receptive to air pollution, and they are the factors in measuring the APTI. Determining the APTI aids in the selection of plant species for plantation in polluted areas in order to minimize the build-up of air pollutants present in the atmosphere. Identifying the plants with low APTI values can then be useful in gearing up with future biomonitoring activities.

Definition of Terms

Some terms in this study will be defined in terms of their actual meanings and usefulness in the study.

Air Pollution- is the addition of harmful substances to the atmosphere resulting in damage to the environment, human health, and quality of life (Microsoft Encarta Reference Suite 2001).

In this study, the term meant as defined.

Air Pollution Tolerance Index- represents the tolerance level of plants to air pollution (http://www.panasia.org.sg/nepalnet/ronast/pollution.htm).

In this study, the term meant the value obtained from the determination of the ascorbic acid (A), relative water content (R), total chlorophyll (T), and pH (P) level of plant leaves by using the formula APTI = [A(T+P) + R]/10.

Plant Species- is any of the kingdom (Plantae) of living things typically lacking locomotive movement or obvious nervous or sensory organs and possessing cellulose cell walls (Merriam-Webster's Collegiate Dictionary, 1996).

In this study, the term referred to the plant samples namely talisay (*Terminalia catappa*), papaya (*Carica papaya*), Indian tree (*Polyathia longifolia*), and mahogany (*Swietenia macrophylla*).

[Test] Area- is a particular extent of space or surface or one serving a special function (Merriam-Webster's Collegiate Dictionary).

In this study, the term referred to test areas in Iloilo City where the leaf samples will be taken, namely, Jaro Plaza; Bonifacio Drive-Gen. Luna St.; and PSHSWVC.

Bioindicator- is a species or system used to derive information on environmental factors from the presence or absence of a species, symptoms of biological damage, population age and weight structure, and community composition or food web parameters (http://www.bio.vu.nl/do/soilecology/Bioindicator_systems/bioindicator_systems.html).

In this study, the term referred to the plant species, which has the lowest APTI value among the given plant species.

Sample- is a representative or a single item from a larger whole or group ((Merriam-Webster's Collegiate Dictionary, 1996).

In this study, the term refers to the leaves of plants species identified for testing.

Extract- is a solution of essential constituents of a complex material (Merriam-Webster's Collegiate Dictionary).

In this study, the term meant the crude juice of the test plant species collected from the osterization of the plant samples.

Scope and Delimitation of the Study

This study aimed to determine the APTI of three plant species common in Iloilo City, namely, talisay, papaya, Indian tree, and mahogany.

In order to obtain the APTI of the four plant species in the different test areas, we used four parameters, namely, total chlorophyll content, relative water content, ascorbic acid content, and pH.

The descriptive statistical tools used in this study were the mean and standard deviation. The One-Way Analysis of Variance (ANOVA), set at 0.05 alpha level of significance, and the Scheffe Test were used as the inferential statistical tools.

In determining the APTI of the four plant species used in the study, we obtained these plants, which are common in the areas of Jaro Plaza, Bonifacio Drive-Gen. Luna St., and PSHSWVC. The study started in November 2001, beginning with Jaro Plaza, and ended in December 2001 with Bonifacio Drive-Gen. Luna Street.

The parameters were determined on the same day the plant samples were gathered.

The data acquired were not 100% accurate due to some inevitable factors. During the dry weight determination, the temperature of the oven was not constant because its thermostat was broken. The temperature ranged from 70°C and 90°C.

However, only three of the four parameters - total chlorophyll content, relative water content, and pH - were determined by the researchers. The researchers were not able to obtain the ascorbic acid content of the plant species because the chemical, dichlorophenol indophenol, was unavailable.

Chapter 2

Review of Related Literature

This chapter consists of five parts, namely, (1) Effects of Air Pollution on Plant Life; (2) Response of Plants to Air Pollution; (3) Talisay; (4) Papaya; and (5) Mahogany.

Air pollution is the addition of harmful substances to the atmosphere resulting in damage to the environment, human health, and quality of life. One of many forms of pollution, air pollution occurs inside homes, schools, and offices; in cities; across continents, and even globally. Air pollution makes people sick — it causes breathing problems and promotes cancer — and it harms plants, animals, and the ecosystems in which they live (Microsoft Encarta Reference Suite 2001).

Effects of Air Pollution on Plant Life

Air pollution has direct damaging effect on plants. Chronic injury to agricultural forests, and ornamental vegetation by increasing quantities and varieties of air pollutants and their alterations to ecosystems now affects all over the world (Encyclopedia Americana, 1989).

Other aspects of air pollution that affect trees and forests are oxidants (nitrogen dioxide, sulfur dioxide, heavy metals, chlorofluorocarbons through stratospheric ozone depletion and increased UV-B radiation, carbon dioxide through climate modification, and aerosols that reduce photosynthetically active radiation (http://www.metla.fi/archive/forest/1996/06/msg00003.html).

Acid deposition makes trees less cold tolerant. Likely the mechanisms include an alteration of the seasonal change cycles in the trees due to excess nitrogen, which stimulates growth, making them unprepared for cold.

Sulfur dioxide damage rarely occurs in cities and is less severe around remote industrial sources. Damage from such low-level long-term exposure is usually associated with decline in tree growth, accumulation of sulfate in leaves, changes in foliation, variations in nutrient cycling, changes in lichen populations, and alterations in coniferous ecosystems.

Sulfate serves primarily to lower the soil pH, while nitrate not only lowers the soil pH lower than sulfate can, but also acts as a nutrient, stimulating tree growth, and leading to faster consumption and possible depletion of base cations. Nitrate is able to lower soil pH to the point where aluminum is brought into the Al^{3+} state in the soil solution, where it then displaces base cations from the soil solution, and inhibits the uptake of the base cations by the roots. Lower soil pH inhibits root growth, making trees more susceptible to drought. In addition, the excess nitrogen in the sap and leaves attracts insects.

Ozone is the most serious air pollutant threat to leafy vegetables, field and forage crops, shrubs, and fruit and forest trees. Ozone enters tree leaves through the stomata, attacking the cells inside the leaves. In response, photosynthesis rates are reduced (chlorophyll is destroyed), more sugars are retained in the leaves, and less starch is transported to the roots. As a result, insects are attracted to the leaves, and the trees do not have enough starch reserves in the roots to survive repeated defoliations.

Response of Plants to Air Pollution

Different plant species vary largely in terms of their reaction to air contaminants. The responses of plants to pollutants may provide a simple method of monitoring gaseous impurities, as was as providing pollution abatement in their presence. To develop the use of plants as bioindicators necessitates an appropriate selection of plant characteristics to be monitored. Thus, levels of ascorbic acid, chlorophyll a and b, relative water content, and leaf extract pH, are essential to establish an air pollution tolerance index (APTI) for a particular plant species (http://data.cseindia.org/news/FMPro).

According to a study done on eight indoor common foliage plants in establishing their APTI (http://www.entnet.org/education/greenoffice.html), it appeared that ascorbic acid is a strong reductant and in high amounts favors pollution tolerance in plants. Thus plants that maintain high ascorbic acid levels, even under polluted conditions, are considered to be tolerant of air pollution.

Expected performance index is an expression of the total characterization of plant species with reference to its behavior under polluted environment. Scientists in India conducted a study on the APTI of twenty-five plants species in Bhopal (http://sdnp.delhi.nic.in/resources/paryaabs/v12n14/plant.html). It was determined that air pollution tolerance level of each plant was different, and that plants did not display a uniform behavior (Tiwari and Bansal in http://sdnp.delhi.nic.in/resources/paryaabs/v12n14/plant.html). Plants having higher APTI value are more tolerant to air pollution than those having lower APTI values. Species having low APTI values may act as bioindicators of pollution.

Plants could be strong environmental indicators because unlike animals, which move from one location to another, they stay on site exposed to a full array of environmental stresses available at a site (http://www.enn.com/news/ennstories/1999/10/102899/cattail_6793.asp). In general, bioindicators should show a distinct, easily measured response to a pollutant and the response should be measured with an acceptable accuracy and precision (http://www.umweltbundesamt.de/whocc/AHR10/V-FC-2.htm#a1). Plants can also be useful in recording the history of mutation stress at a given site.

Tolerance level also depends on the kind of plant species. Certain higher plants are more commonly reported as suffering damage from atmospheric pollution. Researchers in India (Tiwari, et al in http://sdnp.delhi.nic.in/resources/paryaabs/v12n14/plant.html) found out that a deciduous species was more susceptible to pollution stress than the evergreen species when they exposed an evergreen, *Mimusops elengi*, and a deciduous plant, *Ficuz religlosa*, to varying concentrations of sulfur dioxide (SO_2).

Soares (1995, in http://www.ucl.ac.uk/mapel/adiepubs.html), along with his colleagues discovered from his research that climax species are less able to buffer against acidifying inputs and are subsequently more prone to acidifying air pollution damage. Nitrate assimilation produces hydroxyl ions, which in conjunction with high base cation content and more neutral leaf pH, provides better metabolic buffering and therefore make pioneer and ruderal species less susceptible to acidifying inputs.

In another study, Soares (1996, http://www.ucl.ac.uk/mapel/adiepubs.html) observed that the ability of plants to store nitrogen (N), coupled with NHx assimilation leading to the production of acidity, suggests that pH is an important factor that plants have to control, in the presence of excess NHx. Multivariate assessment of physiological characteristics of higher plants and mosses provided a means of assessing plant susceptibility to atmospheric NHx and acidity. Plants that are capable of foliar nitrate (NO_3^-) assimilation have higher buffering capacities against acidity. Plants, which assimilate most of their NO_3^- in the leaf, tend to have high base cation contents, which may also contribute towards overall buffering ability.

Talisay

Commonly known as tropical almond and wild almond, talisay (*Terminalia catappa*) is a large semi-deciduous tree from the

Malay Peninsula, which is widely planted in tropical areas as a street tree. It thrives as an ornamental tree in many tropical cities in the world (http://www.crfg.org/fg/xref/xref-t.html).

This is a small to medium-sized tree with whorled horizontal branches and large obovate, dark green leaves. The flowers are axillary and occur in slender spikes. The fruit is flattened or compressed and narrowly winged (http://www.naturia.per.sg/buloh/plants/sea_almond.htm). The 2 inches long, greenish or reddish, fruit has a thin oily seed that is edible raw or roasted.

The leaves form a rosette and are found only at the end of a branch. During the dry season, the leaves turn into autumn colors of red, copper, gold. The tree usually sheds all its leaves twice a year in January-February and July-August. The tree first drops its leaves when it reaches 3-4 years (http://www.nparks.gov.sg/f&f/terminalia.html).

The bark, roots and leaves contain tannin and the fruit also yields a dye. The leaves contain agents for chemoprevention of cancer and probably have anti-carcinogenic potential. In Taiwan the fallen leaves of tropical almond are used as an herbal drug in the treatment of liver related diseases (http://www.tropilab.com/terminalia-cat.html).

Papaya

Papaya (*Carica papaya*), or pawpaw, is one of the most common fruits in tropical countries. It is an erect, usually branchless, fast-growing tree. The trunk is soft, grayish, marked with scars. The leaves are rounded, deeply lobed, with long-stalks borne on the top of the tree. The male flowers are in clusters, and the female are sessile. The fruit is ovoid, yellow-orange when ripe, fleshy, juicy, and contains numerous black seeds (A.C. Sas, 1990).

In the wild, the tree grows to about 1.8 m (about 6 ft) high, but cultivated trees may be about 7.6 m (about 25 ft) high. Papaya is also exploited for its latex, which contains papain, a proteolytic (protein-digesting) enzyme used in meat tenderizers. A few other species of the representative genus are eaten locally in the tropics (Microsoft Encarta Suite 2001).

Papayas need warmth and a frost-free environment, but can often withstand light freezes with some kind of overhead protection. Prolonged cold, even if it does not freeze, may adversely affect the plants and the fruit.

Papaya plants can also be grown from cuttings, which should be hardened off for a few days and then propped up with the tip touching moist, fertile soil until roots form. Semihardwood cuttings planted during the summer root rapidly and should fruit the following year (http://www.crfg.org/pubs/ff/papaya.html).

Mahogany

In the natural rainforest, Mahogany (*Swietenia macrophylla*) is a very large canopy tree, sometimes reaching over 150 feet in height, with trunks sometimes more than 6 feet in diameter above a large basal buttress. It is a generally open-crowned tree, with gray to brownish-red fissured bark.

Mahogany varies from yellowish, reddish, pinkish, or salmon colored when freshly cut, to a deep rich red, to reddish brown as the wood matures with age. Mahogany is fine to medium texture, with uniform to interlocking grain, ranging from straight to wavy or curly. Irregularities in the grain often produce highly attractive figures such as fiddleback or mottle. Mahogany polishes to a high luster, with excellent working and finishing characteristics. It responds well to hand and machine tools, has good nailing and screwing properties, and turns and carves superbly (http://tropicalhardwoods.com/htm/tropical_hardwoods/mahogany.htm).

Chapter 3

Research Design and Methodology

This study determined the air pollution tolerance index (APTI) of three plant species, namely, talisay (*Terminalia catappa*), papaya (*Carica papaya*), Indian tree (*Polyathia longifolia*), and mahogany (*Swietenia macrophylla*), which are common in some areas in the city, namely, Jaro Plaza, Bonifacio Drive-Gen. Luna Street, and Philippine Science High School Western Visayas Campus.

It was hypothesized that that there will be no significant difference in the APTI of talisay, papaya, Indian tree, and mahogany when compared with other values among the given areas.

The Research Design

The One-Spot Case Study was used as the experimental design of the study. In this design, there were three test areas, which have four plant species in common. Triplicates of the leaf samples of these plant species were selected at random. The extract of these plants was tested for their APTI values. The APTI values among the test areas were compared, using the One-Way Analysis of Variance (ANOVA).

Materials

This study required the use of a spectrophotometer, pH meter, Wattman filter paper, top loading balance, osterizer, mortar and pestle, and centrifuge machine.

As for reagents and chemicals, the study used 80% acetone, distilled water, dichlorophenol indophenol, glacial acetic acid, and chloroform.

The crude extract was the test material.

Procedure

Determination of Test Areas

Two areas, which are considered to be highly exposed to air pollution, within the city have been chosen to be the test sites. These are Jaro Plaza and Bonifacio Drive-Gen. Luna Street. Moreover, one area, the Philippine Science High School Western Visayas Campus, which is deemed to be less exposed to air pollution, was also chosen as the control test site.

Gathering of Samples

Twenty grams of leaves of each plant sample were taken from each test area for the determination of three parameters: (1) pH; 2) total chlorophyll content; and (3) ascorbic acid content. As for the determination of the relative water content, ten leaves of each sample of mahogany, Indian tree, and talisay were needed. As for papaya, only two leaves of each sample were required. The samples were washed and placed in wide glass containers.

Biological Testing

Each sample was recorded against 80% acetone by a spectrophotometer to estimate the total chlorophyll. The fresh, turgid, and dry weights of the sample were used to determine the relative water content. Test, standard, and black solutions of the leaf extract from the sample were titrated against a standard dye solution to measure the ascorbic acid content. The leaf extract was used with a pH meter to get the pH level of the plant species.

Finally, the data obtained from the tests above were used to solve for the APTI by the formula, APTI = [A(T+P)+ R]/10.

All the tests were done following the same set of procedures.

Measuring the Total Chlorophyll Content

Half gram of fresh leaves was cut into pieces and pounded using a mortar and pestle. Enough 80% acetone was added to allow the tissues to be thoroughly homogenized. The tissues were continuously homogenized. The supernatant was decanted through a Wattman filter paper into a 25-ml volumetric flask, and made up to volume with 80% acetone. Five mL of this solution were transferred into a 50-mL volumetric flask and made up to volume with 80% acetone.

The absorbance of the leaf tissue extract was measured against 80% acetone at 645 nm and 663 nm in the spectrophotometer.

Total chlorophyll (T) in mg/L was calculated using the formula, $T = [1000 \times W]/[(20.2 \times OD_{645} + 8.02 \times OD_{663}) V]$, where W is the fresh weight of the weight sample, OD is the optical density, and V is the volume of acetone chlorophyll extract.

Measuring the Relative Water Content

The fresh weight of the leaves was determined using a top loading balance. They were dipped in distilled water for 24 hours. The turgid weight of the leaves was determined, and then oven-dried for another 24 hours at 80°C. The dry weight of the leaves was measured.

Relative water content (R) in percentage was then determined using the formula, $R = [(F - D)/(T - D)] \times 100$, where F is the fresh weight of the leaves, D is the dry weight of the leaves, and T is the turgid weight of the leaves.

Measuring the Ascorbic Acid Content

Two-and-a-half grams of leaf sample were osterized with 25 mL of distilled water, and subjected to centrifugation. The standard solution from dichlorophenol indophenol was also prepared in a conical flask by mixing 2 mL of leaf extract, 2 mL of glacial acid, 2.5 mL of chloroform, and 8 mL of distilled water. The standard solution with known amount of ascorbic acid and the blank solution were also prepared. The test, standard, and blank solutions all underwent titration against the standard dye solution. The titer value of the test, standard, and blank solutions was recorded.

Ascorbic acid content in mg/100 mL was then determined using the formula, A = [(T - B) x 4 x dilution]/[S - B], where T is the titer value of the test solution, S is the standard solution, and B is the blank solution.

Measurement of pH level

Fifteen grams of fresh leaves was osterized with 75 mL of distilled water. The pH level of leaf extract was measured with a pH meter.

Determining the APTI

All the data gathered from the preceding procedures were utilized for the calculation of APTI by following the formula, APTI = [A(T+P) + R]/10, where A is the ascorbic acid content, T is the total chlorophyll, P refers to the pH, and R denotes the relative water content of the plant samples.

Statistical Data Analysis

After each test, the APTI of the plant sample was calculated and duly tabulated.

The average APTI of each plant species in each test area was recorded on a separate table. The mean and standard deviation were used as the descriptive statistical tools in this case.

In determining the significant difference in the APTI values of the three plant species among the test areas, the One Way Analysis of Variance (ANOVA), set at 0.05 alpha level of significance, and the Scheffe Test, as post hoc multiple comparison test, were utilized.

Chapter 4

Results

This study determined the air pollution tolerance index (APTI) of three plant species, namely, talisay (*Terminalia catappa*), papaya (*Carica papaya*), Indian tree (*Polyathia longifolia*), and mahogany (*Swietenia macrophylla*), which are common in some areas in the city, namely, Jaro Plaza, Bonifacio Drive-Gen. Luna Street, and Philippine Science High School Western Visayas Campus (PSHSWVC).

Furthermore, it compared the APTI of these plant species. It also determined if there was a significant difference in the APTI of these plants among the given areas. Finally, it established which among the plant species is considered the best bioindicator of air pollution based on their APTI.

It was hypothesized that that there will be no significant difference in the APTI of talisay, papaya, Indian tree, and mahogany when compared with other values among the given areas.

Determination of Air Pollution Tolerance Index of Different Plants in Different Study Sites

The mean values of the APTI of talisay found in the following sites were as follows: Jaro Plaza, 6.193133; Bonifacio Drive-Gen. Luna St., 5.680400; and PSHSWVC, 7.539267. Data are represented in Table 1.

The mean values of the APTI of papaya found in the following sites were as follows: Jaro Plaza, 6.734200; Bonifacio Drive-Gen. Luna St., 6.939900; and PSHSWVC, 7.012800. Data are represented in Table 1.

The mean values of the APTI of Indian tree found in the following sites were as follows: Jaro Plaza, 5.497400; Bonifacio Drive-Gen. Luna St., 5.150600; and PSHSWVC, 6.900567. Data are represented in Table 1.

The mean values of the APTI of mahogany found in the following sites were as follows: Jaro Plaza, 5.990467; Bonifacio Drive-Gen. Luna St., 4.880167; and PSHSWVC, 6.257633. Data are represented in Table 1.

Papaya had the highest APTI value in the Jaro Plaza area, which means that they were the most air pollution tolerant plant while Indian Tree had the lowest APTI value, which means they were the most sensitive plant to air pollution.

Table 1

Means of APTI values of different plants in different study sites

Plants	Sites	N	APTI	S.D.
Talisay	Jaro Plaza	3	6.193133	1.413736
	Gen. Luna St.	3	5.680400	0.8851548
	PSHSWVC	3	7.539267	0.8467928
Papaya	Jaro Plaza	3	6.734200	0.9521795
	Gen. Luna St.	3	6.939900	1.094360
	PSHSWVC	3	7.012800	0.8382735
Indian Tree	Jaro Plaza	3	5.497400	0.2625612
	Gen. Luna St.	3	5.150600	0.1141603
	PSHSWVC	3	6.900567	5.66E-2
Mahogany	Jaro Plaza	3	5.990467	0.3555327
	Gen. Luna St.	3	4.880167	0.5720262
	PSHSWVC	3	6.257633	0.7124040

In PSHSWVC, Talisay had the highest APTI value, which means that they were the most air pollution tolerant plant, while Mahogany was the most sensitive to air pollution having the lowest APTI value.

Papaya was the most air pollution tolerant plant having the highest APTI value in the Bonifacio Drive-Gen. Luna St. area, while mahogany was the most sensitive to air pollution having the lowest APTI value.

The most polluted test area was Bonifacio Drive-Gen. Luna St. since the plant species recorded had the lowest APTI values among the three sites. PSHSWVC, the control study site, was the least polluted area since the plant species recorded had the highest APTI values among the three sites.

<u>Differences in the APTI values of Different Plants in Different Sites</u>

The One-Way Analysis of Variance (ANOVA), set at 0.05 alpha level of significance showed that there was no significant difference in the mean APTI values of talisay, papaya, and mahogany in the three different sites as reflected by $\underline{F}(2)=0.174$, $\underline{p}>0.05$, $\underline{F}(2)=0.936$, $\underline{p}>0.05$, and $\underline{F}(2)=0.053$, $\underline{p}>0.05$, respectively. Data are represented in Table 2.

Table 2

One-way Analysis of Variance of significant difference in the APTI values of plants in different plants

Variable (APTI)		Sum of squares	df	Mean square	F	Sig.
Talisay	Between groups	5.530	2	2.765	2.371	0.174
	Within groups	6.998	6	1.166		
	Total	12.529	8			
Papaya	Between groups	0.125	2	6.262E-02	0.067	0.936
	Within groups	5.614	6	0.936		
	Total	5.739	8			
Indian Tree	Between groups	5.152	2	2.576	90.725	0.000
	Within groups	0.170	6	2.839E-02		
	Total	5.322	8			
Mahogany	Between groups	3.202	2	1.601	4.997	0.053
	Within groups	1.922	6	0.320		
	Total	5.124	8			

The One-Way ANOVA, however, showed that there was a significant difference in the mean APTI values of Indian tree in the three different sites as reflected by $\underline{F}(2)=0.000$, $\underline{p}<0.05$.

The Scheffe test showed that significant differences existed between the APTI values of Indian trees found in PSHSWVC and Jaro Plaza, as well as between Indian trees found in PSHSWVC and along Bonifacio Drive-Gen. Luna St.

Data are represented in Table 3.

This means that Indian tree had significantly differentiated the pollution status of Jaro Plaza and Bonifacio Drive-Gen. Luna St. from that of PSHSWVC.

Determination of the Best Bioindicator among Different Plants

Mahogany was the best bioindicator since it had the lowest mean APTI value among the group, followed by Indian tree and talisay. Papaya was the least potent bioindicator as it had the highest mean APTI value.

This establishes that mahogany was most sensitive to air pollution among group, although Indian tree had potentially differentiated the pollution status of the test sites. Papaya was least sensitive or the plant, which can best tolerate an immense degree of air pollution.

Data are represented in Table 4.

Table 3

Scheffe Test for One-Way ANOVA of the APTI values of Indian Tree in Table 2

(I) Test Areas	(J) Test Areas	Mean Difference (I-J)	Std. Error	Sig.
Jaro Plaza	PSHSWVC	-1.403167*	0.138	0.000
	Gen Luna St.	0.3468000	0.138	0.115
PSHSWVC	Jaro Plaza	1.4031667*	0.138	0.000
	Gen Luna St.	1.7499667*	0.138	0.000
Gen Luna St.	Jaro Plaza	-0.3468000	0.138	0.115
	PSHSWVC	-1.749967*	0.138	0.000

* The mean difference is significant at the 0.05 level

Table 4

Grand Average of APTI values

Plants	Mean	Standard Deviation
Talisay	6.470933	1.251438
Papaya	6.895633	0.8469939
Indian tree	5.849522	0.8156190
Mahogany	5.709422	0.8002993

Chapter 5

Summary, Conclusions, and Recommendations

This study determined the air pollution tolerance index (APTI) of some growing plants species in Iloilo City. Specifically, this study answered the following questions:

1. What is the APTI of the four plant species, namely, (a) talisay (*Terminalia catappa*), (b) papaya (*Carica papaya*), (c) Indian tree (*Polyathia longifolia*), and (d) mahogany (*Swietenia macrophylla*), which are common in some areas in the city, namely, (1) Jaro Plaza, (2) Bonifacio Drive-Gen. Luna Street, and (3) Philippine Science High School Western Visayas Campus (PSHSWVC)?

2. Compare the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany that are found among the given areas.

3. Is there a significant difference in the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany when compared with other values among the given areas?

4. Which among the plant species, i.e., (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany is considered the best bioindicator of air pollution based on their APTI?

Based on these questions, it is hypothesized that there is no significant difference in the APTI of (a) talisay, (b) papaya, (c) Indian tree, and (d) mahogany when compared with other values among the given areas.

Findings

This study was able to establish the following findings:

1. The APTI values of the different plant species in the different test areas were determined using four parameters, namely, (a) total chlorophyll content, (b) relative water content, (c) ascorbic acid content, and (d) pH.

The mean values of the APTI of talisay found in the following sites were as follows: Jaro Plaza, 6.193133; Bonifacio Drive-Gen. Luna St., 5.680400; and PSHSWVC, 7.539267.

The mean values of the APTI of papaya found in the following sites were as follows: Jaro Plaza, 6.734200; Bonifacio Drive-Gen. Luna St., 6.939900; and PSHSWVC, 7.012800.

The mean values of the APTI of Indian tree found in the following sites were as follows: Jaro Plaza, 5.497400; Bonifacio Drive-Gen. Luna St., 5.150600; and PSHSWVC, 6.900567.

The mean values of the APTI of mahogany found in the following sites were as follows: Jaro Plaza, 5.990467; Bonifacio Drive-Gen. Luna St., 4.880167; and PSHSWVC, 6.257633.

2. There was no significant difference in the APTI values of talisay, papaya, and mahogany. However, there was a significant difference in the APTI values of Indian tree.

This means that Indian tree had significantly differentiated the pollution status of Jaro Plaza and Bonifacio Drive-Gen. Luna St. from that of PSHSWVC.

3. Mahogany was the best bioindicator among the group since it had the lowest mean APTI value, while papaya was the plant most tolerant to air pollution.

Conclusions

The researchers have established that the best bioindicator among the four plant species was mahogany having the lowest mean APTI value, followed by Indian tree and talisay. The plant that was least sensitive to air pollution is papaya. Hence it can be considered as the most air pollution tolerant plant.

Indian tree had different tolerance to air pollution in the three test areas. Indian tree was least tolerable in Bonifacio Drive-Gen. Luna St. and most tolerable in PSHSWVC.

The most polluted area among the three sites is Bonifacio Drive-Gen. Luna St. having the lowest APTI values, while the least polluted area is PSHSWVC having the highest APTI values.

Recommendations

The researchers recommend the use of mahogany plants in biomonitoring works such as observing the amount of air pollution in an area since they are bioindicator plants because they are most sensitive to air pollution having the lowest APTI values.

It is greatly recommended that more papaya plants - the most tolerant plant to air pollution having the highest APTI values - should be planted in areas suspected to be polluted.

It is highly recommended for further studies to be conducted on suspected polluted areas using various plant species abundant in these areas.

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