

Use of Leaves as Bio-Indicator to Assess Air Pollution Tolerance Index (APTI) And Elemental Concentration of Heavy Metals at Katsina Central Market Grinding Area, Katsina State-Nigeria

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ABSTRACT

Monitoring air pollution and environmental health are essential to ensure viable cities. Air pollution Tolerance Index (APTI) is used to assess how tolerant plant species are of air pollution, it can also serve to identify tolerant plant species that can be useful for pollution removal. APTI is calculated from parameters that are affected by air pollutants, such as ascorbic acid content, total chlorophyll content, relative water content, and P_H of leaf extract. In this study, we compared APTI values of *Ficus citrifolia* leaves between control and grinding areas. The results revealed that APTI value of *F. citrifolia* leaves in the control area is high compared to that from the grinding site. Heavy metal concentrations were also studied. Correlation between APTI values and elemental concentrations indicated that *F. citrifolia* leaves were sensitive to air pollution. Thus, the APTI of tree leaves is useful proxy measure of air pollution.

Keywords : Urban Pollution, Grinding, *Ficus Citrifolia*, Leaves, Heavy Metals, Tolerance Index

I. INTRODUCTION

Air pollution is a growing problem worldwide and it is especially serious in large cities. With the speed of urbanization and industrialization in the past decades, pollution emitting sources have increased both in number and intensity. Urban growth is expected to continue; therefore, large scale urban planning and development projects are urgent challenges (Alhowaish, 2015).

Among air pollutant, the issue of particulate matter deserves particular attention because of its adverse health effects (Sierra-vargas, 2012). Dust originated

from anthropogenic activities is a major concern due to the heavy metals usually found in these particles (Mafugai, 2014). Heavy metals accumulate in human body, and they are toxic even at a relatively low level (Costa, 2012). Heavy metals also pose an ecological risk to plants, such as trees in urban habitats (Nadgorska-Socha, 2017). There is considerable uptake from the soil via the root system, but certain atmospheric depositions were also possible (Mirecki, Agaric, Sanic and Milenkovic, 2015).

Trees provide an alternative way of monitoring urban air quality due to their constant exposure and cost-effective sampling. The Air Pollution Tolerance Index

(APTI) was proposed by Singh, Rao, Agrawal, Pandey and Naryan (1991). It is an index provided to express the capacity of plants to counter the adverse effects of air pollution. APTI is a composite measure of tree-health, it is calculated from ascorbic acid content of leaves, total chlorophyll content, P_H of leaf extract and relative water content. These parameters are affected by air pollutants making APTI an especially useful tool to assess air pollution (Alotaibi, Alhaibi, AL-Shamsi, Shahrani and Namazi, 2020). APTI can give information about the pollution level of cities based on plants. Based on APTI, the most tolerant and best suited plants to protect against pollution can be selected and the sensitive plant species can also be used as bio - indicators (Karmakar, 2019).

A reduction in chlorophyll content can be induced by SO_2 pollution and dust deposition on the surface of the leaf (Aleksandra, Marta, Michal and Gabriel, 2017). Ascorbic acid is an antioxidant, its concentration increases with auto exhaust and industrial pollution rates. Acidic air pollutants decrease leaf extract P_H . Relative water content shows varying responses to pollution among plant species based on general tolerance, although higher water content helps to maintain the physiological balance of plants under stress (Vanda, Edina, Bela, Sarawut and Szilard, 2020).

APTI and each of its parameters were found to vary among the land use type, as urbanization and industrialization activities can cause severe contamination. Overall plant tolerance usually increases in response to anthropogenic pollution at urban and industrialization sites (Kuddus, Kumari and Ramteke, 2011).

Heavy metal is any relative dense metal that is noted for its potential toxicity especially in environmental context. The term has particular application to cadmium, lead, mercury and arsenic. All of which appears in the world health organization list of ten

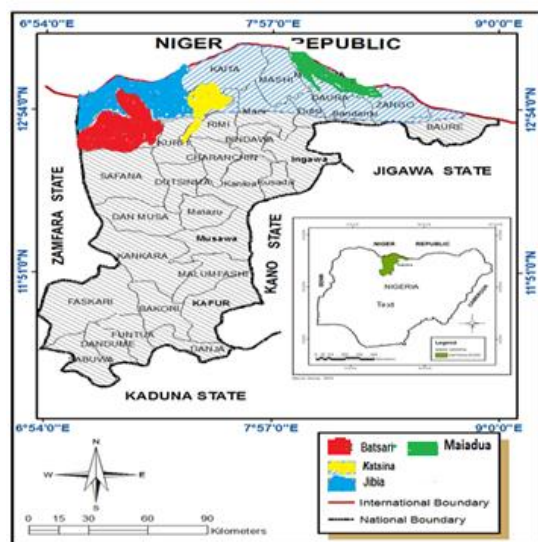
chemicals of major public concern (WHO, 2011). Other examples are chromium, manganese, nickel, cobalt and zinc. Heavy metals cannot be degraded or destroyed, to small extent, they enter our bodies via food, drinking water and through air as a result of air pollution due to anthropogenic activities such as exhaust from vehicles or grinding machines (Duffus, 2002). Heavy metals are dangerous because they tend to bio-accumulate. They bind to vital cellular components of the body such as structural protein, enzymes and nucleic acids and interfere with their functions. Long term exposure to toxic heavy metals may lead to carcinogenic, central and puerperal nervous system effects for human (Balrd, 2012).

The aim of this study was to assess the level of air pollution based on the parameters of tree leaves under increasing anthropogenic impacts. Our hypotheses were; The elemental concentration on tree leaves would increase at urban study site compared to resident/control areas, there would be correlation between APTI value and other parameters such as fine and coarse dust and the elemental concentrations in the leaf tissue, and the APTI values of leaves would reflect the air quality as a composite proxy measure to assess the level of air pollution in grinding areas.

II. Materials and Methods

2.1 Sampling Sites

The study was conducted in Katsina State, Northern Nigeria. Katsina State is located between latitudes $11^{\circ}08'N$ and $13^{\circ}22'N$ and longitudes $6^{\circ}52'E$ and $9^{\circ}20'E$. The state covers an area of 23,938 sq km and lies in the Northern Nigerian Sahelian Savannah. The state is bordered by Niger Republic to the North, Jigawa and Kano States to the East, Kaduna State to the South and Zamfara State to the West. The state has 34 Local Government areas.



Map of Katsina State showing study areas

**Figure 1 : Map of Katsina Showing the Study Area**

2.2 Samples Collection and Preparation

The leaves sample was collected from katsina central market grinding area, katsina state. The control sample was collected from the biological garden Umaru Musa Yar'adua university, katsina Nigeria, where it has been identified.

2.3 Sample Treatment

The sample were washed and rinsed several times with deionized water to remove the surface contaminations. The sample was cut into pieces using stainless steel knife and dried indoor for two weeks and then grinded into fine powder using laboratory mortar and pestle. the sample was then sieved.

2.4 Chemical Analysis

2.4.1 Ascorbic Acid Determination

0.5g of fresh leaf sample was homogenized with 20 ml of extraction solution, which was made by mixing 5.0 g oxalic acid and 0.75 g of EDTA in 100 ml distilled water. To collect the supernatant, the above solution was centrifuged at 10,000 rpm (rev/min) for 30 min. 1 ml of supernatant solution was added to 5 ml of 2,6-dichlorophenol indophenol (DCPIP) (prepared by adding 6.0 g of DCPIP in 200ml distilled water) and mixed by vibration. When the solution turned pink, a spectrophotometer was used to measure absorbance at 520 nm (E_s). A few drops of 1% ascorbic acid were added to the mixture for total removal of pink color, and absorbance was then measured once again at 520 nm (E_t). blank was made by mixing extract solution and DCPIP (E_0) (Adnan, Sajid and Maroof, 2023).

Ascorbic acid content is determined by;

$$\text{Ascorbic acid (mg/g)} = [E_0 - (E_s - E_t)] \times V/W \times V1 \times 1000$$

Where W = Fresh leaf weight, V1 = Supernatant solution volume, V = Volume mixture

2.4.2 Chlorophyll Content Determination

1.0 g of leaf sample, 10 ml of 80% acetone was used to extract chlorophyll. At 645 nm and 663 nm, the filtered extract's absorbance was measured spectrophotometric ally (Adnan, Sajid and Maroof, 2023). The formula for the calculation;

$$\text{Total chlorophyll (mg/g)} = [(20.2 \times A_{645}) + (8.02 \times A_{663}) \times V] / 1000 \times W$$

Where A_{645} = Absorbance at 645 nm, A_{663} = Absorbance at 663 nm, V = Total volume of extract, W = Fresh leaf weight in gram.

2.4.3 Relative Water Content (RWC)

Fresh weight of entire leaves was measured instantly (initial weight). Then leaves were soaked in water overnight and dried off, so weight can be measured to determine their saturated weight. Same leaf sample were placed in oven at 80°C for 24 h to measure oven dry weight (Adnan, Sajid and Maroof, 2023). The formula which was mentioned below was used to determine RWC;

Relative water content (%) = $\left[\frac{\text{Initial weight} - \text{Dry weight}}{\text{Saturated weight} - \text{Dry weight}} \right] \times 100$

2.4.4 Leaf P_H Determination

50 ml of distilled water was used to homogenize 5.0 g of leaf sample to determine the P_H of the suspension, which was then determined by using digital P_H meter (Adnan, Sajid and Maroof, 2023).

2.4.5 Air Pollution Tolerance Index (APTI)

Air pollution tolerance index was measured by the used of the following formula as described by Singh and Rao (1983).

$$\text{Air Pollution Tolerance Index} = \frac{[A(T + P) + R]}{10}$$

A = Ascorbic acid content (mg/g). P = P_H of leaf extract.

T = Total chlorophyll content (mg/g). R = Relative water content of leaf (%).

2.4.6 Heavy Metals Determination

2.0 g of leaves sample was weighed in 250 cm³ beaker and 20 cm³ of 15.6 m nitric and hydrochloric acid (1:3) was added. The mixture was digested on a hot plate and clear solution was observed, the beaker was

cooled and the content was diluted with 20 cm³ deionized water, filtered and made up to mark in 100 cm³ volumetric flask. the blank solution was prepared using the same procedure but without sample. The solution was analyzed for cadmium, lead, chromium and nickel using Atomic Absorption Spectrophotometry Analysis (AAS) (Patience, 2014). Working standards of 0.2 ppm, 0.5 ppm, 1 ppm, 2 ppm and 5 ppm was prepared for each metal to be analyzed. Calibration curves for the different metals was plotted using the result obtained from the working standards. The concentrations of the metals were obtained from the calibration curves (Patience, 2014).

III. Results and Discussion

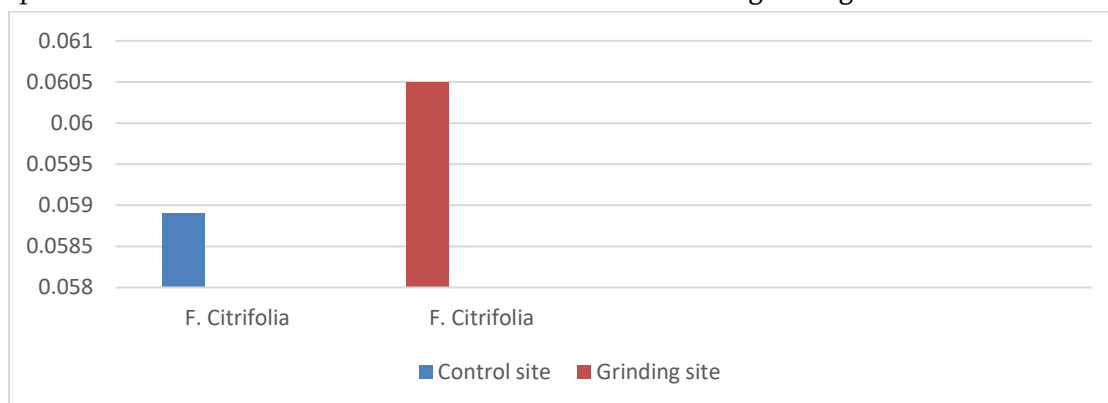
The four biochemical parameters (ascorbic acid content, P_H, RWC and Total chlorophyll content) were used to estimate the APTI value shown in (Table 1) as the method is simple and less costly as compared to other methods used to forecast air pollution.

Table 1 Comparison of Biochemical Parameters of *F. citrifolia* Between Control and Grinding Area

Plant species	Control site					Grinding site				
<i>F. citrifolia</i>	RWC (%)	TCC mg/g	AA (mg/g)	P _H	APTI	RWC (%)	TCC mg/g	AA (mg/g)	P _H	APTI
	90.1250	1.7560	0.0589	6.50	9.061	80.0970	0.65530	0.0605	4.67	8.042

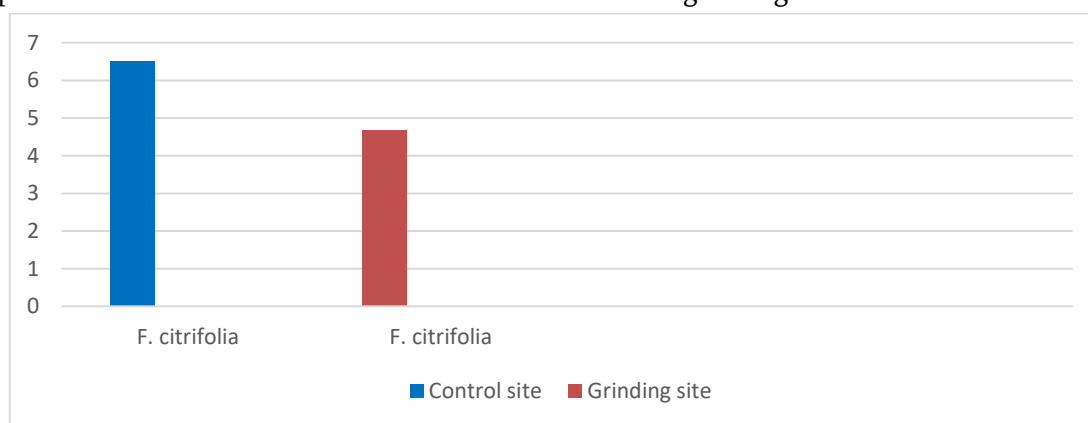
3.1 Ascorbic Acid (mg/g)

Ascorbic acid has strong reducing power, that is dependent on P_H because ascorbic acid is the primary redox buffer and activate variety of physiological mechanisms, including photosynthesis and generation of other antioxidants (Bhadauria, Dixit and Singh. 2022). Plants with high concentration of ascorbic acid and P_H are more resilient to air pollution than those with lower concentration (Verma, Singh and Sharma. 2023). In our present results of ascorbic acid as presented in the fig. 2, it shows significant difference between control and grinding site. *F. citrifolia* leaves of control site has the value of (0.0589 mg/g) and that of grinding area has (0.0605 mg/g). this implies that *F. citrifolia* leaves is sensitive to air pollution which is similarly explained by Adnan, Sajid and Maroof, 2023 that ascorbic acid is natural detoxifier which play a vital role in reducing the air pollution effect in plant tissue.

Fig. 2. Comparison of ascorbic acid of *F. citrifolia* leaves in control and grinding area.

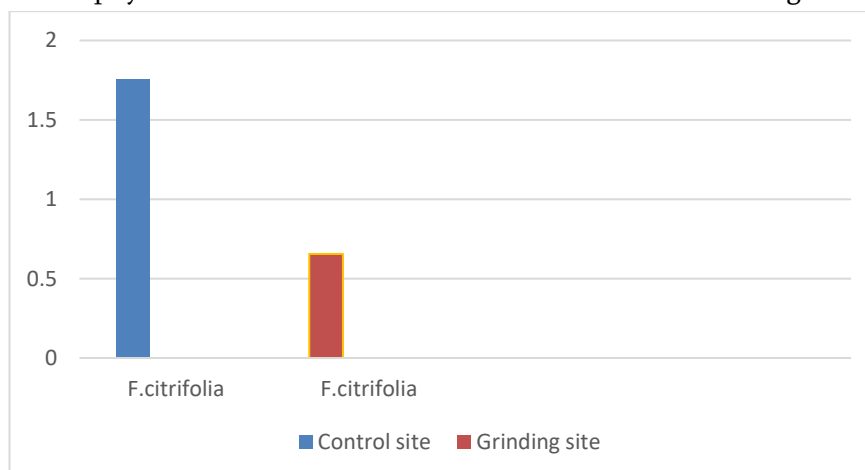
3.2 P_H

The result of P_H parameters shown in fig.3. The results revealed that *F. citrifolia* leaves of control area has 6.50 and that of grinding site has 4.67. According to (Gupta, Bisht and Gautam, 2022) low P_H show good correlation with air pollution sensitivity which reduce the photosynthesis.

Fig. 3 comparison of P_H values of *F. citrifolia* leaves in control and grinding area.

3.3 Total Chlorophyll Content (TCC) (mg/g)

Total chlorophyll content was revealed in fig.4. The data shows that *F. citrifolia* leaves of grinding area has the lower value of (0.65530 mg/g) compare to that of control area which has (1.7560 mg/g). (Timilsina, Dong, Hassanuzzaman, Lui and Hu. 2022) described that the concentration of chlorophyll level in plants decreases under pollution stress. Hence, synthesis or degradation linked with the concentration of SO₂.

Fig. 4 comparison of chlorophyll content values of *F. citrifolia* leaves in control and grinding area.

3.4 Relative Water Content (RWC) (mg/g)

The results of RWC is shown in fig. 5. Fig. *F. citrifolia* leaves of control site shows (90.1250%) while that of grinding site shows (80.0970%). Our finding for RWC is similar with that of (Kuddus, Kumari and Ramteke. 2011) & (Barjoe, Malverdi, Kouhkan, Alipourfard, Rouhani, Farokhi and Khaledi. 2023) who reported that air pollutants increase cell permeability, which causes water and dissolved nutrients being lost and early leaf senescence occur as a result.

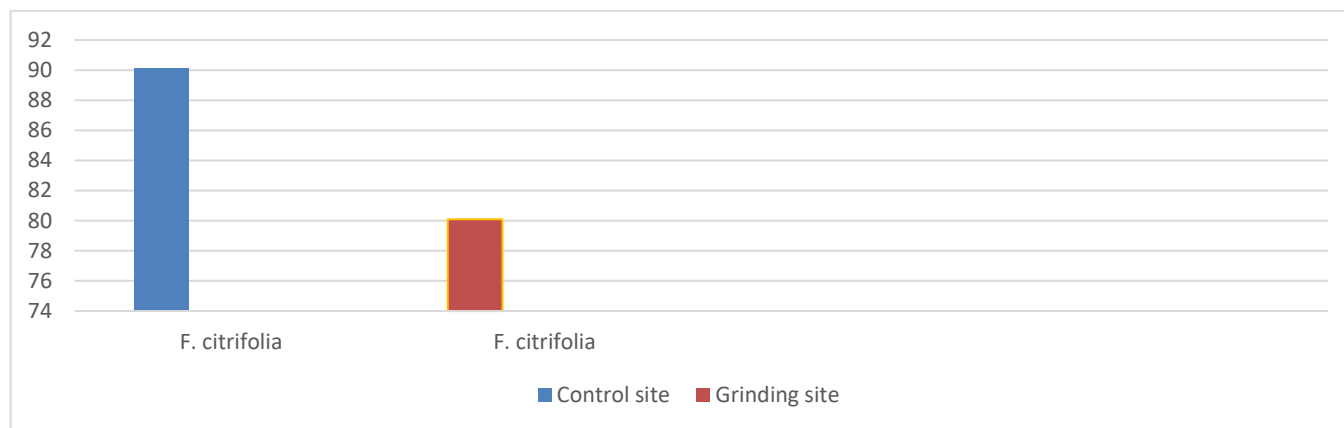


Fig. 5 comparison of RWC values of *F. citrifolia* leaves in control and grinding area.

3.5 Air Pollution Tolerance Index (APTI)

Fig. 6 shows that the APTI value of control site is higher (9.061) compared to grinding site (8.042). This indicate that *F. citrifolia* leaves have sensitive degree to air pollution. Thus, low APTI value indicated that plant is susceptible to pollution while high value means plant is tolerant to it (Sadia, Jeba, Uddin and Salam, 2019). Thus, grinding site *F. citrifolia* leaves are suffering from a more severe case of air pollution as a result of emissions from grinding machines when compared with control site which is heavily planted and there is no industrialization (grinding activities).

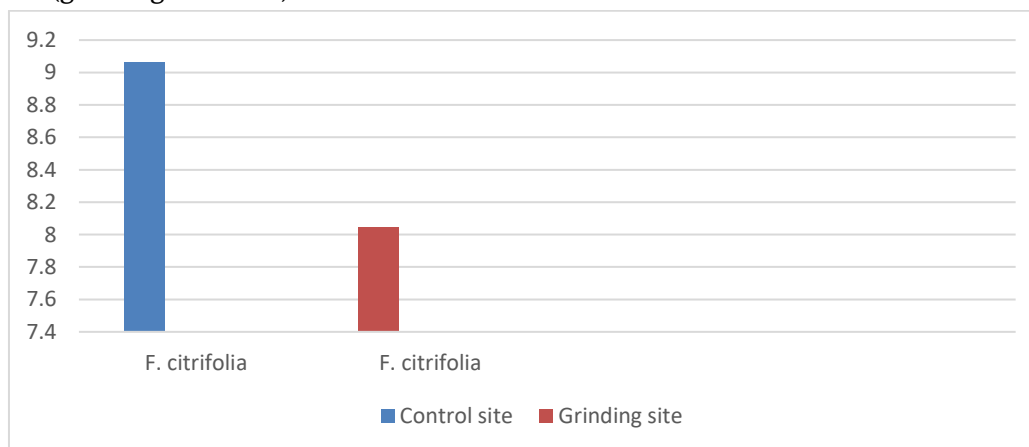


Fig. 6 Comparison APTI values of *F. citrifolia* leaves in control and grinding area.

3.6 Heavy Metals

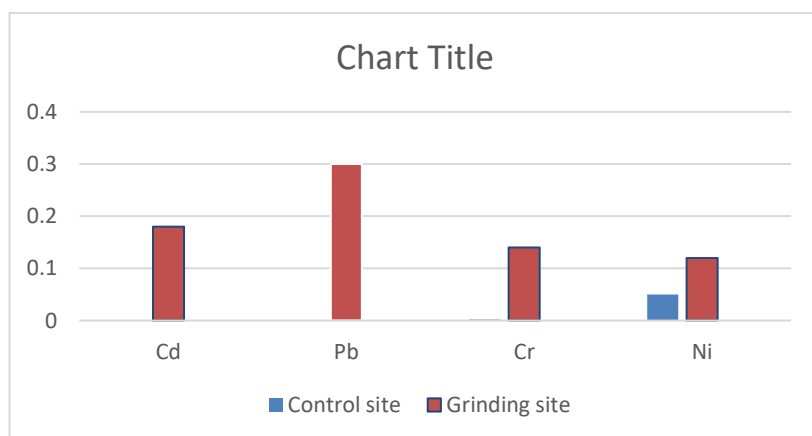
Average heavy metal concentrations (Cd, Pb, Cr, and Ni) in the leaves sample of *F. citrifolia* for both control and grinding site were presented in Table 2,3 and fig 7 respectively.

Table 2 Average Concentrations (mg/kg) $\pm$ SD of Heavy Metals at Control Site

Plant species	Control site			
<i>F. citrifolia</i>	Cd	Pb	Cr	Ni
	0.001 $\pm$ 0.009	0.0014 $\pm$ 0.02	0.0021 $\pm$ 0.005	0.05 $\pm$ 0.009
WHO				
Permissible limit	0.3mg/kg	0.01mg/kg	0.1-0.2mg/kg	0.1mg/kg

Table 3 Average Concentrations (mg/kg) $\pm$ SD of Heavy Metals at Grinding Site

Plant species	Control site			
<i>F. citrifolia</i>	Cd	Pb	Cr	Ni
	0.18 $\pm$ 0.09	0.30 $\pm$ 0.02	0.14 $\pm$ 0.03	0.12 $\pm$ 0.04
WHO				
Permissible limit	0.3mg/kg	0.01mg/kg	0.1-0.2mg/kg	0.1mg/kg

**Fig. 7 Heavy metal concentration *F. citrifolia* leaves in control and grinding area.**

3.6.1 Cadmium

Cadmium is of no use to the body and is toxic even at low level. The negative effect of cadmium on the body are numerous and can impact nearly all the system in the body including cardiovascular, reproductive system, kidney eyes and even brain (WHO, 2014). Cadmium enter our body via food, drinking water and air due air pollution (industrialization or exhaust from vehicles) (Duffus, 2002). Results from our finding indicated that concentration of Cd in *F. citrifolia* leaves of control site is lower 0.001 mg/kg compared to grinding site 0.18mg/kg. Higher concentration in grinding site may

be as a result of exhaust from grinding machines. Even though, level of Cd in grinding site was found to be below HWO permissible exposure limit 0.3mg/kg, but long term exposure may lead to bioaccumulation. (Zainab and Talib, 2020) reported that the amount of Cd absorbed by the trees from environment is larger than the small plants. It is due to the industrial activities. They reported the concentration of Cd in *F. carica* of Muthana area to be 0.0588mg/kg.

3.6.2 Lead

Lead is highly poisonous metal (whether swallowed or inhaled), affecting almost every organ and system in the body. Exposure to lead chemical primarily occurs through ingestion to lesser extent inhalation

and occasionally by direct contact. Part of lead toxicity result from its ability to mimic other metals which act as cofactors in many enzymatic reaction, displacing them at the enzymes on which they act (Hodel and Chang, 2004). From the results obtained, the concentration of Pb in *F. citrifolia* leaves of control site was found to be 0.0014mg/kg and that of grinding site is 0.30mg/kg. The level of Pb at grinding site is above the WHO permissible exposure limit 0.01mg/kg, which is a matter of concern due to acute and chronic toxicity of Pb at trace level. Pooja, Richa, Supriya, Vinay and Dinesh, 2018 reported that Pb concentration in plant leaves and vegetables grown in industrial and urban areas have increased in recent decades owing to human activities and road traffic. According to their findings, Pb in *ficus* leaves samples collected from roadsides had shown that concentration of Pb was significantly above WHO permissible limit. The concentration ranges from 2.5-14.1mg/kg.

3.6.3 Chromium

Chromium at an elevated level is toxic for both plants and animals. Most of Cr present in food is in trivalent form [Cr(III)] which is essential nutrient, but in hexavalent form [Cr(VI)] is toxic, which can be sourced by combustion of fuels. This is occurring through the oxidation of chromium present in fuel additives or from wear on engine parts containing chromium (Patience, 2014). The concentration of Cr from *F. citrifolia* leaves of control site was found to be 0.0021mg/kg. The value is low compared to grinding site 0.14mg/kg which agreed with WHO permissible exposure limit 0.1-0.2mg/kg. According to (Sadeeq, Qingling, Shiyong, Amin, Hafiz, Adeel, Gang and Hefa, 2023), chromium is released into the environment through anthropogenic activities and has gained significant attention in the recent decades as environmental pollutant.

3.6.4 Nickel

Humans are exposed to nickel by breathing air, drinking water, food and smoking cigarettes. Symptoms of excess nickel include weakness, fatigue, nausea and headache (Smith, Illustre and Osterloh, 2012). Concentration of nickel in *F. citrifolia* leaves of control site was found to be 0.05mg/kg while that of grinding site is 0.12mg/kg. The result of control site is far below WHO permissible exposure limit 0.1mg/kg while that of grinding site agreed with the limit. Husain, Khan, Khan and Wulli uli, (2006) reported to have 0.22 mg/kg in the leaves of *D. alba* obtained from roadside. This value may be due to the constant contact between vehicle exhaust and leaves samples.

IV. CONCLUSION

Trees are constantly exposed to air pollutants; these pollutants build up inside them. The leaves natural characteristics are changed and they become more vulnerable to pollution as a result. Both Plant and human being lives are threatened by pollutants from anthropogenic activities such as emission from grinding machines. The sensitivity of plants leaves to air pollution can be determine using air pollution tolerance index (APTI). However, in this study, APTI (ascorbic acids content, total chlorophyll content, P_H and relative water content) parameters and elemental concentration of *Ficus citrifolia* leaves from grinding and control areas were determined. Our findings demonstrated that *F. citrifolia* leaves of grinding site indicates high pollution levels due to biochemical parameters being altered when compared to control site. Therefore, leaves can be used as reliable bio-indicators of urban air pollution. Correlation between APTI values and elemental concentration confirmed that APTI efficiently indicated the level of air pollution. *F. citrifolia* leaves were sensitive based on their average APTI values. Thus, APTI values can be used to select pollution tolerance species used for green belt development. A plant species with lower

APTI value are useful as bio-indicators of air pollution and as proxy for urban health.

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