# ASSESSMENT OF AIR POLLUTION TOLERANCE INDEX OF ROADSIDE PLANTS IN VICINITY OF AIZAWL, MIZORAM, INDIA

**A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PHILOSOPHY**


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# ASSESSMENT OF AIR POLLUTION TOLERANCE INDEX OF ROADSIDE PLANTS IN VICINITY OF AIZAWL, MIZORAM, INDIA

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## ABSTRACT

Air pollution has become a threat to human health, and its level is predicted to increase massively due to industries and vehicles increase in all the places around the world. The air quality in urban areas and other industrial areas are adversely affected by pollutants emission from both stationary and mobile sources. Vegetation in urban areas helps in maintaining the nature for people living in urban areas and cities, and thereby helps in maintaining public health and living conditions along with providing unique biodiversity (Ulrich, 1984). Areas having adequate vegetation such in form of plantation along road side and parks can significantly reduce the ambient pollutions and also be responsible for atmospheric cooling. When plants are in exposed to air pollutants, these plants experiences changes in physiology before showing visible damage in the leaves. However, some plants have the tendency to survive in polluted environment and can thus help in cleaning the various sources of man-made pollution (Joshi et al., 2016).

Air pollution tolerance index (APTI) indicates the capability of plant species which are able to encounter air pollution. Plants purify the air by intercepting particulate matter and smokes therefore act as a scavenger for pollutants. The plants that are sensitive to pollutants act as a bio-indicator of pollution to a particular pollutant. . Leaves can play a role of filters that can fight against different types of air pollutants, and help in recovering the quality of air in polluted areas. The ability of leaves to intercept the dust particles depends upon their Water holding capacity, chlorophyll content, leaf ascorbic acid content, and height and canopy of trees etc. according to (Fowler et al., 1989). The tolerance of different plants species also depends upon their morphological and physiological features. However, the features of plants changes according to their location and the environmental factors,

Air pollution tolerance index (APTI) is used for monitoring of air quality and to develop appropriate management measures through plantation of selected native plant species to harvest various kinds of pollutants. The ability of leaves to intercept the dust particles depends upon their Water holding capacity, chlorophyll content, leaf ascorbic acid content, and height and canopy of trees etc. according to (Fowler et al., 1989).

In the present study, 3 study sites were selected and in each site belt transect along the road side were stretch in and/or around Aizawl city was selected in replicates for detailed investigation. 3 sites i.e. roadside stretch of Sikulpuikawn to Bawngkawn, New capital complex, Khatla and Lalsavunga Park, Hlimen was taken for APTI study for three seasons Pre-monsoon, Monsoon and Post-monsoon. Pre-monsoon season is between the months of February to May, Monsoon season is between June to September and Post-monsoon season is between the months of October to January. The common/dominant important tree species common to all study sites was selected to determine Air Pollution Tolerance Index (APTI). The fresh leaf samples were analyzed for chlorophyll, ascorbic acid, pH, and relative water content.

From all the three sites, plant species that are most common to all the sites are taken for the evaluation of Air pollution tolerance index. Biochemical parameters like relative water content, pH of the leaf extract, Chlorophyll and Ascorbic Acid of the leaf are evaluated for the common plant species i.e*Ficusbenjamina, Mangiferaindica, Artocarpusheterophyllus, Ficusreligiosa.*

The relative water content for all the sites showed *Mangiferaindica* varies from 84.63(pre-monsoon) to 90.23(monsoon), *Ficusbenjamina* varies from 65.85(pre-monsoon) to 71.67(monsoon) *Artocarpusheterophyllus* varies from 60.45 (pre-monsoon)to 65.54(monsoon) and *Ficusreligiosa*varies from 51.56(pre-monsoon) to 60.48(monsoon) in all the seasons. The pH of leaf extract for all the sites showed *Mangiferaindica* varies from 7.5(pre-monsoon) to 7.7(monsoon),, *Ficusreligiosa* varies from 6.8(pre-monsoon) to 6.9(monsoon),, *Artocarpusheterophyllus* varies from 6.2(pre-monsoon) to 6.3(monsoon), and *Ficusbenjamina*varies from 5.7(pre-monsoon) to 6.1(monsoon). Total chlorophyll for all the sites showed *Mangiferaindica* varies from 1.59(pre-monsoon) to 2.56(monsoon), *Ficusreligiosa* varies from 0.38(pre-monsoon) to 0.51(monsoon), *Artocarpusheterophyllus* varies from 0.85(pre-monsoon) to 2.24(monsoon) and *Ficusbenjamina*varies from 0.44(pre-monsoon) to 0.68(monsoon). The Ascorbic acid content for all the sites showed *Mangiferaindica* varies from 0.05(pre-monsoon) to 0.12(monsoon), *Ficusreligiosa* varies 0.18(pre-monsoon) to 0.24(monsoon), *Artocarpusheterophyllus* varies from 0.02(pre-monsoon) to 0.03(monsoon) and *Ficusbenjamina*varies from 0.18(pre-monsoon) to 0.28(monsoon).

The Air pollution tolerance index content for all the sites showed that the values for *Mangiferaindica* varies from 8.89(pre-monsoon) to 11.07(monsoon), *Ficusbenjamina*varies from 7.69(pre-monsoon) to 9.57(monsoon), *Ficusreligiosa* varies 6.44(pre-monsoon) to 8.02(monsoon), and *Artocarpusheterophyllus* varies from 6.28(pre-monsoon) to 7.63(monsoon). Different seasons showed different values in APTI where monsoon seasons showed higher APTI values with comparison of pre-monsoon and post-monsoon. Pre-monsoon season showed the least values as compared to monsoon and post-monsoon. This could be due to weather conditions and other anthropogenic activities.

Most of the tree species that are commonly found in the area are not planted with proper planning and management, therefore the observed result could differ according to the age of the species. *Mangiferaindica* are the most common species found in all sites and seasons which have the highest APTI value so it is the most tolerant species found in all the sites. *Artocarpusheterophyllus*have the least APTI value for all the sites and different seasons and could be categorized as sensitive against air pollution. Due to the pollution level and anthropogenic activities difference in all the sites, the values of the same species also differs accordingly.

According to the documented tree species at different sites, the common tree species from all the sites are*Mangiferaindica, Ficusreligiosa, Ficusbenjamina,* and *Artocarpusheterophullus*. These species are the most common species that are present in all the sites with the highest frequency of occurrence. These selected species are further evaluated for four biochemical parameters and APTI was calculated. The selected species showed different parameter values and APTI for all different seasons and sites. *Mangiferaindica*was found having highest APTI value for all the season and sites whereas *Artocarpusheterophyllus* have the lowest APTI value and was categorized as sensitive species against air pollution. *Ficusbenjamina* was also observed to be high in APTI which could be tolerant and could fight against air pollution. The values of Air pollution tolerance index of these tree species varies according to the seasons of pre-monsoon, monsoon and post-monsoon. The conditions such as pollution levels and population activities of the site also plays an important role in the value of APTI for air pollution.

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## CERTIFICATE FROM SUPERVISOR

This is to certify that the Dissertation entitled, "Assessment of air pollution tolerance index of roadside plants in vicinity of Aizawl**,** Mizoram, India", is a bonafied work assigned to John Lianngura, (Regn. No. MZU/M.Phil./585 of 29.05.2020), Department ofEnvironmental Science, for partial fulfillment of the requirement for the degree of Masterof Philosophy under Mizoram University.

The report submitted by the candidate is her own study and carried out byher and result embodied in the Dissertation have not been submitted for award of degreeany other elsewhere. It is recommended that this dissertation be placed before theexaminers for the award of the degree of Master of Philosophy.

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**December, 2021**

# DECLARATION

I, John Lianngura, hereby declare that the subject matter of this thesis is the recordof work done by me, that the contents of this dissertation did not form basis of theaward of any previous degree to me or to do the best of my knowledge to anybody else, and that the dissertation has not been submitted by me for any research degree inany other University/Instituted.

This is being submitted to the Mizoram University for the degree of Master of Philosophy in Department of Environmental Science.

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# CHAPTER - I

# INTRODUCTION

# INTRODUCTION

Air pollution has become a threat to human health, and its level is predicted to increase massively due to industries and vehicles increase in all the places around the world. The air quality in urban areas and other industrial areas are adversely affected by pollutants emission from both stationary and mobile sources. The major pollutants which contribute to low and poor quality in urban areas are carbon monoxide (CO), nitrogen oxides (NOx), sulphur oxides (Sox), particulate matter (PM), etc (Enete et al., 2013). Pollutant such as nitrous oxide ($NO_2$) is responsible for the immune system and can cause impairment in the immune system and asthma, it can also reduce the lungs functionality and cardiovascular diseases. Particulate matters are very dangerous and can be a reason for the lung cancer and increased mortality (Schwela, 2000). Vegetation in urban areas helps in maintaining the nature for people living in urban areas and cities, and thereby helps in maintaining public health and living conditions along with providing unique biodiversity (Ulrich, 1984). Areas having adequate vegetation such in form of plantation along road side and parks can significantly reduce the ambient pollutions and also be responsible for atmospheric cooling. The plant species are exposed to various chemicals and emissions from the activities of surrounding region. When they are in exposed to air pollutants, these plants experiences changes in physiology before showing visible damage in the leaves. However, some plants have the tendency to survive in polluted environment and can thus help in cleaning the various sources of man-made pollution (Joshi et al., 2016).

Air pollution tolerance index (APTI) indicates the capability of plant species which are able to encounter air pollution. Plants purify the air by intercepting particulate matter and smokes therefore act as a scavenger for pollutants. The plants that are sensitive to pollutants act as a bio-indicator of pollution to a particular pollutant. . Leaves can play a role of filters that can fight against different types of air pollutants, and help in recovering the quality of air in polluted areas. Air pollution tolerance index (APTI) is used for monitoring of air quality and to develop appropriate management measures through plantation of selected native plant species to harvest various kinds of pollutants. Kumari and Deswal (2017) argued that validation of plants in response to a particular of pollutant and APTI based on biochemical parameter (Panda et al., 2018) is of paramount importance.

Millions of humans and animals breathe in the air with high concentrations of pollutants in urban areas. This had led to many health effects on the people such as clinical effects, impairment in pulmonary functionality, reduction in physical performance, medical consultations are frequent and admitted patients with complicated situations and may be even death. According to studies of WHO/UNEP (1992), high level air pollution causes respiratory disease and infections to at least 10% of the total of diseases and cancer takes about 4%. Categorization of plants to tolerant group and sensitive group is very important as they can be used as bio-indicator

The ability of leaves to intercept the dust particles depends upon their Water holding capacity, chlorophyll content, leaf ascorbic acid content, and height and canopy of trees etc. according to (Fowler et al., 1989). The tolerance of different plants species also depends upon their morphological and physiological features. However, the features of plants changes according to their location and the environmental factors,

During present time, there is an ample scope to study the plants-pollutant interaction and absorption of pollutants by plants. Primary pollutants such as $SO_2$, $NO_2$, CO, SPM etc. enters into plants body through the stomatal apertures during gaseous exchanges. Free radicals activate oxidation to disturb many physiological activity, plant hormones, chlorophyll and carotenoids and amino acids which leads to shrink the plant growth. In the leaves, $NO_2$ forms the nitrous acid which converted to ammonia and consequently leading in the formation of amino acids and further proteins. In combination of $SO_2$ and $NO_2$ tend to because more lose in yields than $SO_2$ alone. (Das Monalisa et al., 2018).

### 1.1 Air pollution and its health effects:

Millions of humans and animals breathe in the air with high concentrations of pollutants in urban areas. These air are highly polluted with pollutants especially particulate matters in most cities. This had led to many health effects on the people of urban areas in the form of clinical effects, impairment in pulmonary functionality, reduction in physical performance, medical consultations are frequent and admitted patients with complicated situations and may be even death. According to studies, respiratory disease and infections contributes to at least 10% of the total of diseases and this may be the result of high level air pollution. And, cancer takes about 4% apart from all the diseases which indicates that the effects and consequences of air pollution are high on the urban population. Another study by WHO revealed that there is higher level of most of the respiratory diseases in urban areas as compared to occurrence in the rural areas (WHO/UNEP, 1992, cited in Repetto, 1994). Due to industrialization and urbanization, air pollution has become a serious problems and mitigation is getting hard. Particulate matter is a major pollutant due to its impact on plant and animal and even human beings. Therefore, categorization of plants to tolerant group and sensitive group is very important since from the introduction we know that sensitive plants can be used as bio-indicator and tolerant plants can be used as a useful tool for reduction of the pollutants to reduce pollution in the urban areas. Plants with respect to nature are interrelated and if there is any alteration in the atmosphere, it effects the physiology and biochemistry of the plants directly. Vegetation plays a major role as a sink for air pollution reducing pollution level in the atmosphere. Plants are affected internally before showing noticeable outcome to leaves when exposed to air pollutants.

### 1.2 Sources and effects of air pollutants:

| POLLUTANTS | EMISSION SOURCES | | MAJOR EFFECTS | |
|---|---|---|---|---|
| | Natural Sources | Anthropogenic sources | Health Effects | Environmental Effects |
| PM (Particulate matter) | Windblown dust, pollen spores, photo chemically produced particles | Vehicles, industries, buildings, combustion from residence. Etc. | Cancer, respiratory problems, lungs, heart, liver infections. | Visibility reduction |
| Sulfur dioxide ($SO_2$) | Volcanic emissions | Petrol, smelting of iron, fossil fuels. Etc. | Problems in heart, lungs, other respiratory problems | Can cause acid rain. |
| CO( Carbon monoxide) | Animal metabolism, forest fires, volcanic activity | Burning of carbonaceous fuels, emission from IC engines | Anoxemic infections. i.e. cardiovascular infections | |
| NOX ($NO_2$) Nitrogen dioxide | Lightning, forest fires. Etc. | Combustion of fossil fuels, burning in high temperature. Etc. | Respiratory infections. | Ozone formation |
| Pb (Lead) | | Exhaust from automobiles, effluents from industries. Etc. | Effects central nervous system | |
| $O_3$ (Ozone) | It is present in the atmosphere | When sunlight reacts with NOX and hydrocarbons, it forms ozone | Asthma and other respiratory infections. | It interferes photosynthesis by the process of greenhouse effect |

### 1.3 Tree selection for more effective air quality control:

Planting of a selected particular trees in the urban areas are very effective due to their higher effect of carbon dioxide through the process of photosynthesis. They also help by giving shade and screening of wind. Carbon emissions reduction can be achieved by more planting of trees in urban areas and can reduce up to 18kg per year per tree by the study of Rosenfeld et al (1998).

The present study models for estimating carbon sequestration by trees are generally based on AGB (above ground biomass) production such as plant or tree height and their stem diameter according to the study of Nowak and David (1994). All the trees have different ability to store carbon according to their structure. Therefore, selection of trees and planning are very important according to their ability. Trees with higher potential of carbon sequestration can effect more on the control of carbon emission. Since carbon emission have increased values each year, urban planting of selected higher carbon storing capable trees can help control in pollutants and pollutions.

### 1.4 National ambient air quality standards:

For managing effectively of air quality and ambient air quality for the reduction of air pollution and pollutants, making standards of certain pollutants are very important. Therefore, National ambient air quality standards (NAAQS) was developed. So, CPCB (central pollution control board) had made the first standards for ambient air quality on 1982, November 11th according to the Air Act 1981 under section 16(2). These standards were revised by the Central pollution control board in 1994 and later in 2009 again. The standards are shown in Table below: -

| Pollutants (in microgram/meter) | Average in Time | Concentration | |
|---|---|---|---|
| | | Industrial, residential areas | Areas that are sensitive |
| $SO_2$ (Sulphur dioxide) | Annual<br>24 hours | 50<br>80 | 20<br>80 |
| $NO_2$ (Nitrogen dioxide) | Annual<br>24 hours | 40<br>80 | 30<br>80 |

| | | | |
|---|---|---|---|
| PM 10 (particulate matter) | Annual<br>24 hours | 60<br>100 | 60<br>100 |
| PM 2.5 (particulate matter) | Annual<br>24 hours | 40<br>60 | 40<br>60 |
| $O_3$ (Ozone) | 8 hours<br>1 hour | 100<br>180 | 100<br>180 |
| Pb (Lead) | Annual<br>24 hours | 0.50<br>1.0 | 0.50<br>1.0 |
| CO (Carbon monoxide) | 8 hours<br>1 hour | 02<br>04 | 02<br>04 |
| $NH_3$ (ammonia) | Annual<br>24 hours | 100<br>400 | 100<br>400 |
| Benzene | Annual | 05 | 05 |
| BaP (benzene alpha particulate) | Annual | 01 | 01 |
| AS (arsenic) | Annual | 06 | 06 |
| Ni (Nickel) | Annual | 20 | 20 |

### 1.5 Effects of air pollution on bio-chemical parameters:

Bio-chemical parameters that are used to assess the changes in the tolerance level of plants species with respect to air pollution are shown below: -

#### 1.5.1 Effects on ascorbic acid content:

Ascorbic acid is a known anti-oxidant compound which increases the tolerance of the plants to oxidative stresses and it effects the physiological activities of the plants. It acts as a primary substrate for cyclic pathway of enzymatic detoxification. ROS (reactive oxygen species) produced like $H_2O_2$, $O_2$- , OH-, during the process of photo-oxidation of $SO_3$- to $SO_4$. Therefore, Free radical are produced under $SO_2$ exposure that increases the free radical production such as ascorbic acid. Ascorbic acid acts and plays a very important role in synthesis of cell wall, cell division, and defense and carbon fixation.

### 1.5.2 Effects on total chlorophyll content:

Pollutants in the environment not only decrease the chlorophyll content but may also cause in the increase the chlorophyll content, therefore, chlorophyll is used as the index of productivity of plant. High concentration of $SO_2$ can cause destruction of chlorophyll structure. Decrease in the concentration of chlorophyll may disrupt thylakoid membranes in the chloroplasts. Vehicular exhausts that primarily consist of SPM Sulphur dioxide ($SO_2$) and nitrogen oxides ($NO_2$) can cause visible injuries to the leaves and cause reduction in the photosynthetic pigments. In the cells, $SO_2$ dissolves to give bisulfite and sulfite ion at low concentrations. Higher chlorophyll content of plants varies from one individual to other. Plant species that have low chlorophyll content have high pollution load. Lower concentration of $NO_2$ induces the chlorophyll production but at higher concentrations, therefore, photosynthetic pigments decreased and reduction was observed.

### 1.5.3 Effects on relative water content (RWC) content:

Relative water content value of all plant species that are not exposed to pollutions are usually found to be high in value as compared to polluted plant species. The relative water content (RWC) indicates change in hydration condition of leaves and will generate higher acidity condition when their relative water content is low. Plants species that have higher relative water content are better for drought resistance in plants. Low relative water content of leaf shows lower availability of water in soil but excessive water causes weakening in the leaves. Relative water substance has a connection with protoplasmic porousness in cells which causes loss of water. Increase in relative water content in a particular species improves its tolerance against drought which are better to survive in low water areas.

### 1.5.4 Effects on leaf extract pH:

$SO_2$, $NO_2$ forms acid radicals in the leaf by reacting with water in cellular level which further effects the chlorophyll molecules according to Turk and Wirth (1975). Higher pH improves tolerance against air pollution. Increase in pH could be due to the formation of hydroxide of aluminum in the leaf tissue probably increasing pH of the leaf extract. Higher level in pH increases their capability and effectiveness in conversion of sugar (hexose) to ascorbic acid. In acidic condition of pollutants, the leaf pH is reduced and these reductions are more in plants that are sensitive with the comparison to that of tolerant plant species.

## 1.6 Effects of vegetation on air quality:

Plants and other vegetation helps in removal of dust particles from the atmosphere in urban areas according to the study of Beckett et al., (1998, 2000). The properties of the dust particles and vegetation are both important in performing their interactions. Leaves are likely to act as an absorber in the environment especially in polluted areas and environment (Maiti et al., 1993). Small vegetation removes small particles from the air stream and are much effective than are large vegetation regarding their elements. They decrease in dust concentration of the air. The ability of leaves to intercept the dust particles depends upon their Water holding capacity, chlorophyll content, leaf ascorbic acid content, and height and canopy of trees etc. according to Fowler et al., (1989), Nowak and David (1994), Beckett et al., (2000). The tolerance of different plants species depends upon their morphological and physiological features. Different biotic and abiotic factors controls plants life. The features of different plants changes according to their location and the environmental factors, therefore, different plant species exhibit different tolerability in different places. Different Studies showed that in polluted areas the tree leaves turned in to smaller size and the stomata also changes. (Panda et al, 2018)

## 1.7 Plants-pollutant interactions and role in absorption of pollutants:

Primary pollutants such as $SO_2$, $NO_2$, CO, SPM etc. enters into plants body through the stomatal apertures during gaseous exchanges. Free radicals activate oxidation to disturb many physiological activity, plant hormones, chlorophyll and carotenoids and amino acids which leads to shrink the plant growth. In the leaves, $NO_2$ forms the nitrous acid which converted to ammonia and consequently leading in the formation of amino acids and further proteins. In combination of $SO_2$ and $NO_2$ tend to because more lose in yields than $SO_2$ alone. Whereas, SPM causes encrustation on leaves due to particulate penetration into the epicuticle wax which May reduction in the intensity of incident light and disturbing of the balance of thermal condition in leaves. On the other hand, Gaseous and particulate fluorides are deposited on plant surfaces and through the leaf stomata moves along transpiration stream accumulate at toxic levels in leaf tips and margin. (Das monalisa et al., 2018)

## 1.8 Effects of particulate matter on vegetation:

When plants are exposed to PM, may have different phototoxic responses. The particulate deposited and the effects on vegetation includes Nitrates and sulfates with their forms of acidic and acidifying deposition, heavy metals, and even trace elements. Particulate matter sizes are related to how they get deposited, and may be useful to change the chemical composition according to Whitby (1978). Dusts are less soluble and reactive than other forms of nitrate and sulphate particles in general as mentioned by Fowler et al (1989) and Grantz et al., (2003). But when dusts with higher pH values which are greater or equal to 9 may cause direct injury to leaf tissues on which they are deposited according to Vardak et al., (1995) or indirectly by alteration of soil pH. Suspended particulate matter are very crucial and dangerous air pollutants which are common in most of the urban areas in the world. The standards of SPM are also exceeded many times and it is very difficult to maintain as well. The levels of suspended particulate matters have been constantly high in various cities around the world and focusing on India over the past years. The annual average suspended particulate matter concentration in areas of residential of various cities have also been increasing each year.

## 1.9 Effects of other air pollutants:

Other parameters like desired particulate matter and polycyclic aromatic hydrocarbons at some stations in the city of Delhi and Noida are much higher than the prescribed limits of 120 microgram/ m3 in industrial areas and 60 microgram/m3 in residential areas according to the CPCB. The concentration of polycyclic aromatic hydrocarbons (PAHs) have also trending upwards in values year after year. However, lead concentration have been noticeably going downwards due to the introduction of Pb (Lead) free petrol or diesel in the country from the year 2000. In recent time, air pollution in the urban areas is a critical problem in India like other fast developing countries. The quality of the urban environment marked effected by tolerant tree species Plantation which causes the cleanliness and beauty of life in cities. Due to gradual spread of economics in India, hasty industries and commercial increase in urban areas have led a concern over its possible impacts on the surrounding environment according to Central pollution control board (2000). They analyses air quality at various cities in India for the period years and the most common form of air pollution was known to be SPM which shows good result with traffic-related pollutants even though there were many monitoring stations which shows sulphur dioxide and nitrogen dioxide levels exceed the standard limits. (Das monalisa et al., 2018).

## OBJECTIVES:

The major objectives of the present work envisage the followings:

1. Documentation of woody plant species on Road-side Vegetation of selected study sites.
2. Selection of plant species common/dominant at all selected sites to study air pollution tolerance index (APTI).
3. Analysis of Relative Leaf Water Content (RWC), Total Chlorophyll Content (TCh), Ascorbic Acid (AA), and Leaf extract pH of the selected plant species.
4. To determine air pollution tolerance index (APTI) for selected plant species.

# CHAPTER - II

# LITERATURE REVIEW

## REVIEW OF LITERATURE

Dhankhar et al., (2015) studied the air pollution tolerance index of 15 selected plants species growing at residential, campus and industrial sites of Rohtak City, Haryana. They studies the plant species which are common to all the sites with the most abundant species around the sites. Different parameters were studied for all the plants which results in different observations amongst the three sites. Plants species at the residential sites showed the least APTI values whereas plant species at the industrial sites showed the highest APTI values due to the pollution exposure level difference. *F.virens* and *E.obliqua* showed that they are the most suitable tree species for the green belt areas and are recommended for air pollution management in terms of longevity.

Kumari and Deswal (2017) studied air pollution tolerance index of selected plants i.e.,*Ficus religosa*, *Delonix regia*, *Polyalthia longofolia* (Ashoka tree) and *Plumeria* sp on traffic roads of Noida. They observed that selection of the right species is important for combating air pollution problems. They argued that Plumeria species possessed high APTI value and Ashoka tree species showed least value according to the final calculation of index. *Ficus religosa*, *Delonix regia* also showed good value and could still be used as an indicator for pollution control

Chandan Sahu et al., (2015) studied air pollution tolerance index of selected plants on *Tectona grandis, Ficus religiosa, Mangifera indica, Tamarandis indica, Azadirachta indica.* They also studied on the anticipated tolerance index, carbon sequestration and dust collection potential on the selected plants where they also observed that selection of the right species is important for combating air pollution problems. They reported *T. indica* has low APTI and API and is considered as poor category for plantation whereas *F. religiosa*, *M. indica and A. indica* has high APTI and API are considered as good category since they have acceptable value.

Deepika et al., (2016) evaluated air pollution tolerance index for 21 species of plants in educational institute of Delhi where *Magnifera indica*, *Ficus religiosa*, and *Ficus benghalensis* were categorized as most tolerant plant species as they have high level of ascorbic acid content which helps in maintaining their level of chlorophyll. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. They also observed that plant species having broad leaves and good canopy cover supported by high APTI as compared to the plant species having small and compound leaves with low canopy cover.

Horaginamani et al., (2010) studied air pollution tolerance index in Tiruchirappalli urban area and evaluated APTI for 14 plant species. They studied on the air pollution tolerance index where they also suggested that selection of the right species is important for combating air pollution problems. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. Among the selected species, they reported that *Azadirachta* sp, *Psidium* sp., *Mangifera indica*, *Largerstromia* sp., *Morinda* sp, *Hibiscus* sp, *Ixora* sp, *Polyalthia* sp, *Achras*sp and *Cassia* sp. possessed high APTI as compared to other species.

Lakshmi et al. (2008) carried out research in industrial area of Visakhapatnam and on the APTI of 24 species of plants, The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated and of this 4 species namely *Ficus religiosa*, *Zizypus jujuba*, *Phyllanthus emblica* and *Cassia fistula* were categorized as indicator of industrial air pollution. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution.

Karda et al., (2015) studied APTI of 12 plant species in Jalgaon city, Maharashtra. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. They reported that *Plumeria* sp. and *Ficus* sp. possessed relatively higher APTI than *Bougainvillea* sp. and *Tabernamontana divariata*. They also argued that *Polyalthia* sp. and *Alstonia* sp. have higher APTI value in the said area than the reports for species from earlier studies for other areas.

Kuddus et al., (2011) studied air pollution tolerance index in the city of Allahabad where 7 common plant species in the area were taken for detailed investigation. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. They reported that *Magnifera indica* showed highest APTI and *Artocarpus chaplasa* possessed lowest APTI. They argued *Magnifera indica* as pollution tolerant and *Artocarpus chaplasa* pollution sensitive bioindicator plant.

Begum and Harikrishna (2010) evaluated the tolerance of selected plant species according to APTI values and heavy metal concentration. The physiological and biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values. They observed that *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata* were considered the most tolerant species in the industrial locations of South Bengaluru. These mentioned plants were considered to be tolerant species in the industrial areas. The APTI values for the other species studied were reported low and were considered as sensitive species.

Lohe et al., (2015) studied the air pollution tolerance index for 7 plants species in Nagal village of Dehradun city, India. The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. The results showed that *Eucalyptus globus* exhibited the highest value of tolerance at all sites. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution

Marimuthu and Lavanya (2014) evaluated the air pollution tolerance index of selected plant species at two locations along the road sides of residential area and railway junction. The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated and they observed that air pollution tolerance index was highest for *Ficus benghalensis* in the first location and *Syzygium cumini* in the second location.

Krishnaveni et al., (2013) evaluated the APTI of selected plant species in Perumalmalai hill, Salem District, Tamil Nadu with the biochemical parameters like leaf extract pH, ascorbic acid, total chlorophyll and relative water content. The results concluded that *Nerium oleander* that have high APTI value was identified as intermediate species that are tolerant to air pollution. *Ficus benghalensis, Psidiumguajava, Spathodea campanulata, Opuntia ficus indica* was identified as a sensitive species since they have lower APTI value.

Thawale et al., (2011) evaluated the APTI of selected plant species by studying the biochemical changes in *Azadirachta indica*, *Mangifera indica*, *Delonix regia* and *Cassia fistula* of industrial, commercial and residential areas of Nagpur city in India. This study showed that the four biochemical parameters (i.e., chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. Their changes against the air pollution tolerance index of plants were evaluated where they observed that these plants can be used as a bioindicators of air pollution.

Gupta et al., (2016) evaluated APTI and API of four selected plant species i.e. *Terminaliya arjuna*, *Morus alba*, *Dalbergia sissoo* and *Polyathia longifolia* for the study on their tolerance against air pollution and for green belt development. The physiological and biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values. It was observed that there was change in the biochemical parameters of Total chlorophyll content, pH, relative water content and ascorbic acid. The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. Their observations shows that the APTI values for the four selected species are sensitive and are useful for the use of biological indicators.

Chauhan (2010) evaluated the APTI of selected plants species of *Ficus religiosa, Mangifera indica*, *Polyalthia longifolia*, *Delonix regia.* It was observed that there was change in the biochemical parameters of total chlorophyll content, pH, relative water content and ascorbic acid. The APTI was studied in the leaf samples of all selected plant species collected from polluted area and then compared with same species from a controlled area that is not exposed to pollution. It was observed that there was reduction of chlorophyll ‘a’ content in the leaves of *Ficus religiosa* with a great value and reduction was also found in the *Mangifera indica* with a lower value while greater reduction of ascorbic acid was found in the leaves of *Delonix regia* and lower reduction of ascorbic acid was found in the leaves of *Polyalthia longifolia*.

Jyothi and Jaya (2010) evaluated the plants species alongside the national highway of Thiruannathapuram of Kerala where they studied the APTI of *Polyalthia longifolia*, *Clerodendron infortunatum*, *Eupatorium odoratum* and *Hyptis suaveolus*. The study showed that the biochemical parameters of chlorophyll, pH, relative water content and ascorbic acid content) of the selected plant species change their responses against air pollution. They observed that *Polyalthia longifolia* shows the highest APTI values and are categorized to be a tolerant species and other species as sensitive species as they show comparatively lower and are sensitive to air pollutants.

Panigrahi et al., (2014) studied the biochemical parameters of plant species and evaluated the APTI of *Mangifera indica*, *Boungainvillea spectabilis, Nerium indicum, Azadirachta indica, Clatropis procera, Saraca indica, Shorea ribusta, Eucalyptus spp., Ficus religiosa and Tectona grandis.* The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. It is observed in a study that *Mangifera indica* was the most tolerant species having the highest APTI value i.e, 20.80 which is followed by *Bougainvillea spectabilis* (20.32), *Nerium indicum* (18.94), *Azadirachta indica* (18.73) and *Clatropi sprocera* (18.10) respectively.

Radhapriya et al., (2012) evaluated the APTI of plant species around the cement industry of Coimbatore, India. The physiological and biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values The study shows that all the plant species around the cement industry are highly exposed to air pollution as compared to the plant species from the control areas. According to the observed APTI value, it was noticed that about37% of the plant species studied were categorized as tolerant against air pollution. Plant species like *Mangifera indica*, *Bougainvillea species*, *Psidum quajava* showed high APTI values and 33% of the species i.e., *Thevetia neriifolia*, *Saraca indica*, *Phyllanthusemblica* and *Cercocarpus ledifolius* are observed to have low APTI values.

Gupta et al., (2011) studied the air pollution tolerance index of ten plant species that are selected from the urban area and the biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. APTI value was found to be high in *Psidium guajava*

(31.75%), *Swietenia mahoganii* (28.08%), *Mangifera indica* (27.97%), *Polyanthia longifolia* (25.58%) and *Ficus benghalensis* (25.02%). According to APTI value, the most tolerant plant species that can be useful for green belt development were *Ficusbenghalensis, Mangifera indica, Swieteniamahoganii,* and *Saraca indica.*

Yannawar and Bhosle (2014) evaluated the APTI values of plant species that grows along roadsides of Nanded city. The biochemical parameters such as pH of the leaf extract, ascorbic acid, total chlorophyll content, and relative water content was evaluated. The study showed that *Azadirachta indica*, *Moringa oleifera*, *Euginia jambolana* and*Tamarindus indica* were categorised as tolerant against air pollution according to their APTI value while *Mangiferaindica*, *Polyalthia longifolia*, *Ficus benghalensis*, *Delonixregia*, *Acacia nilotica*, *Leucaena leucocephala* and *Dalbergiasissoo* were categorized as immediately tolerant and *Ficusreligiosa*, *Phyllanthus emblica*, *Ficus glomerata* and *Eucalyptus* spp. were categorized as sensitive species against air pollution.

Gholami et al., (2016) studied the air pollution tolerance index in polluted areas of selected six plant species, namely, *Conocarpus*, *Myrtus*, *Prosopis*, *Eucalyptus*, *Ziziphus* and *Lebbek*, which are common in the region of Ahvaz. The study showed that *Myrtus* has the highest APTI and are considered to be tolerant against plant pollution, whereas *Prosopis* has the lowest APTI are considered to be sensitive against plant pollution. The observed results of assessment of the air pollution tolerance index indicate that plants with higher APTI can be used for the reduction of air pollution and plants with lower APTI can be used as an indicator for the measurement air pollution. Dust deposition on leaf surfaces was also determined in the study.

Ogunrotimi et al., (2017) studied the air pollution tolerance index of the 12 tree species from the roadside of the selected sites. The biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values. The study showed that the air pollution tolerance index of the selected tree species is between 9.2 and 12.7. *Polyalthia longifolia* shows the highest APTI value *Psidum guajava* shows the lowest APTI. The study considered that *Polyalthia longifolia*, *Mangifera indica*, *G.*

*arborea, T. grandis and T. catappa* were categorized as tolerant species against air pollution from all the selected tree species.

Agbaire and siefarienrhe (2009) studied the air pollution tolerance index of selected plant species around the around Otorogun gas plant inughelli-south local government area of delta state in Nigeria. The physiological and biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values. The result showed order of tolerance as *Emilia samtifolia* (1.49%), *Manihot esculenta* (2.19%), *Elaesis guineensis* (2.41%), *Impereta cylindrica* (25.56%), *Eupatorium odoratum* (35.17%), *Psidium guayava* (45.11%).

Meerabai et al., (2012) evaluate the effect of pollutants that are released from an industry at Kurnool, Andhra Pradesh, India by studying the air pollution tolerance index on *Cajanus cajan*. The biochemical parameters were studied i.e., leaf relative water content, ascorbic acid content, total leaf chlorophyll and leaf extract pH were used to evaluate the APTI values. According to the study, there was an increase in APTI of the plant species collected from the industry area. There was an increase in 13.14% APTI value. Therefore, it indicates that there is tolerance of the plant species to the pollution released from the industry. They concluded that the plant species may be recommended to the farmers from the area that is being urbanized for their economic growth.

# CHAPTER - III

# METHODOLOGY

## MATERIALS AND METHODS

### 3.1 Selection of study sites:

A total of 3 study sites were selected and in each site belt transect along the road side were stretch in and/or around Aizawl city was selected in replicates for detailed investigation. Sampling and documentation of plants was carried out following Misra (1968), Mueller-Dombois and Ellenberg (1974) using transect method. All the plants having >30cm gbh (girth at breast height) was recorded and documented. The plant specimen was identified with the help of herbarium at the Department of Environmental Science, Mizoram University, and Botanical Survey of India Regional Office at Shillong, and was counter-checked with the regional floras available (Haridasan and Rao, 1985; Kanjilal et al., 1934-1940).

### 3.2 Description of study area:

Aizawl is the capital of the state of Mizoram in India. It is the center of administrations where all the important government offices and commercial institutes are present. Aizawl has a mild, sub-tropical climate due to its physiographic location. In the summer, the average temperature ranges from 20–30 °C and in the winter 11–21 °C. There has been huge rise in vehicle and traffic intensity in the city which directly affects the environment and human health. Due to urbanization, the city is becoming congested year by year since job opportunity and other better institutions are available than other places of the state. Offices and institutions are heavily congested inside the city even though extension of the city is planned for better land use and control of heavy traffics. The rapid growth of population in Aizawl has laid much pressure on the land, the economy and the overall infrastructure of the place. With the absence of a proper urban planning, the city has simply lived in irregularity, and its improper infrastructure and services have not been able to manage. The space of the state has been highly disturbed in the city with infrastructure and for jobs or any other employment largely concentrated in the city and it attracts people and resources from other districts, towns and villages of the state. The lack of proper planning has resulted in construction of buildings on dangerous and steep slopes, a bad transport system, unplanned roads, poor management of different types of waste, lack of open spaces, insufficient pavements and vehicle parking areas, and other municipal deficiencies. There have become significant sources of pollutants causing air pollution so it is considered feasible to study the plants species around the city on how they tolerate the pollution and to understand their mitigating capabilities. The main sources of air pollution in Aizawl are vehicles therefore samples will be taken

from the busiest locations i.e. Roadsides locations that are being continuouslyexposed to air pollution from vehicles and other sources

**Sikulpuikawn to Bawngkawn (Site 1):**

Sikulpuikawn to Bawngkawn is the roadside stretch of Aizawl city which is about 6 km in distance located at the most centre part of the city. It is the busiest road stretch in the Capital. There are heavy traffic, buildings and institutes along the stretch. It is commercially active all week and pollution level could also be high since motor vehicles are running almost all day in great numbers. The roadside stretch especially Dawrpui, Zarkawt, Chanmari are commercial area so there are much more disturbance in the environment. The topography and associated limited available land has encouraged intensive utilization of useable lands. All residential areas have mixed land-use, including commercial and small-scale industrial uses. Recently, the municipal corporation took the initiative to shift production and manufacturing units out of inner city areas. There are proposals to make these ‘restricted residential areas’. Less economically competitive land-uses like green spaces, parks and playgrounds are but a fraction of the built-up space. There is little space left for construction or widening of roads. Even if this is made possible with a huge amount of outlay, it may come at the cost of immense environmental and physical degradation, the area is quite large and has different species of plants along the roadside, and Trees planted along the stretch are not planned and are distributed unevenly. Strengthening institutional and infrastructural capacities to cope with increasing demand is highly needed. It is also necessary, given the threat of global warming, to increase utilisation of renewable sources of energy. Buildings and constructions are piled along the stretch of the area. There are vehicle parking areas, shops and stalls along the side of the roads and with multiple congestions during working hours. The roads are busy till night since commercial areas are situated along the way. The road stretch between Dawrpui to Khatla have a diverse plant species along the Assam Rifles area other than that plant species along the way have limited areas for plantation since buildings are congested along the stretch of the site. Therefore, a study on how the common plants along the stretch is very important on how they react to the pollution.

**New capital complex, Khatla (Site 2):**

New Capital Complex is located in Khatla, Aizawl, Mizoram. The area consist of different government offices and institutions such as the new secretariat building, UD&PA office, Directorate of Economics& statistics, NABARD, etc. It is only a few minutes' drive from the main economic hubs of the city, depending on the traffics in a particular day. Since the whole complex is situated away from main road of the city and enough greenery is present, many people would go for walks through the area in mornings and evenings. Since it is an urbanized area, traffics and other disturbance are not highly present but noticeable in number. The area is not over polluted yet there are traffics running all day. According to time difference, the numbers of vehicles are high and low during the day with respect to the office hours. Since the topology of the area is not plain proper planning of the area is difficult. Mainly government offices and quarters are constructed in the area for the improvement of traffic and to reduce congestion around the city. It is also an alternative route for travelling or transport towards the west side of the city. There are different plant species that are planted artificially and naturally.

**Lalsavunga Park area, Hlimen (Site 3):**

Lalsavunga Park is a tourist spot near Aizawl, Mizoram. It is about eight kilometre from Aizawl in the place Hlimen. It is about 1179 meters of elevation and the area of the park is about 120 acres and the mountain range is 1 km long. Inside the park, a black top road of 0.544km is construced along with a suspension bridge which is 27 meters long. Apart from these, there are 12 rest sheds, a children's playground, a view tower, 3 cabins, a meeting hall, restaurants and staff quarter inside the park. The park was inaugurated on 3$^{rd}$ October 2018 by the then Chief Minister Pu Lal Thanhawla. The place is rich in flora and has lot different species of plants. Even though proper planning of vegetation is not maintained, the locals have made an initiative planting trees along the approach road of the park. The park is clean and unwanted disturbance are minimum around the area. It is a good place for exercising and relaxation since it consist of good views and fresh air.  It is great sites for controlled environment since it have vast plant species and pollution level could be low since there is no interference from major pollution source.

### 3.3 Selection of plant species and determination of APTI:

The common/dominant important tree species common to all study sites was selected to determine Air Pollution Tolerance Index (APTI).

### 3.4 Collection of leaf samples and analysis:

Fully mature leaves of selected plant species was collected in early morning, in a container with precautions so that leaves are not damaged. Minimum of 3 replicas was taken for better result. The fresh leaves collected were examined and analyzed for the four parameters relative water content, pH, ascorbic acid and chlorophyll content. Finally, Air Pollution Tolerance Index (APTI) following the standard methodologies was calculated for three seasons i.e. Pre-monsoon, Monsoon and Post-monsoon. Pre-monsoon season is between the months of February to May, Monsoon season is between June to September and Post-monsoon season is between the months of October to January.

#### 3.4.1 Relative leaf water content (RWC):

To calculate and determine the relative leaf water content, the following procedure was adopted. After the samples are taken in the Laboratory, the fresh leaves were weighed to know the fresh weight (FW) of the samples. The leaf samples were dipped in water for turgid weight at normal room temperature or overnight. After immersing it in water, the samples was taken out of the water and properly dried lightly with tissue paper and weighed to know turgid weight (TW). Samples were oven dried at $80^{o}C$ for 24 hours and weighed again to know the dry weight

(DW) (Barrs and Weatherley, 1962). Then the following formula was used to calculate relative water content:

$$\text{Relative water content} = \frac{FW-DW}{TW-DW} \times 100$$

Where, FW is Fresh weight, DW is dry weight and TW is turgid weight

### 3.4.2 Total chlorophyll content (TCh):

Extraction and determination of chlorophyll was performed by using the method of Arnon (1949). Fresh leaves of 1 gram was cut into pieces and then crushed with mortar and pestle and the extract was mixed with 5ml of 80% acetone and was kept for 15min. The liquid portion of the extract was centrifuged at 2500 rpm for10 min. After centrifugation, the supernatant was taken out and with the help of UV spectrophotometer it was measured at 645nm and 663nm. After the absorbance noted, the calculation was made as follows:

$$\text{Chlorophyll a (mg/g)} = \frac{12.7\ D\ (663) - 2.69\ D\ (645) \times V}{1000 \times W}$$

$$\text{Chlorophyll b (mg/g)} = \frac{22.9D\ (645) - 4.68D\ (663) \times V}{1000 \times W}$$

Total Chlorophyll = Chlorophyll a (mg/g) + b (mg/g)

D = the absorbance of the extract at the wavelength

V = total volume of the extract used for chlorophyll (ml), and

W = weight of the leaf sample (g).

### 3.4.3 Ascorbic acid (AA):

Ascorbic acid content that is expressed in mg/g was measured using Spectrophotometric method following the method of Bajaj and Kaur (1981). Fresh leaf of 1 gram was added into a test-tube and 4 ml of EDTA extracting solution oxalic acid was added, orthophosphoric acid (1ml) , 5% acid of tetraoxosulphate vi acid (1ml) was also added to this mixture, lastly, ammonium molybdate (1ml) was added and then 3ml of distilled water. The solution was then allowed to stand for 15 minutes. After letting it stand for a while, the liquid extract absorbance at 760nm was calculated and evaluated using a spectrophotometer. The concentrations of ascorbic acid present in the sample were evaluated by extrapolating it from an ascorbic standard curve .

### 3.4.4 Leaf extract pH:

5 gram of the fresh leaves was crushed and homogenized in 10ml distilled water. The extract was filtered and then using pH meter, the pH of the leaf extract was determined.

### 3.4.5 Air pollution tolerance index (APTI)

The APTI was computed using the method outlined by Singh and Rao (1983), as follows:

$$APTI = \frac{A\,(T+P) + R}{10}$$

Where,

A is ascorbic acid content in mg/g

T is total chlorophyll content in mg/g

P is pH of the leaf extract

R is the relative water content of leaf in %

According to the study of Deepika et al., 2016 on evaluating the APTI values, the tree species were classified to sensitive , tolerant, Intermediate and moderately tolerant.

# CHAPTER - IV

# RESULTS

## RESULTS

There are different plants species present on the roadsides of all sites are not uniform in some area and are distributed not very often. The tree species that are most commonly found on the stretch between Sikulpuikawn and Bawngkawn (Site-1) are presented in Table 1.1. Six species of trees from the family Moraceae are found in site 1. The species of this family are diverse around the whole city. The common fruits species usually found in this site are mango (*Mangifera indica*) and jackfruit (*Artocarpus heterophyllus*). The most common species that are distributed along the roadside stretch between Site 1 among the list are: *Ficus benjamina, Mangifera indica, Artocarpus heterophyllus, Ficus religiosa.*

**Table 1.1: Tree species abundantly found on the stretch between Sikulpuikawn and Bawngkawn (site-1)**

| Sl. | Species | Family | Services | Phenology |
|---|---|---|---|---|
| 1 | *Ficus Benjamina* L | Moraceae | It is used for making ropes, constructions carpentry, fruit crates, and drawers. | Flowers throughout the year. |
| 2 | *Ficus elastic* Roxb | Moraceae | The fruit contains sugars and vitamins and is use for treatment of stomach problems which are usually general pain. | Flowering period and fruiting period is sporadically all year round |
| 3 | *Mangifera indica* L | Anacardiacea e | Some parts of the plant are used as antiseptic, astrigents, laxatives. They are also used for treating diarrhea, asthma, cough, insomnia, teeth problems. | Flowering during rainy seasons and fruiting starts from the end of rainy season |
| 4 | *Artocarpus* | Moraceae | The leaves are used for treating | Fruiting |

| | | | | |
|---|---|---|---|---|
| | *heterophyllus* Lamk | | stomach pain, boils, ulcers, it is also used for curing skin disease and asthma. | matures during the rainy season from July to August |
| 5 | *Ficus benghalensis* L | Moraceae | The banyan tree has been used for many medicinal purposes from ancient times. The leaves and barks have anti-inflammatory and analgesic properties. It is also use in treating ulcers and skin diseases. | Flowering and Fruiting Time is around November-January |
| 6 | *Eucalyptus globules* Labill | Myrtaceae | The eucalyptus leaves are used for air freshener and chewing gum flavors. They are also used in medicinal applications like antiseptics, dental products, cough syrups when it is in the form of oil. The oil can be used in artificial flavoring. | Flowering starts from December till May. |
| 7 | *Gulmohar delonix regia* Boj | Fabaceae | These trees are used for treatment of bacterial and microbial infections as it has medicinal properties such as anti-microbial, anti-bacterial anti-diarrheal and anti-inflammatory. | Flowering starts from April to May and could extend till June. |
| 8 | *Mesua ferrea* L | Calophyllaceae | It is traditionally used medicinal purpose due to its properties like antipyretic, anti-allergic, anti-inflammatory, cardio tonic. It is also used as blood purifier and several other effects. | Flowering starts from the rainy season. |

| | | | | |
|---|---|---|---|---|
| 9 | *Ficus religiosa* L | Moraceae | *Ficus religiosa* are traditionally used for treatment of gonorrhea and skin diseases. It is also used as antiulcer, antibacterial, antidiabetic. | Flowering starts from February and fruiting starts from May to June. |
| 10 | *Bougainvillea* Comm | Nyctaginaceae | It can flower in different colors which are used for decorations and are ornamental plants | Flowering period is all throughout the year. In some region, flowering period is seasonal. |
| 11 | *Grevillea robusta* A. cunn | Proteaceae | It is used for carpentry and woodworks. They are also used in constructions because they are resistant against pests and rots. | Flowering starts from October to November |
| 12 | *Fucus geniculata* Kurz. | Moraceae | Ficus Geniculata is one of them which is being under-utilized and commonly known "putkal" which belong from species Moraceaes. It also shows the different antioxidant and antimicrobial properties. It also used for curing leucorrhoea, urinary tract infection and gastro-intestinal infection. | Flowering period and fruiting period is around October to March |

Tree species abundantly found on New Capital Complex, Khatla (Site-2) are presented in Table 1.2. Five tree species from the family Moraceae are found in site 2 i.e. New Capital Complex which is very similar to site 1 due to the similarity in area and land use. Due to the improper planning of the area, trees found in the area are not evenly distributed. There is a specific area where they plant Cherry blossoms species with a proper planning called “Cherry blossom avenue” with great number that is for beautification purpose. Other trees species planted around the area are also not planned where different tree species are planted with uneven distribution. The most common species that are distributed along the roadside stretch of Site 2 among the list above are: *Ficus Benjamina, Mangifera indica, Artocarpus heterophyllus, Ficus religiosa.*

**Table 1.2: Tree species abundantly found on New Capital Complex, Khatla (Site-2).**

| Sl | Species | Family | Service | Phenology |
|---|---|---|---|---|
| 1 | *Chukrasia tabularis* Juss | Meliaceae | They have a strong astringent properties. They are used to treat diarrhea. They are planted in coffee plantations as a shade for better yielding. It is an ornamental plant for some countries like Vietnam and Malaysia. | Flowering period and fruiting period is around May to March |
| 2 | *Fucus geniculata* Kurz. | Moraceae | It is one of them which is being under-utilized and commonly known "putkal" which belong from species Moraceaes. It also shows the different antioxidant and antimicrobial properties. It also used for curing leucorrhoea, urinary tract infection and gastro-intestinal infection. | Flowering period and fruiting period is around October to March |

| | | | | |
|---|---|---|---|---|
| 3 | *Mangifera indica* L | Anacardiaceae | Some parts of the plant are used as antiseptic, astrigents, laxatives. They are also used for treating diarrhea, asthma, cough, insomnia, teeth problems. | Flowering during rainy seasons and fruiting starts from the end of rainy season |
| 4 | *Artocarpus heterophyllus* Lamk | Moraceae | The leaves are used for treating stomach pain, boils, ulcers, it is also used for curing skin disease and asthma. | Fruiting matures during the rainy season from July to August |
| 5 | *Prunus cerasoides* D.Don | Rosaceae | It is an herb that is used for the treatment of skin diseases and also used as a uterine tonic. | It flowers in autumn and winter |
| 6 | *Ficus Benjamina* L | Moraceae | It is used for making ropes, constructions carpentry, fruit crates, and drawers. | Flowers throughout the year. |
| 7 | *Gulmohar delonix regia* Boj | Fabaceae | These trees are used for treatment of bacterial and microbial infections as it has medicinal properties such as anti-microbial, anti-bacterial anti-diarrheal and anti-inflammatory. | Flowering starts from April to May and could extend till June. |
| 8 | *Mesua ferrea* L | Calophyllaceae | It is traditionally used for medicinal purpose due to its properties like antipyretic, anti-allergic, anti-inflammatory, cardio tonic. It is also used as blood purifier and several other effects. | Flowering starts from the rainy season. |

| | | | | |
|---|---|---|---|---|
| 9 | *Ficus religiosa* L | Moraceae | *Ficus religiosa* are traditionally used for treatment of gonorrhea and skin diseases. It is also used as antiulcer, antibacterial, antidiabetic. | Flowering starts from February and fruiting starts from May to June. |
| 10 | *Bougainvillea* Comm | Nyctaginaceae | It can flower in different colors which are used for decorations and are ornamental plants | Flowering period is all throughout the year. In some region, flowering period is seasonal. |
| 12 | *Ficus elastica* Roxb | Moraceae | The fruit contains sugars and vitamins and is use for treatment of stomach problems which are usually general pain. | Flowering period and fruiting period is sporadically all year round |

**Table 1.3: The tree species that are mostly found on the stretch between Lalsavunga park, Hlimen (site-3) are:**

| Sl. | Species | Family | Service | Phenology |
|---|---|---|---|---|
| 1 | *Morus* L | Moraceae | It was much used in folk medicine, especially in the treatment of ringworm. It is also a drug for diabetes | The season occurs twice a year in the south of India; the first from October through November, and the second occurring March to May |
| 2 | *Bischofia jauanica* Blume | Phyllanthaceae | It is used for building productions, furniture since it is durable. The fruits and seeds are also useful as a lubricant and making beverages. | Flowering period is around February to May. |
| 3 | *Mangifera indica* L | Anacardiaceae | Some parts of the plant are used as antiseptic, astrigents, laxatives. They are also used for treating diarrhea, asthma, cough, insomnia, teeth problems. | Flowering during rainy seasons and fruiting starts from the end of rainy season |
| 4 | *Artocarpus heterophyllus* Lamk | Moraceae | The leaves are used for treating stomach pain, boils, ulcers, it is also used for curing skin disease and asthma. | Fruiting matures during the rainy season from July to August |
| 5 | *Prunus cerasoides* D.Don | Rosaceae | It is an herb that is used for the treatment of skin diseases and also used as a uterine tonic. | It flowers in autumn and winter |
| 6 | *Gmelina arborea* Roxb | Lamiaceae | It is used for carpentry, constructions. They are used as musical instruments, plywood and particle board. The fruits and leaves are also used for silkworm rearing. | Flowering starts from February to April and Fruiting starts from May to June. |
| 7 | *Haldina cordifolia* Roxb | Rubiaceae | It is used for the treatment of cough that are chronic. It is also | Flowering and Fruiting Time is a round |

| | | | | |
|---|---|---|---|---|
| | | | used as a treatment for stomach problems such as jaundice, fodder and inflammation in the stomach, the roots are also useful in treatment of dysentery and diarrhea. | July – December and October - March |
| 8 | *Mesua ferrea* L | Calophyllaceae | It is traditionally used for medicinal purpose due to its properties like antipyretic, anti-allergic, anti-inflammatory, cardio tonic. It is also used as blood purifier and several other effects. | Flowering starts from the rainy season. |
| 9 | *Ficus religiosa* L | Moraceae | *Ficus religiosa* are traditionally used for treatment of gonorrhea and skin diseases. It is also used as antiulcer, antibacterial, antidiabetic. | Flowering starts from February and fruiting starts from May to June. |
| 10 | *Ficus Benjamina* L | Moraceae | It is used for making ropes, constructions carpentry, fruit crates, and drawers. | Flowers throughout the year. |
| 11 | *Ficus semicordata* Buch. - Ham. ex Sm. | Moraceae | It is used for wood for burning and also used in mortars, it is also making ropes and the leaves are used as fodder. The fruits and roots are used as medicine and are edible for humans and animals. | Flowering & fruiting throughout the year |
| 12 | *Musa sylvestris* LA Colla | Musaceae | The leaves are used for fodder and the tree parts are eaten as vegetables. They are also used for treatment of intestinal problems They are also used as treatment for dysentery and diarrhea. Fruits are nutrition for animals and birds. | The flower appears in the sixth or seventh month. Unlike other fruit which have a growing season, they are available all year round. |

Without proper planning of the area, plant species are unevenly distributed along the park, naturally occurring plant species are diverse and distributed throughout the park. Five species of trees from the family Moraceae are found in the area. Plant species that are used for beautification of the area like Cherry blossom and Ficus species are common around the park.

From all the three sites, plant species that are most common to all the sites are taken for the evaluation of Air pollution tolerance index. Biochemical parameters like relative water content, pH of the leaf extract, Chlorophyll and Ascorbic Acid of the leaf are evaluated for the common plant species i.e *Ficus benjamina, Mangifera indica, Artocarpus heterophyllus, Ficus religiosa*

**Relative water content:**

**Pre-monsoon season**

Relative water content of the selected tree species ranges from 87.31 to 60.45 where it is observed highest in *Mangifera indica* (87.31) followed by *Ficus benjamina* (68.65), *Artocarpus heterophyllus* (61.23) and *Ficus religiosa* (52.36) in site 1. It is observed highest in *Mangifera indica* (86.54) followed by *Ficus benjamina* (66.24), *Artocarpus heterophyllus* (61.23) and *Ficus religiosa* (51.26) in site 2. In site 3, it is observed highest in *Mangifera indica* (81.63) followed by *Ficus benjamina* (65.85), *Artocarpus heterophyllus* (60.45) and *Ficus religiosa* (51.56). (Figure 1.1)

The relative water content are seen higher in site-1(Sikulpuikawn-Bawngkawn) and lowest in site 3 (Lalsavunga park, Hlimen. (Figure1.1)

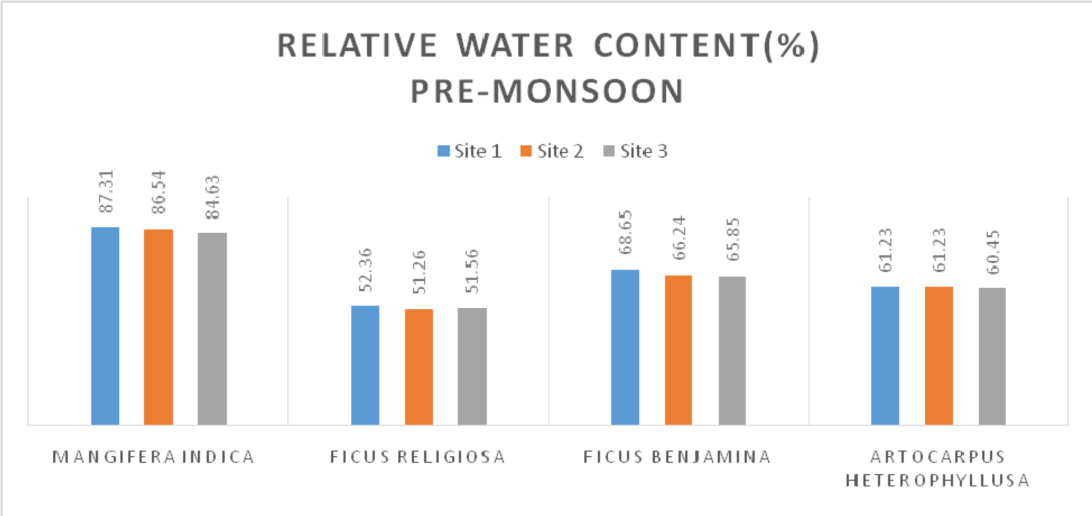


**Figure 1.1: Relative water content (%): Pre-monsoon season**

**Monsoon season**

The relative water content of the plants ranges from 90.23 to 64.47 where it is observed highest in *Mangifera indica* (90.23) followed by *Ficus benjamina* (71.67), *Artocarpus heterophyllus* (65.54) and *Ficus religiosa* (60.48) in site-1(Sikulpuikawn to Bawngkawn). It is observed highest in *Mangifera indica* (88.65) followed by *Ficus benjamina* (70.22), *Artocarpus heterophyllus* (64.84) and *Ficus religiosa* (55.74) in site 2 (New capital complex, Khatla). The relative water content of the plants is observed highest in *Mangifera indica* (88.04) followed by *Ficus benjamina* (70.45), *Artocarpus heterophyllus* (64.47) and *Ficus religiosa* (53.56) for site 3 (Lalsavunga park, Hlimen). (Figure 1.2).

The relative water content are seen higher in site 1 (Sikulpuikawn-Bawngkawn) and lowest in site 3 (Lalsavunga park, Hlimen). (Figure 1.2) .

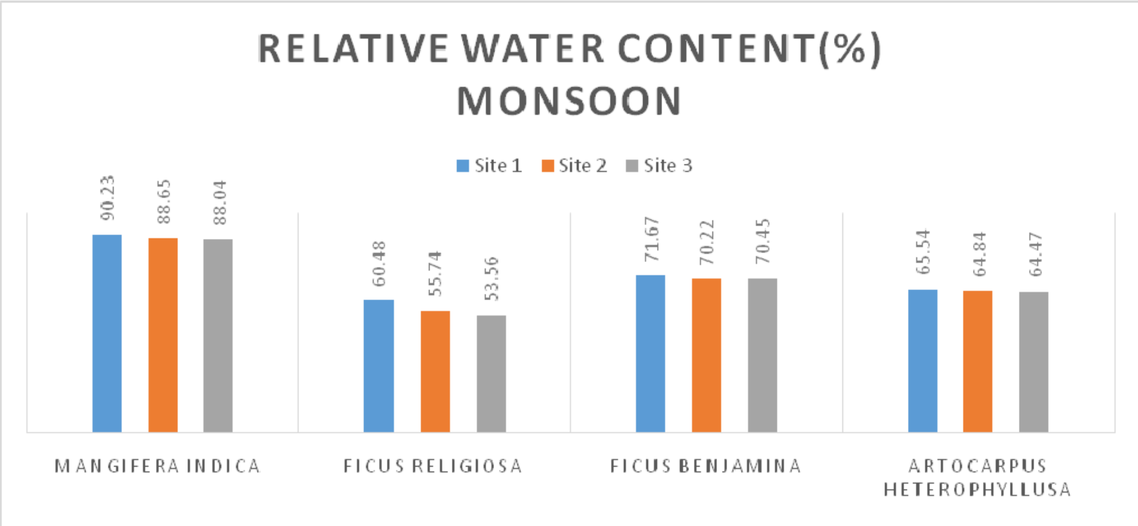


**Figure 1.2: Relative water content (%): Monsoon season**

**Post-monsoon season**

The relative water content of the plants ranges from 88.27 to 62.14 is observed highest in *Mangifera indica* (88.27) followed by *Ficus benjamina* (70.56), *Artocarpus heterophyllus* (63.21) and *Ficus religiosa* (58.23) in site 1.Site 2 showed highest in *Mangifera indica* (87.96) followed by *Ficus benjamina* (68.65), *Artocarpus heterophyllus* (62.24) and *Ficus religiosa* (53.86). And relative water content of the plants in site 3 is observed highest in *Mangifera indica* (87.17) followed by *Ficus benjamina* (67.32), *Artocarpus heterophyllus* (62.14) and *Ficus religiosa* (52.56) (Figure 1.3)

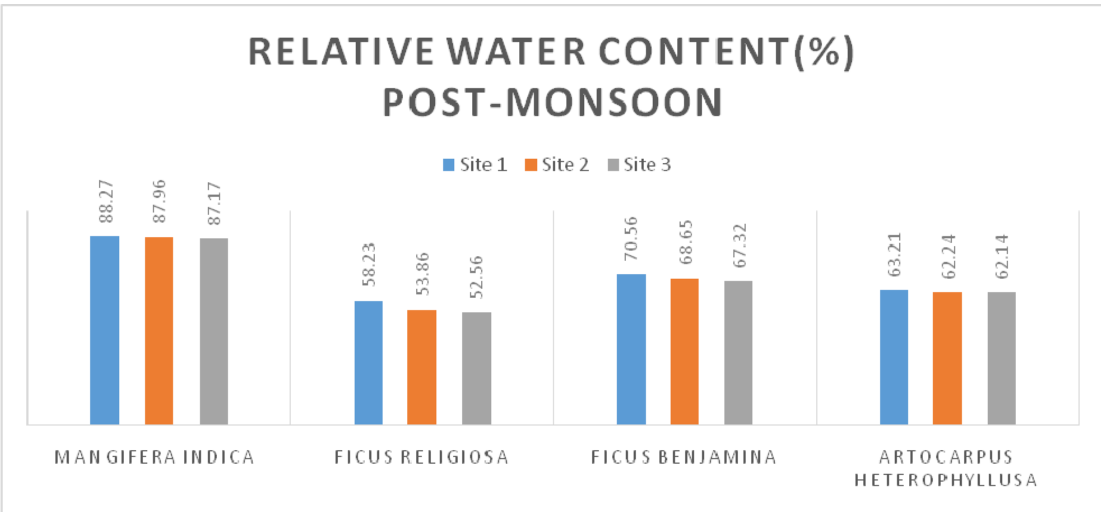


**Figure 1.3: Relative water content (%): Post- Monsoon season**

The relative water content for all the sites showed *Mangifera indica* varies from 84.63(pre-monsoon) to 90.23(monsoon), *Ficus benjamina* varies from 65.85(pre-monsoon) to 71.67(monsoon),, *Artocarpus heterophyllus* varies from 60.45 (pre-monsoon)to 65.54(monsoon), and *Ficus religiosa* varies from 51.56(pre-monsoon) to 60.48(monsoon) in all the seasons. (Figure 1.1-1.3)

Based on the finding, there are variations observed in relative water content from the three sites in different seasons. Monsoon season showed the highest values in every tree species in all the sites whereas Pre-monsoon showed the lowest in every the tree species in all the sites. The values of relative water content showed higher during the monsoon season and lower in pre-monsoon season. Species that are exposed to more pollution or other disturbance have more relative water content, the plants shows higher relative water content i.e more relative water content was seen in Sikulpuikawn to Bawngkawn site. Lalsavunga Park, Hlimen site is not visited by vehicles comparatively to the other two sites.

**pH of leaf extract:**

**Pre-monsoon season**

The pH value of the leaf extract ranges from 7.7 to 5.7 and is observed highest in *Mangifera indica* (7.7) followed by *Ficus religiosa* (6.8) *Artocarpus heterophyllus* (6.2) and lowest in *Ficus benjamina* (5.8) in site 1.The pH value of the leaf extract is observed highest in *Mangifera indica* (7.5) followed by *Ficus religiosa* (6.9) *Artocarpus heterophyllus* (6.2) and lowest in *Ficus benjamina* (6.1) in site 2. The pH value of the leaf extract is observed highest in *Mangifera indica* (7.7) followed by *Ficus religiosa* (6.8) *Artocarpus heterophyllus* (6.3) and lowest in *Ficus benjamina* (5.7) in site 3. (Figure 2.1)

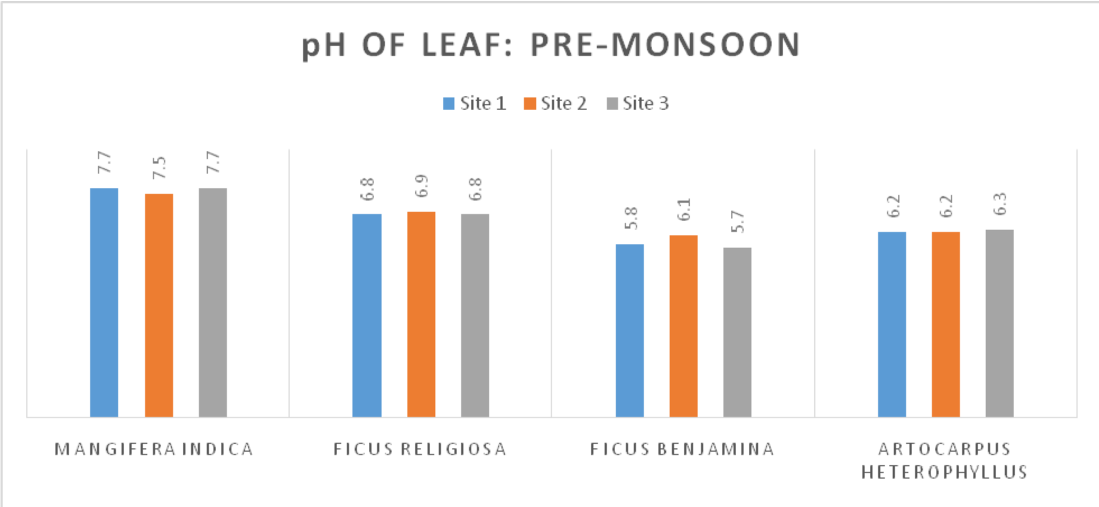


**Figure 2.1: pH of leaf: Pre-monsoon season**

**Monsoon season**

The pH value of the leaf extract ranges from 7.2 to 6.2 and is observed highest in *Mangifera indica* (7.2) followed by *Ficus religiosa* (7.1) *Artocarpus heterophyllus* (6.8) and lowest in *Ficus benjamina* (6.2) in site 1. The pH value of the leaf extract is observed highest in *Mangifera indica* (7.3) followed by *Ficus religiosa* (7.2) *Artocarpus heterophyllus* (6.9) and lowest in *Ficus benjamina* (6.5) in site 2.The pH value of the leaf extract is observed highest in *Mangifera indica* (7.5) followed by *Ficus religiosa* (7.1) *Artocarpus heterophyllus* (6.3) and lowest in *Ficus benjamina* (6.2) in site 3. (Figure 2.2)

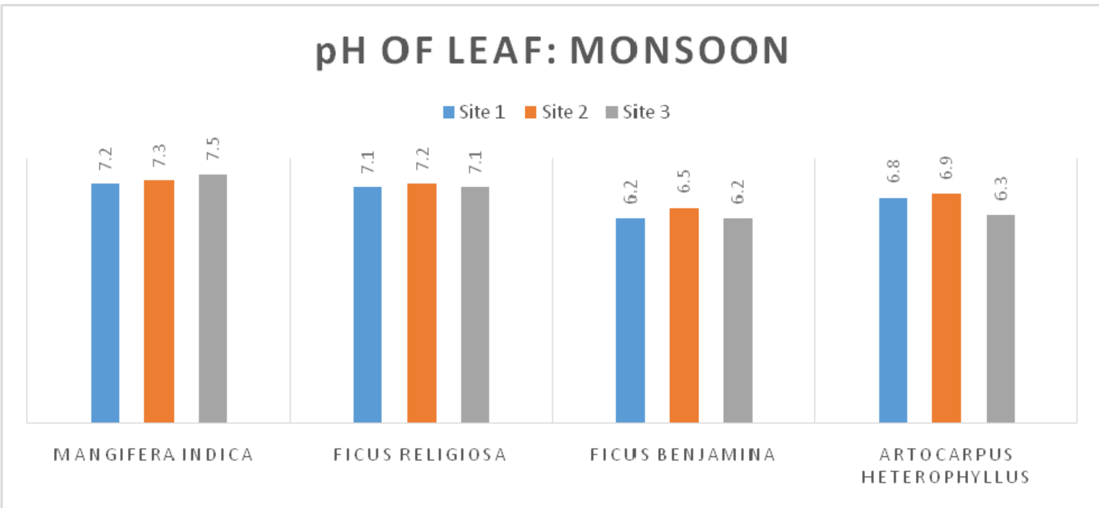


**Figure2.2: pH of leaf: Monsoon season**

**Post-monsoon season**

The pH value of the leaf extract ranges from 7.6 to 6.2 and is observed highest in *Mangifera indica* (7.6) followed by *Ficus religiosa* (6.9) *Artocarpus heterophyllus* (6.5) and lowest in *Ficus benjamina* (6.2) in site 1. The pH value of the leaf extract is observed highest in *Mangifera indica* (7.1) followed by *Ficus religiosa* (6.9) *Artocarpus heterophyllus* (6.5) and lowest in *Ficus benjamina* (6.3) in site 2. The pH value of the leaf extract is observed highest in *Mangifera indica* (7.5) followed by *Ficus religiosa* (7.1) *Artocarpus heterophyllus* (6.4) and lowest in *Ficus benjamina* (6.2) in site 3. (Figure 2.3)

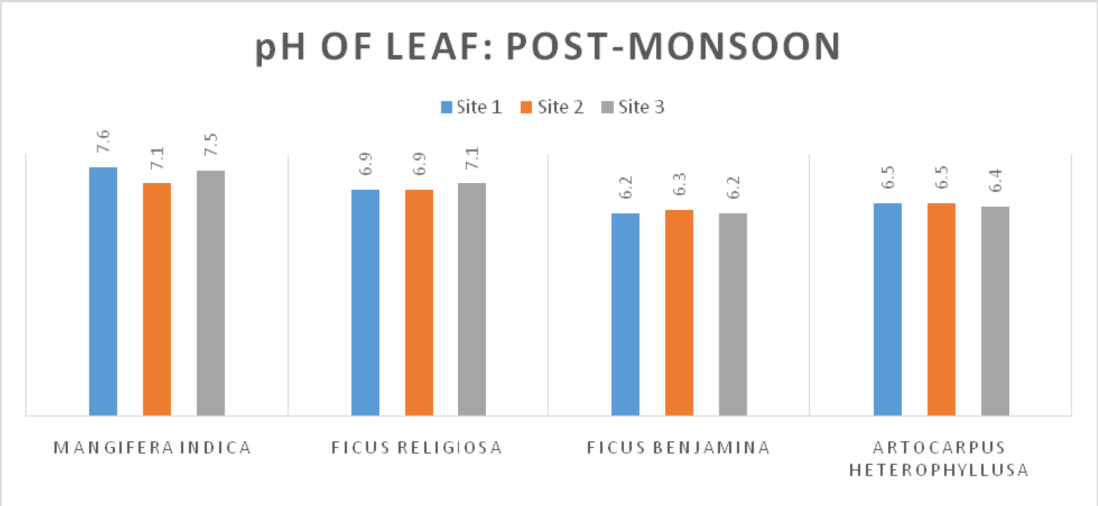


**Figure 2.3: pH of leaf: Post-monsoon season**

The pH of leaf extract for all the sites showed *Mangifera indica* varies from 7.5(pre-monsoon) to 7.7(monsoon),, *Ficus religiosa* varies from 6.8(pre-monsoon) to 6.9(monsoon), *Artocarpus heterophyllus* varies from 6.2(pre-monsoon) to 6.3(monsoon) and *Ficus benjamina* varies from 5.7(pre-monsoon) to 6.1(monsoon),. Based on the finding, Monsoon season showed neutral pH as compared to pre-monsoon seasons. *Mangifera indica* showed the highest pH values while *Ficus benjamina* showed the lowest pH value for all the sites. With higher concentration of acidic air pollutants, the pH of leaves decreases which may decrease the efficiency for conversion of hexose sugar to ascorbic acid. (Figure 2.1-2.3)

Due to weather conditions, there is difference in values of pH in the three seasons. This could be due to temperature, rainfall, and pollution level.

**Total chlorophyll:**

**Pre-Monsoon season**

The total chlorophyll value ranges from 2.34 to 0.38 and is observed highest in *Mangifera indica* (2.34) followed by *Artocarpus heterophyllus* (2.12), *Ficus benjamina* (0.53) and lowest in *Ficus religiosa* (0.48) in site 1. The total chlorophyll value is observed highest in *Mangifera indica* (1.98) followed by *Artocarpus heterophyllus* (1.75), *Ficus benjamina* (0.49) and lowest in *Ficus religiosa* (0.42) in site 2. However, the total chlorophyll value is observed highest in *Mangifera indica* (1.59) followed by *Artocarpus heterophyllus* (0.85), *Ficus benjamina* (0.44) and lowest in *Ficus religiosa* (0.38) in site 3. (Figure 3.1)

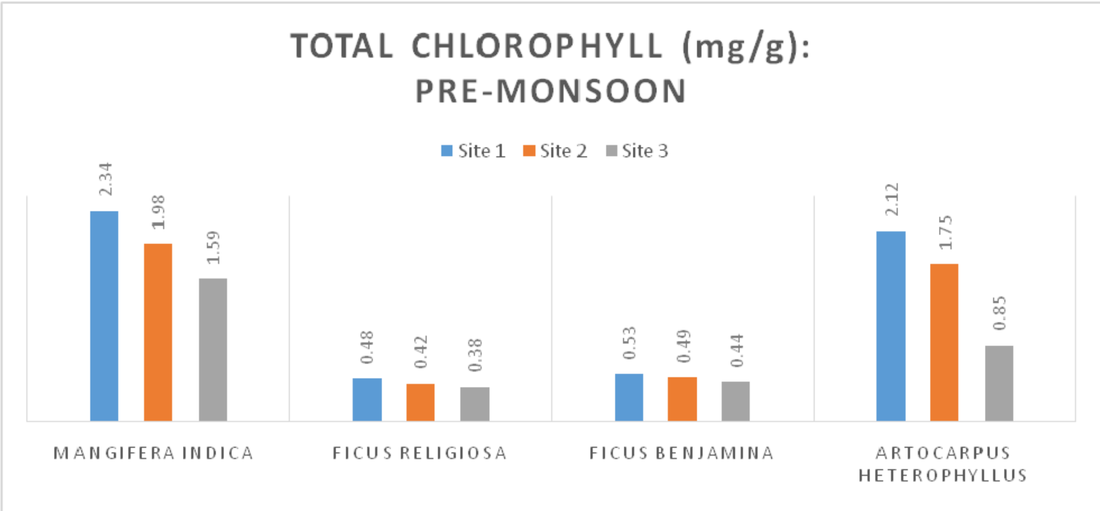


**Figure 3.1. Total Chlorophyll (mg/g): Pre-monsoon season**

**Monsoon season**

The total chlorophyll value ranges from 2.56 to 0.48 and is observed highest in *Mangifera indica* (2.56) followed by *Artocarpus heterophyllus* (2.24), *Ficus benjamina* (0.68) and lowest in *Ficus religiosa* (0.51) in site 1. The total chlorophyll value is observed highest in *Mangifera indica* (2.03) followed by *Artocarpus heterophyllus* (1.96), *Ficus benjamina* (0.56) and lowest in *Ficus religiosa* (0.52) in site 2. The total chlorophyll value is observed highest in *Mangifera indica* (1.95) followed by *Artocarpus heterophyllus* (1.44), *Ficus benjamina* (0.52) and lowest in *Ficus religiosa* (0.48) in site 3. (Figure 3.2)

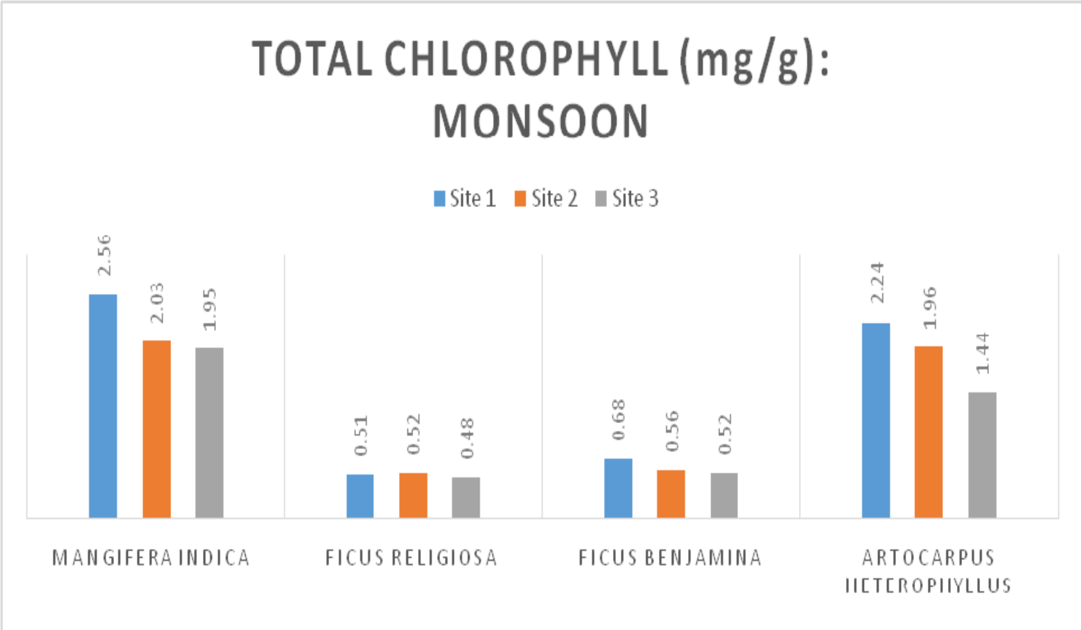


**Figure 3.2. Total Chlorophyll (mg/g): Monsoon season**

**Post-Monsoon season**

The total chlorophyll value ranges from 2.36 to 0.45 and is observed highest in *Mangifera indica* (2.36) followed by *Artocarpus heterophyllus* (2.14), *Ficus benjamina* (0.64) and lowest in *Ficus religiosa* (0.51) in site 1. It is observed highest in *Mangifera indica* (2.08) followed by *Artocarpus heterophyllus* (1.92), *Ficus benjamina* (0.54) and lowest in *Ficus religiosa* (0.49) in site 2. The total chlorophyll value is observed highest in *Mangifera indica* (1.88) followed by *Artocarpus heterophyllus* (1.21), *Ficus benjamina* (0.49) and lowest in *Ficus religiosa* (0.45) in site 3. (Figure 3.3)

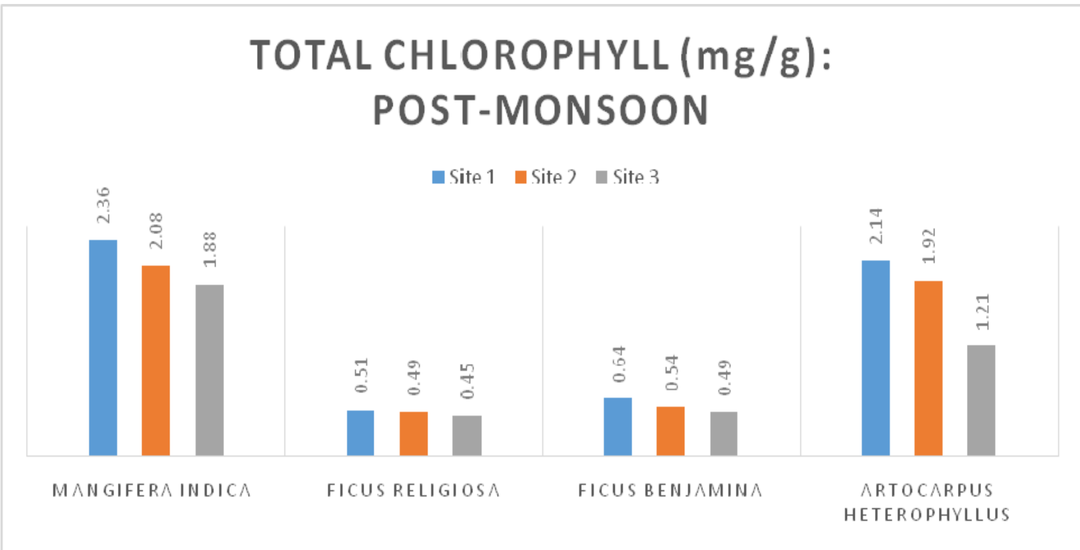


**Figure 3.3. Total Chlorophyll (mg/g): Post-monsoon season**

Total chlorophyll for all the sites showed *Mangifera indica* varies from 1.59(pre-monsoon) to 2.56(monsoon), *Ficus religiosa* varies from 0.38(pre-monsoon) to 0.51(monsoon), *Artocarpus heterophyllus* varies from 0.85(pre-monsoon) to 2.24(monsoon) and *Ficus benjamina* varies from 0.44(pre-monsoon) to 0.68(monsoon). Based on the finding, highest value for Total chlorophyll was seen in *Mangifera indica* while lowest pH value was seen in *Ficus religiosa* for all the sites. (Figure 3.1-3.3)

There is difference in values for all the sites in different seasons. Monsoon season showed higher concentration as water content level improves the chlorophyll level. The observed result may be due to the reason of difference in the tree species specifications like leaf ages , the tree height, canopy type of the tree and the leaf shape and sizes. With addition to the difference in the level of exposure against pollution and disturbances, the result differs for all the sites with variation.

**Ascorbic acid content:**

**Pre-Monsoon season**

The Ascorbic acid content of leaf value ranges from 0.28 to 0.03 and is observed highest in *Ficus benjamina* (0.28) followed by *Ficus religiosa* (0.24) *Mangifera indica* (0.12) and lowest in *Artocarpus heterophyllus* (0.02) in site 1. In site 2, ascorbic acid content of leaf value is observed highest in *Ficus benjamina* (0.21) followed by *Ficus religiosa* (0.19) *Mangifera indica* (0.08) and lowest in *Artocarpus heterophyllus* (0.04). The Ascorbic acid content of leaf value is observed highest in *Ficus benjamina* (0.18) followed by *Ficus religiosa* (0.18) *Mangifera indica* (0.05) and lowest in *Artocarpus heterophyllus* (0.03) in site 3. (Figure 4.1)

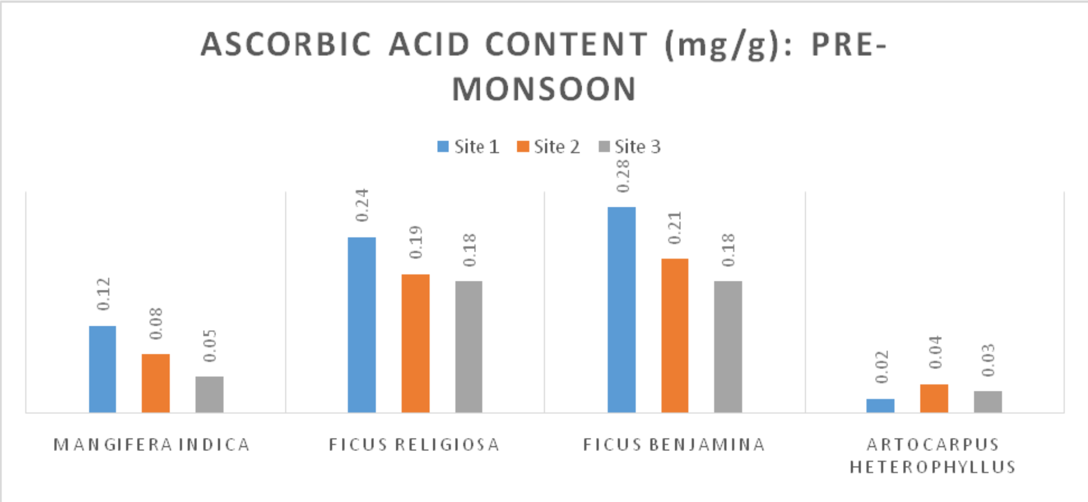


**Figure 4.1. Ascorbic acid content (mg/g): Pre-monsoon season**

**Monsoon season**

The ascorbic acid content of leaf value ranges from 0.35 to 0.04 and is observed highest in *Ficus benjamina* (0.35) followed by *Ficus religiosa* (0.26) *Mangifera indica* (0.21) and lowest in *Artocarpus heterophyllus* (0.12) in site 1. It is observed highest in *Ficus benjamina* (0.21) followed by *Ficus religiosa* (0.21) *Mangifera indica* (0.11) and lowest in *Artocarpus heterophyllus* (0.06) in site 2. The Ascorbic acid content of leaf value is observed highest in *Ficus benjamina* (0.31) followed by *Ficus religiosa* (0.2) *Mangifera indica* (0.07) and lowest in *Artocarpus heterophyllus* (0.04) in site 3.(Figure 4.2)

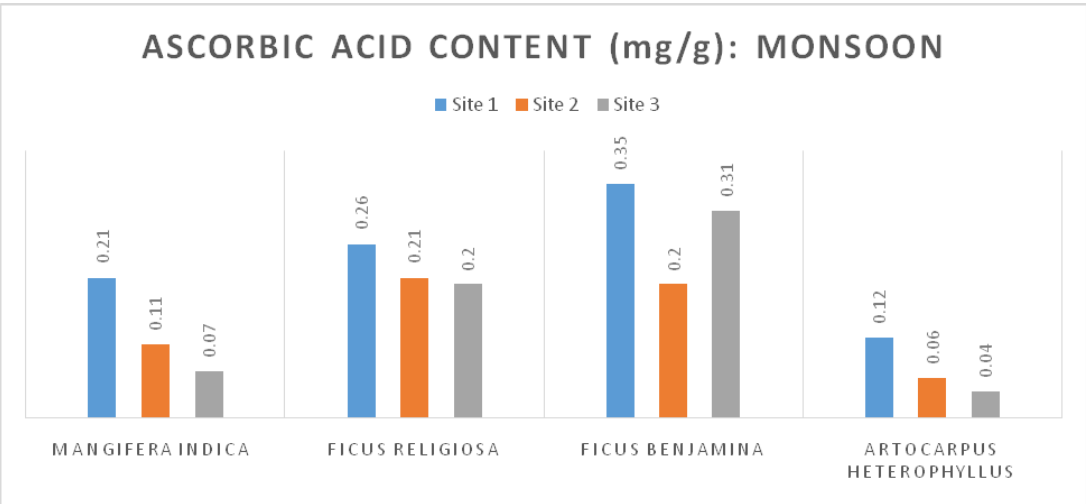


**Figure 4.2. Ascorbic acid content (mg/g): Monsoon season**

**Post-Monsoon season**

The ascorbic acid content of leaf value ranges from 0.29 to 0.04 and is observed highest in *Ficus benjamina* (0.29) followed by *Ficus religiosa* (0.26) *Mangifera indica* (0.19) and lowest in *Artocarpus heterophyllus* (0.11) in site 1. In site 2, the Ascorbic acid content of leaf value is observed highest in *Ficus religiosa* (0.21) followed by *Ficus benjamina* (0.19) *Mangifera indica* (0.12) and lowest in *Artocarpus heterophyllus* (0.08). The Ascorbic acid content of leaf value is observed highest in *Ficus benjamina* (0.29) followed by *Ficus religiosa* (0.19) *Mangifera indica* (0.07) and lowest in *Artocarpus heterophyllus* (0.04) in site 3. (Figure 4.3)

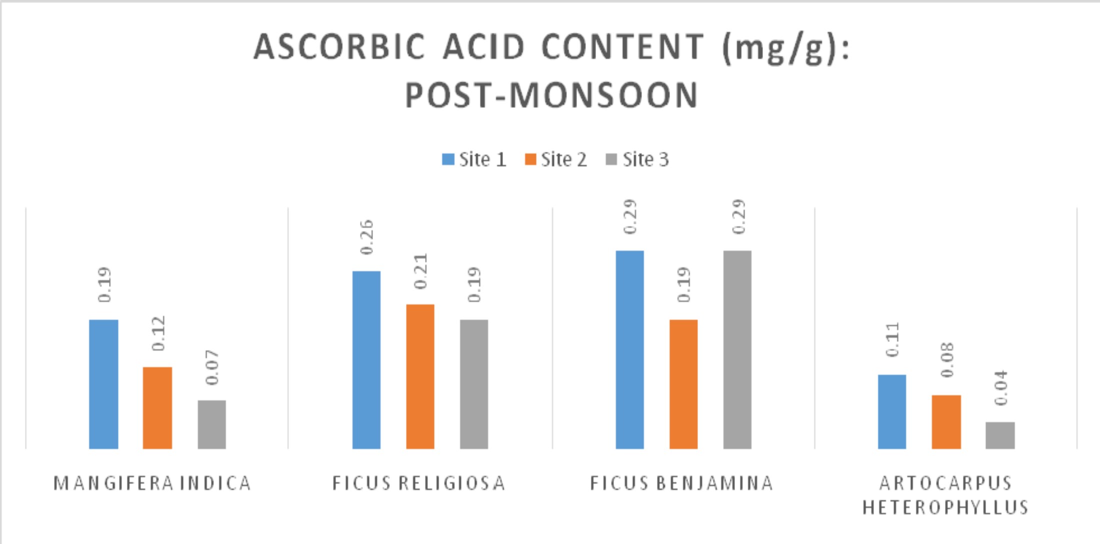


**Figure 4.3. Ascorbic acid content (mg/g): Post-Monsoon season**

The Ascorbic acid content for all the sites showed *Mangifera indica* varies from 0.05(pre-monsoon) to 0.12(monsoon), *Ficus religiosa* varies 0.18(pre-monsoon) to 0.24(monsoon), *Artocarpus heterophyllus* varies from 0.02(pre-monsoon) to 0.03(monsoon) and *Ficus benjamina* varies from 0.18(pre-monsoon) to 0.28(monsoon). Based on the finding, highest value for Total chlorophyll was seen in *Ficus benjamina* while lowest value was seen in *Artocarpus heterophyllus* for all the sites. (Figure 4.1-4.3)

There are differences in values with the difference in seasons since weather condition plays an important role in the leaf conditions. Higher concentration of ascorbic acid in plants shows that they are of exposure to higher concentration of $SO_2$, and shows higher tolerance of the plant. With addition to the difference in the level of exposure against pollution and disturbances, the result differs for all the sites with variation.

### Air pollution tolerance index (APTI)

### Pre-Monsoon season

Air pollution tolerance index (APTI) of the selected tree species ranges from 9.93 to 6.28 for site 1 and is observed highest in *Mangifera indica* (9.93) followed by *Ficus benjamina* (8.63), *Ficus religiosa* (6.98), and lowest in *Artocarpus heterophyllus* (6.28) (Table 2.1)

**Table 2.1: Air pollution tolerance index (APTI) of the selected tree species: Site 1 (Sikulpuikawn to Bawngkawn).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 87.31±2.58 | 7.7±0.13 | 2.34±0.01 | 0.12±0.02 | 9.93 |
| 2 | *Ficus religiosa* | 52.36±1.82 | 6.8±0.24 | 0.48±0.03 | 0.24±0.01 | 6.98 |
| 3 | *Ficus benjamina* | 68.65±2.15 | 5.8±0.28 | 0.53±0.02 | 0.28±0.02 | 8.63 |
| 4 | *Artocarpus heterophyllus* | 61.23±2.58 | 6.2±0.17 | 2.12±0.01 | 0.02±0.03 | 6.28 |

Air pollution tolerance index (APTI) of the selected tree species for site 2 ranges from 9.41 to 6.44 and is observed highest in *Mangifera indica* (9.41) followed by *Ficus benjamina* (8), *Ficus religiosa* (6.51), and lowest in *Artocarpus heterophyllus* (6.44). (Table 2.2)

**Table 2.2: Air pollution tolerance index (APTI) of the selected tree species: Site 2 (New capital complex, Khatla).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 86.54±1.95 | 7.5±0.23 | 1.98±0.02 | 0.18±0.04 | 9.41 |
| 2 | *Ficus religiosa* | 51.26±1.65 | 6.9±0.18 | 0.42±0.02 | 0.19±0.03 | 6.51 |
| 3 | *Ficus benjamina* | 66.24±2.24 | 6.1±0.22 | 0.49±0.03 | 0.21±0.04 | 8 |
| 4 | *Artocarpus heterophyllus* | 61.23±2.12 | 6.2±0.15 | 1.75±0.01 | 0.04±0.05 | 6.44 |

Air pollution tolerance index (APTI) of the selected tree species for site 3 ranges from 8.92 to 6.25 and is observed highest in *Mangifera indica* (8.89) followed by *Ficus benjamina* (7.69), *Ficus religiosa* (6.44), and lowest in *Artocarpus heterophyllus* (6.25). (Table 2.3)

**Table 2.3: Air pollution tolerance index (APTI) of the selected tree species: Site 3 (Lalsavunga Park, Hlimen).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 84.63±2.15 | 7.7±0.24 | 1.59±0.03 | 0.05±0.07 | 8.92 |
| 2 | *Ficus religiosa* | 51.56±1.95 | 6.8±0.15 | 0.38±0.02 | 0.18±0.09 | 6.44 |
| 3 | *Ficus benjamina* | 65.85±2.44 | 5.7±0.31 | 0.44±0.01 | 0.18±0.04 | 7.69 |
| 4 | *Artocarpus heterophyllus* | 60.45±1.98 | 6.3±0.17 | 0.85±0.02 | 0.03±0.12 | 6.25 |

**Monsoon season**

The Air pollution tolerance index (APTI) of the selected tree species for site 1 ranges from 11.07 to 7.63 and is observed highest in *Mangifera indica* (11.07) followed by *Ficus benjamina* (9.57), *Ficus religiosa* (8.02), and lowest in *Artocarpus heterophyllus* (7.63) (Table 3.1).

**Table 3.1: Air pollution tolerance index (APTI) of the selected tree species: Site 1 (Sikulpuikawn to Bawngkawn).**

| Sl.no | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 90.23±2.21 | 7.2±0.44 | 2.56±0.12 | 0.21±0.04 | 11.07 |
| 2 | *Ficus religiosa* | 60.48±1.88 | 7.1±0.17 | 0.51±0.08 | 0.26±0.03 | 8.02 |
| 3 | *Ficus benjamina* | 71.67±2.41 | 6.2±0.54 | 0.68±0.06 | 0.35±0.09 | 9.57 |
| 4 | *Artocarpus heterophyllus* | 65.54±2.65 | 6.8±0.31 | 2.24±0.14 | 0.12±0.18 | 7.63 |

The Air pollution tolerance index (APTI) of the selected tree species for site 2 ranges from 9.89 to 7.01 and is observed highest in *Mangifera indica* (9.89) followed by *Ficus benjamina* (8.43), *Ficus religiosa* (7.19), and lowest in *Artocarpus heterophyllus* (7.01) (Table 3.2).

**Table 3.2: Air pollution tolerance index (APTI) of the selected tree species: Site 2 (New capital complex, Khatla).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 88.65±2.56 | 7.3±0.23 | 2.03±0.18 | 0.11±0.09 | 9.89 |
| 2 | *Ficus religiosa* | 55.74±2.15 | 7.2±0.15 | 0.52±0.06 | 0.21±0.04 | 7.19 |
| 3 | *Ficus benjamina* | 70.22±1.56 | 6.5±0.32 | 0.56±0.09 | 0.2±0.05 | 8.43 |
| 4 | *Artocarpus heterophyllus* | 64.84±1.97 | 6.9±0.14 | 1.96±0.14 | 0.06±0.07 | 7.01 |

Air pollution tolerance index (APTI) of the selected tree species for site 3 ranges from 9.46 to 6.75 and is observed highest in *Mangifera indica* (9.46) followed by *Ficus benjamina* (79.12), *Ficus religiosa* (6.87), and lowest in *Artocarpus heterophyllus* (6.75) (Table 3.3).

**Table 3.3: Air pollution tolerance index (APTI) of the selected tree species: Site 3 (Lalsavunga Park, Hlimen).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 88.04±2.18 | 7.5±0.25 | 1.95±0.21 | 0.07±0.06 | 9.46 |
| 2 | *Ficus religiosa* | 53.56±1.95 | 7.1±0.16 | 0.48±0.09 | 0.2±0.04 | 6.87 |
| 3 | *Ficus benjamina* | 70.45±2.11 | 6.2±0.27 | 0.52±0.07 | 0.31±0.09 | 9.12 |
| 4 | *Artocarpus heterophyllus* | 64.47±1.87 | 6.3±0.21 | 1.44±0.17 | 0.04±0.03 | 6.75 |

**Post- Monsoon season**

The Air pollution tolerance index (APTI) of the selected tree species for site 1 ranges from 10.71 to 7.27 and is observed highest in *Mangifera indica* (10.71) followed by *Ficus benjamina* (9.03), *Ficus religiosa* (7.74), and lowest in *Artocarpus heterophyllus* (7.27) (Table 4.1).

**Table 4.1.: Air pollution tolerance index (APTI) of the selected tree species: Site 1(Sikulpuikawn to Bawngkawn).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 88.27±2.26 | 7.6±0.18 | 2.36±0.14 | 0.19±0.06 | 10.71 |
| 2 | *Ficus religiosa* | 58.23±1.63 | 6.9±0.23 | 0.51±0.06 | 0.26±0.04 | 7.74 |
| 3 | *Ficus benjamina* | 70.56±1.96 | 6.2±0.21 | 0.64±0.09 | 0.29±0.08 | 9.03 |
| 4 | *Artocarpus heterophyllus* | 63.21±1.88 | 6.5±0.17 | 2.14±0.17 | 0.11±0.05 | 7.27 |

The Air pollution tolerance index (APTI) of the selected tree species for site 2 ranges from 9.89 to 6.89 and is observed highest in *Mangifera indica* (9.89) followed by *Ficus benjamina* (8.16), *Ficus religiosa* (6.93), and lowest in *Artocarpus heterophyllus* (6.89). (Table 4.2).

**Table 4.2: Air pollution tolerance index (APTI) of the selected tree species: Site 2 (New capital complex, Khatla).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 87.96±2.24 | 7.1±0.31 | 2.08±0.17 | 0.12±0.07 | 9.89 |
| 2 | *Ficus religiosa* | 53.86±2.10 | 6.9±0.24 | 0.49±0.04 | 0.21±0.05 | 6.93 |
| 3 | *Ficus benjamina* | 68.65±1.89 | 6.3±0.11 | 0.54±0.09 | 0.19±0.08 | 8.16 |
| 4 | *Artocarpus heterophyllus* | 62.24±1.66 | 6.5±0.19 | 1.92±0.14 | 0.08±0.04 | 6.89 |

The Air pollution tolerance index (APTI) of the selected tree species for site 3 ranges from 9.37 to 6.51 and is observed highest in *Mangifera indica* (9.37) followed by *Ficus benjamina* (8.67), *Ficus religiosa* (6.69), and lowest in *Artocarpus heterophyllus* (6.51). (Table 4.3).

**Table 4.3: Air pollution tolerance index (APTI) of the selected tree species: Site 3 (Lalsavunga Park, Hlimen).**

| Sl. | Name of species | Relative water content | pH | Chlorophyll | Ascorbic Acid | APTI |
|---|---|---|---|---|---|---|
| 1 | *Mangifera indica* | 87.17±1.97 | 7.5±0.06 | 1.88±0.12 | 0.07±0.06 | 9.37 |
| 2 | *Ficus religiosa* | 52.56±2.14 | 7.1±0.14 | 0.45±0.07 | 0.19±0.02 | 6.69 |
| 3 | *Ficus benjamina* | 67.32±1.76 | 6.2±0.21 | 0.49±0.03 | 0.29±0.07 | 8.67 |
| 4 | *Artocarpus heterophyllus* | 62.14±2.19 | 6.4±0.17 | 1.21±0.16 | 0.04±0.05 | 6.51 |

The Air pollution tolerance index content for all the sites showed that the values for *Mangifera indica* varies from 8.89(pre-monsoon) to 11.07(monsoon), *Ficus benjamina* varies from 7.69(pre-monsoon) to 9.57(monsoon), *Ficus religiosa* varies 6.44(pre-monsoon) to 8.02(monsoon), and *Artocarpus heterophyllus* varies from 6.28(pre-monsoon) to 7.63(monsoon). Based on the findings, highest value for Air pollution tolerance index was seen in *Mangifera indica* while lowest was seen in *Artocarpus heterophyllus* for all the sites. Higher APTI value of plant species are seen in Site 1 since the area is more exposed to pollution and disturbance. On contradiction, lower APTI value of plant species are seen in site 3 since there could be lower pollution level and disturbance. There is not much difference seen between the sites of 1 and 2 since both of them are similar in exposure type of disturbance but not in the same level. (Table 2.1 – 4.3).

Different seasons showed different values in APTI where monsoon seasons showed higher APTI values with comparison of pre-monsoon and post-monsoon. Pre-monsoon season showed the least values as compared to monsoon and post-monsoon. This could be due to weather conditions and other anthropogenic activities.

# CHAPTER - V

# DISCUSSION

## DISCUSSION

The air pollution tolerance index is an index which depends on four parameters like the content of water, pH of leaf extract, ascorbic acid content, and chlorophyll content of plant species (Singh and Rao, 1983). Plants that have high APTI value showing more ability of tolerance against air pollutant (Joshi et al., 2016). In the three sites, there were difference seen in all the parameters but similar outcome was seen in the APTI of the tree species which showed that the tolerant tree species were observed as *Mangifera indica* and *Ficus benjamina* and the sensitive tree species are observed as *Ficus religiosa* and *Artocarpus heterophyllus* in all the three sites.

### Relative water content:

Relative water content refers to the water presence in leaves related to the full turgidity. The reduction in relative water content could be linked with the permeability (protoplasmic), water loss and dissolved nutrients and the leaves aged earlier than usual. *Mangifera indica* showed high relative water content in all the sites while lowest was seen in *Ficus religiosa*. Based on the present study, the relative water content for all the sites showed *Mangifera indica* varies from 84.63 to 90.23, *Ficus benjamina* varies from 65.85 to 71.67, *Artocarpus heterophyllus* varies from 60.45 to 65.54 and *Ficus religiosa* varies from 51.56 to 60.48 in all the seasons. Based on the finding, the values of relative water content showed higher during the monsoon season as rainfall are relatively higher during these season and lower relative water content are seen in pre-monsoon season since weather conditions are dry as compared to monsoon and post-monsoon. Species that are exposed to more pollution or other disturbance have more relative water content, the plants shows higher relative water content i.e more relative water content was seen in Sikulpuikawn to Bawngkawn site. Lalsavunga Park, Hlimen site is not visited by vehicles comparatively to the other two sites

Relative water content of tree species is the capacity of leaf to hold water that helps in maintenance of physiologically balance in the body of plants which are under the conditions of stress of air pollutions (Singh and Rao, 1983). From the study of Deepika et al., 2016, *Mangifera indica* showed higher relative content and lower at *Ficus religiosa* among the two. With comparison and relative studies along with the previous studies, since there are different stress conditions between the sites, the site where pollution exposures are relatively higher, the plants shows higher relative water content i.e., more relative water content was seen in Sikulpuikawn to Bawngkawn site. Lalsavunga Park, Hlimen site is not visited by vehicles comparatively to the other two sites, therefore shows less in water content, Plants having high relative water content determines that the plants will be tolerance to pollutants (Joshi and Bora, 2011).

**Leaf extract pH:**

pH are observed on higher side for most of the trees species which indicates that the trees are exposed to acidic pollutants moderately. The pH of leaf extract for all the sites showed *Mangifera indica* varies from 7.5 to 7.7, *Ficus religiosa* varies from 6.8 to 6.9, *Artocarpus heterophyllus* varies from 6.2 to 6.3 and *Ficus benjamina* varies from 5.7 to 6.1. Based on the present finding, monsoon season showed towards neutral pH as compared to pre-monsoon seasons, since weather conditions are different and rainfall amount are distinctly varied among the three seasons, pH value could differ accordingly. Monsoon and Post-monsoon are comparatively closer in values which could be the result of concentration variation due to rainfall after monsoon. Acidity of leaves could change due to the rainfall which may result in different observations between the sites and seasons. pH value was seen highest in *Mangifera indica* while pH value was seen lowest in *Ficus benjamina* for all the sites. The observed result could be the due to higher concentration of acidic air pollutants.

The pH of leaves decreases which may decrease the efficiency for conversion of hexose sugar to ascorbic acid based on the study of Singh and Rao (1983). On the study of Sarika et al 2015, pH of *Ficus religiosa* also varies from 6.9 to 7.9 where they compared commercial, residential and industrial area of Jalgaon city. pH values were also seen comparatively lower in *Ficus religiosa* and higher in *Mangifera indica* in the study of APTI by Joshi et al., 2016. The reduction of ascorbic acid is observed to be more at higher pH. The pollution level or exposure level difference may be the reason for the variant results between the three sites. Low pH decreases the efficiency of hexose sugar conversion to ascorbic acid and the reducing activity of Ascorbic acid is more at higher pH than at lower pH. Thus high pH can provide tolerance to plants against pollutants.

**Total chlorophyll content:**

From the present study, the Total chlorophyll for all the sites showed *Mangifera indica* varies from 1.59 to 2.56, *Ficus religiosa* varies from 0.38 to 0.51, *Artocarpus heterophyllus* varies from 0.85 to 2.24 and *Ficus benjamina* varies from 0.44 to 0.68. Based on the finding, highest value for Total chlorophyll was seen in *Mangifera indica* while lowest pH value was seen in *Ficus religiosa* for all the sites. Higher concentration of chlorophyll are found during monsoon season which could be due to lower concentration of pollution as rainfall are more during the season. Monsoon season showed higher concentration as water content level could improve the chlorophyll level. The difference in sites geographic conditions and trees condition could also be the reason for value difference in different sites. The level of automobiles movement and activities around the sites are also different for all the sites where there are more anthropogenic activities are more, chlorophyll values are more.

Chlorophyll in plants shows photosynthetic activity, growth, accumulation of biomass, and health of plant. (Chauhan and Joshi, 2008). In the study of APTI of plant species in allahabad city by kuddus et al., 2011, *Mangifera indica* also showed highest chlorophyll content than any other plant species, and in the study of Joshi et al., 2016 *Ficus religiosa and mangifera indica* showed higher values with comparision to other species which could be related with the present study. The present studied trees had chlorophyll concentration in low amount. The observed result could be due to the reason of difference of trees species, leaf ages, tree height, canopy type, leaf sizes and shapes. With addition to the difference in the level of exposure against pollution and disturbances, the result differs for all the sites with variation. *Mangifera indica* showed high total chlorophyll content, and showing tolerance to pollution while *Ficus religiosa* with lowest chlorophyll content was seen showing sensitivity behavior for all the sites. The measurement of chlorophyll is an effective way to evaluate air pollutants effects on trees and plants as it has an important role in plants metabolism. If there is reduction in the chlorophyll content, it directly affects the plant growth and senescence.

**Ascorbic acid content:**

Based on the present study, ascorbic acid content for all the sites showed *Mangifera indica* varies from 0.05 to 0.12, *Ficus religiosa* varies 0.18 to 0.24, *Artocarpus heterophyllus* varies from 0.02 to 0.03 and *Ficus benjamina* varies from 0.18 to 0.28. Based on the finding, highest value for ascorbic acid was seen in *Ficus benjamina* while lowest value of ascorbic acid was seen in *Artocarpus heterophyllus* for all the sites. There are differences in values with the difference in seasons since weather condition plays an important role in the leaf conditions. Higher concentration of ascorbic acid in plants shows that they are of exposure to higher concentration of $SO_2$, and shows higher tolerance of the plant. With addition to the difference in the level of exposure against pollution and disturbances, the result differs for all the sites with variation.

From the study of Joshi and Bora (2011), *Mangifera indica* showed higher value of ascorbic acid than other plant species and even *Ficus religiosa*. This can be realted with the present study since the mentioned species also showed higher values when comparing with other tree species. The concentration of ascorbic acid is a good indicator of tolerance of the plant towards air pollution, particularly $SO_2$. Ascorbic acid is a reducing agent which works in conversion of $SO_2$ to sulphite ($SO_3$). Higher concentration of ascorbic acid in plants shows that they are of exposure to higher concentration of $SO_2$, and shows higher tolerance of the plant. It helps trees in protecting the thylakoids structure (and chlorophyll) from reactive oxygen species (Joshi and Bora, 2011). In the present study, we see difference in the ascorbic acid amongst the three sites where it is the highest in the site where maximum pollution is observed i.e. Sikulpuikawn to Bawngkawn site. Since the roadside stretch is busy all day with vehicles and daily activities around the area, the high amount of ascorbic acid content are seen. *Ficus benjamina* had highest concentration of ascorbic acid followed by *Ficus religiosa* , *Mangifera indica*, and *Artocarpus heterophyllus* respectively.

**Air pollution tolerance index (APTI)**

The air pollution tolerance index is an important parameter to determine susceptibility and resistance of tree or plant species against pollutions. Singh and Rao (1983) used four parameters the relative water content of the tree species, pH of leaf extarct, the chlorophyll content of the leaf and ascorbic acid content of the leaf) for the evaluation of the air pollution tolerance index. Therefore, fusing a multiple of parameters give a reliable result as compared than a single biochemical parameter.

From the present study, The Air pollution tolerance index for all the sites showed *Mangifera indica* varies from 8.89 to 11.07, *Ficus benjamina* varies from 7.69 to 9.57, *Ficus religiosa* varies 6.44 to 8.02, and *Artocarpus heterophyllus* varies from 6.28 to 7.63. Based on the finding, highest value for Air pollution tolerance index was seen in *Mangifera indica* while lowest pH value was seen in *Artocarpus heterophyllus* for all the sites. Higher APTI value of plant species are seen in Site 1 since the area is more exposed to pollution and disturbance. On contradiction, lower APTI value of plant species are seen in site 3 since there could be lower pollution level and disturbance. Weather conditions could also play an important role in APTI value difference. APTI values are higher during the monsoon season since there are more rainfall and weather conditions could alter the pollution level in the sites. As anthropogenic activities are highest in site 1 as compared to Site 2 (New capital complex, Khatla) and Site 3(Lalsavunga, park, Hlimen), the value of APTI showed higher respectively. This could be due to Site 1 i.e. Sikulpuikawn to Bawngkawn is the busiest road stretch along Aizawl city and pollution level is also more compared to the other two sites.Most of the tree species that are commonly found in the area are not planted with proper planning and management, therefore the observed result could differ according to the age of the species. *Mangifera indica* are the most common species found in all sites and seasons which have the highest APTI value so it is the most tolerant species found in all the sites. *Artocarpus heterophyllus* have the least APTI value for all the sites and different seasons and could be categorized as sensitive against air pollution. Due to the pollution level and anthropogenic activities difference in all the sites, the values of the same species also differs accordingly.

# CHAPTER - VI

# SUMMARY & CONCLUSIONS

## SUMMARY AND CONCLUSIONS

Air pollution tolerance index is very important measure for air quality as there is continuous increase in vehicles due to urbanization/modernization caused by population explosion in Aizawl city which leads to the increase in air pollution. The studies are very important for proper planning of cities. We can say that the study shows useful information for selecting tolerant species for planning of plantation of vegetation's around the cities and a great measure for urban heat island reduction. Species that are tolerant should be considered in advance for use in plantation around the cities. However, species that are classified as sensitive helps as bio-indicators for improving air quality in urban areas and are still useful. From this study in respect to urban heat island effect is that tree selection for urban heat island reduction should be based on APTI and not just on which are beautiful in leaves and appearance.

Human beings are very dependent on plants in form of photosynthesis, survival and construction materials etc. In every form, we all need a purified form of substance which could be only achieved if plants grow in better conditions. With increase in urbanization and industrialization, increase in the use of private vehicles, deforestation etc. the level of concentration of air pollutants is increasing massively. Aizawl still lacks in the proper planning and plantation of plants. And since it is the capital of the state we need to maintain and plan on its beauty and sustainability. As per present study, APTI is one of the most applicable and dependent tool which may help in a healthy and tolerant plantation of trees. According to these, we can plan and plant trees around us which are highly tolerant to air pollution.

On the present study, tree species that are found at different sites varies greatly, the tree species are documented and observed that trees are not planted uniformly and with proper planning around the cities i.e. site 1 and site 2. Site 3 is also called city forest therefore, trees are natural grown, although most tree species are natural grown in the area, some trees are planted with planning along the approach road of the park i.e. site 3. Sites 1 and 2 also have some areas which are planted in recent years which are of same species along the roadside stretch but only in specific areas. Since roadsides are filled with buildings and institutions, the cause of the un-uniformity of the tree species is also committed.

According to the documented tree species at different sites, the common tree species from all the sites are *Mangifera indica, Ficus religiosa*, *Ficus benjamina,* and *Artocarpus heterophullus*. These species are the most common species that are present in all the sites with the highest frequency of occurrence. These selected species are further evaluated for four biochemical parameters and APTI was calculated. The selected species showed different parameter values and APTI for all different seasons and sites. *Mangifera indica*was found having highest APTI value for all the season and sites whereas *Artocarpus heterophyllus* have the lowest APTI value and was categorized as sensitive species against air pollution. *Ficus benjamina* was also observed to be high in APTI which could be tolerant and could fight against air pollution. The values of Air pollution tolerance index of these tree species varies according to the seasons of pre-monsoon, monsoon and post-monsoon. The conditions such as pollution levels and population activities of the site also plays an important role in the value of APTI for air pollution.

Based on the findings of the present investigation, the following conclusions are made:

1) Tree species present in all the sites are diverse and not uniform without proper planning and management.

2) Trees species selected for APTI evaluation that are common to all sites showed different values in parameter according to the conditions such as weather, pollution level, human activities.

3) The four parameters i.e. relative water content, total chlorophyll, pH of leaf and ascorbic acid content varies in values with seasons (pre-monsoon, monsoon and post-monsoon).

4) Different sites i.e. Sikulpuikawn to Bawngkawn, New capital complex, Khatla and Lalsavunga Park, Hlimen showed different values in all the parameters and APTI which could be due to geographic differences, anthropogenic activities, pollution levels and populations.

5) Monsoon season showed higher values in all the parameters and APTI which could be due to weather conditions and pollution levels. Post-monsoon

also showed closer to monsoon and pre-monsoon showed the least with comparison to other seasons.

6) Based on the APTI value, *Mangifera indica* and *Ficus benjamina* are categorized as tolerant species whereas *Ficus religiosa* and *Artocarpus heterophyllus* are categorized as sensitive species against air pollution.

7) With the evaluation of APTI, Site 1 (Sikulpuikawn to Bawngkawn) showed the highest value and the tree species along the roadside of this area are more exposed than the other two sites. Site 2 showed slightly similar conditions since it is government office areas with all-day anthropogenic activities. Site 3 (Lalsavunga Park, Hlimen) showed the lease since it is a controlled area with high tree density and less activities around the area.

8) The tolerant species could be planted as a mitigation measure against air pollutions along the roadside with proper planning and management. Sensitive species could also be used as a bio-indicator for mitigating against air pollution.

**Recommendations:**

In light of the outcome of present study, it can be recommended that-

1) Vehicle movements and numbers should be controlled so that air pollution level could decrease accordingly to mitigate air pollution

2) Proper planning and management of tree species along the roadside could be implemented for better environment and air quality.

3) Nursery could be planned along the roadside where buildings are more for supplementing with greenery

4) Awareness of air pollution and vehicle overexploitation and use should be given properly for future control.

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## PHOTO PLATES

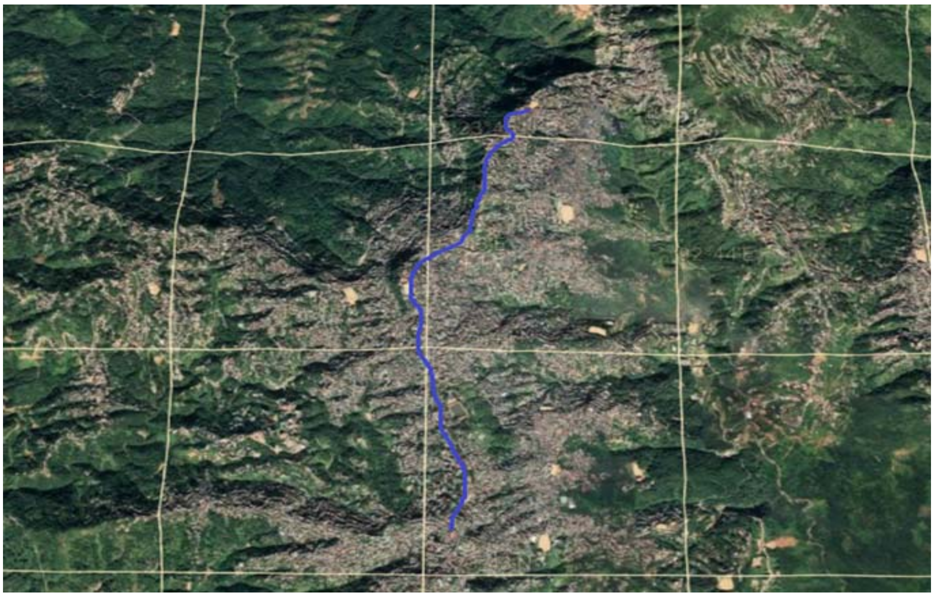

Photo 1: Map of study area (Sikulpuikawn to Bawngkawn)


Photo 2: Map of study area (New capital complex, Khatla)


Photo 3: Map of study area (Lalsavunga Park, Hlimen)

Photo 4: Lalsavunga Park area, Hlimen


Photo 5: Leaves of *Artocarpus heterophyllus*


Photo 6: Leaves of *Ficus benjamina*

Photo 7: Leaves of *Ficus religiosa*

Photo 8: Leaves of *Mangifera indica*

# BIO- DATA

## A) PERSONAL INFORMATION:

| | | |
|---|---|---|
| NAME | : | John Lianngura |
| FATHER'S NAME | : | C. Lalrinliana |
| MOTHER'S NAME | : | H. Lalchhingpuii |
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## B) EDUCATIONAL QUALIFICATIONS:

| Sl No. | Name of Examination | University/Board | Year of Passing | Percentage/ Grade |
|---|---|---|---|---|
| 1 | HSLC | MBSE | 2008 | 72% |
| 2 | AISSCE | CBSE | 2010 | 69% |
| 3 | B.Sc. | Delhi University | 2016 | 55.70% |
| 4 | M.Sc. | Amity University | 2018 | 77.8% |

## PARTICULARS OF THE CANDIDATE

| | | |
|---|---|---|
| NAME OF CANDIDATE | : | JOHN LIANNGURA |
| DEGREE | : | Master of Philosophy |
| DEPARTMENT | : | Environmental Science |
| TITLE OF DISSERTATION | : | Assessment of Air pollution tolerance index of roadside plants in vicinity of Aizawl, Mizoram |
| DATE OF PAYMENT OF ADMISSION (Commencement of First Semester) | : | 1/08/2019 |
| COMMENCEMENT OF SECOND SEM/ DISSERTATION (From conclusion of end semester exams) | : | 1/02/2020 |
| APPROVAL OF RESEARCH PROPOSAL | | |
| DRC | : | 18/03/2020 |
| BOS | : | 18/05/2020 |
| SCHOOL BOARD | : | 29/05/2020 |
| MZU REGISTRATION NO. | : | 1905394 of 2021 |
| M.Phil. REGISTRATION NO. & DATE | : | MZU/M.Phil. /585 of 29.05.2020 |
| DATE OF SUBMISSION | : | 15/12/2021 |
| EXTENSION (IF ANY) | : | One semester (Till 31/07/2021) |

Head
Department of Environmental Science

**PAPER PRESENTED**

1) “Assessment of Air Pollution Tolerance Index of Road Side Plants of Sikulpuikawn to Bawngkawn, Aizawl, Mizoram”. 2nd Annual Convention of North East (India) Academy of Science and Technology (NEAST) & International Seminar on Recent Advances in Science and Technology (IRSRAST) held during 16th–18th November 2020 (Virtual) organized by NEAST, Mizoram University, Aizawl, Mizoram (India).

# 2nd Annual Convention of

North East (India) Academy of Science and Technology (NEAST)

&

## International Seminar on Recent Advances in Science and Technology (ISRAST)

($16^{th}$ -$18^{th}$ November 2020)

(Virtual)

11215150243

*Certificate*

This is to certify that

**Mr./Ms./Dr./Prof. John Lianngura**

**Department of Environmental Science, School of Earth Science and Natural Resources Management Mizoram University, Tanhril, Aizawl–796009**

*has attended and presented an Oral Presentation entitled, "Assessment of Air Pollution Tolerance Index of Road Side Plants of Sikulpuikawn to Bawngkawn, Aizawl, Mizoram" in the 2nd Annual Convention of North East (India) Academy of Science and Technology (NEAST) & International Seminar on Recent Advances in Science and Technology (IRSRAST) during 16th-18th November 2020 (Virtual) organized by NEAST, Mizoram University, Aizawl-796004, Mizoram (India).*

| | |
|---|---|
| Prof. Diwakar Tiwari | Prof. R. Lalthantluanga |
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North East (India) Academy of Science & Technology (NEAST), Mizoram University, Aizawl-796004 (India)

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