Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 11 [11] October 2022 : 77-85

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

ORIGINAL ARTICLE **OPEN ACCESS**

Comparative assessment of Air Pollution Tolerance Index (APTI) of two common plants in three differently polluted areas of Jodhpur

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ABSTRACT
Bioindicators are used to assess environmental conditions which help diagnose and monitor impact of pollutant on the environment and ultimately, human. In this studytwo plants- Neem (Azadirachta indica) and Eucalyptus were assessed for Air Pollution Tolerance Index (APTI) at 3 different sites with varied level of air pollution, for a duration of six months (June 2021 to November 2021).Thethree sampling sites, classified as residential, industrial and highway side reported maximum APTI for neem (8.46) and eucalyptus (8.92) at highway side, while minimum APTIfor neem (8.23) and eucalyptus (7.50) was observed at residential area. Results show that both Neem and Eucalyptus are relatively more tolerant at Highway side as compared to Residential area sampling site, and thus have potential to be utilised as bioindicators.
Keywords:Air Pollution Tolerance Index (APTI), Air pollution, India, Jodhpur, Phytoremediation, Neem (*Azadirachta indica*), Eucalyptus.

Received 14.09.2022 Revised 30.09.2022 Accepted 14.10.2022

INTRODUCTION

Air pollution is caused due to introduction of particulates and other harmful substances in earth's atmosphere. Based on origin of air pollutants, they can be categorised in primary and secondary pollutants. While primary pollutants are emitted directly from the source in atmosphere, secondary pollutant are formed as a result of further reactions on primary pollutants in the atmosphere [1].
An estimate of 1.6 million deaths in 2019 in India — the highest in the world, have been caused by air pollution[2].
Several mitigation strategies have been deployed in order to combat air pollution, but majority of them require sizeable inputs, skilled labour and higher maintenance cost, which make Phytoremediation desirable, profitable and aesthetic choice among all the available options [3].
Phytoremediation of air pollutants in terms of creating green belts and buffer zones in and around industrial settlements is quite common practice, which is now being extended as urban forestry in urban areas to deal with rampant worsening air quality events [4].
Worse or poor air quality events are associated with substantial pollutant load, which create stress response [5] in plants of such belts or buffer zone.
Therefore, a need to design these green zones resulted in a quest to search of plants which were tolerant to air pollution.
This led to assessing Air Pollution Tolerance Index (APTI) of plants – plants with higher score were recommended as sink for pollutants, while the ones with lower score were recommended as bio-indicator of air pollution in that area.
Pertaining to the fact that Industrial areas face relatively more polluted air quality events as compared to Residential area, and with rapid urbanisation, need of commute and cargo transport has headed to a swift

rise in number of vehicles– this study considered three sampling sites: a Residential area, an Industrial area and a Highway side, to comparatively assess tolerance of two commonly found plants in this region: Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus* spp.).

MATERIAL AND METHODS

1. Area of Study

Jodhpur, located between 26.28° North latitude and 73.02° East longitude, is the second largest district of the state Rajasthan. Also known as the Gateway to the Thar desert, climate of the district in general is hot and dry- spans across 11.6% of the total arid zone of the state. Jodhpur frequently records temperature exceeding 40 degrees Celsius in months April to June and receives average rainfall around 360 millimeters.

The study was held at 3 different sampling sites of Jodhpur – Residential (Fig 1), Industrial (Fig 2) and Highway side (Fig 3).

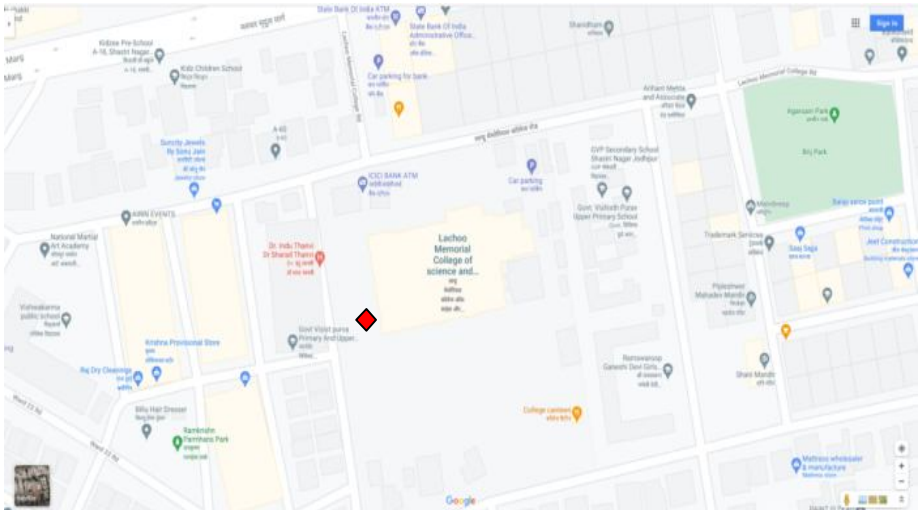

Fig 1: Residential area sampling site.

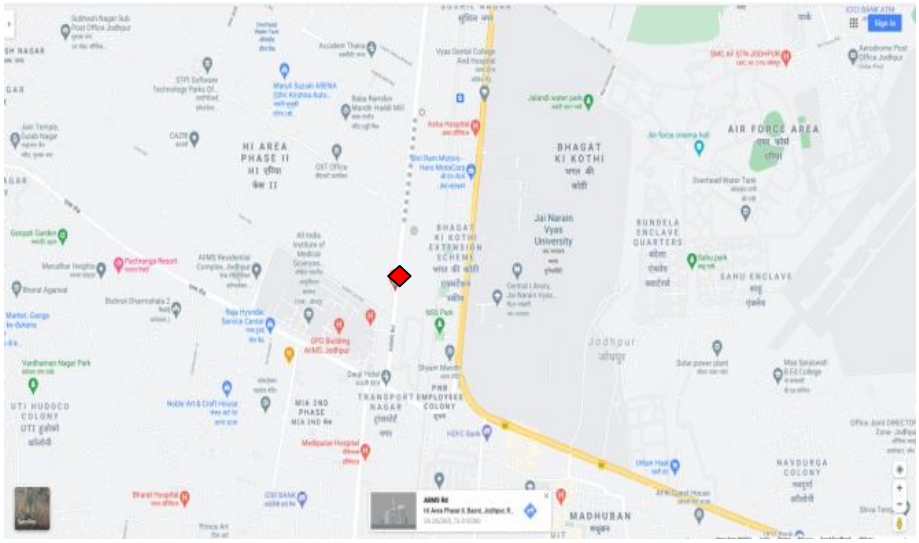

Fig 2: Industrial area sampling site.

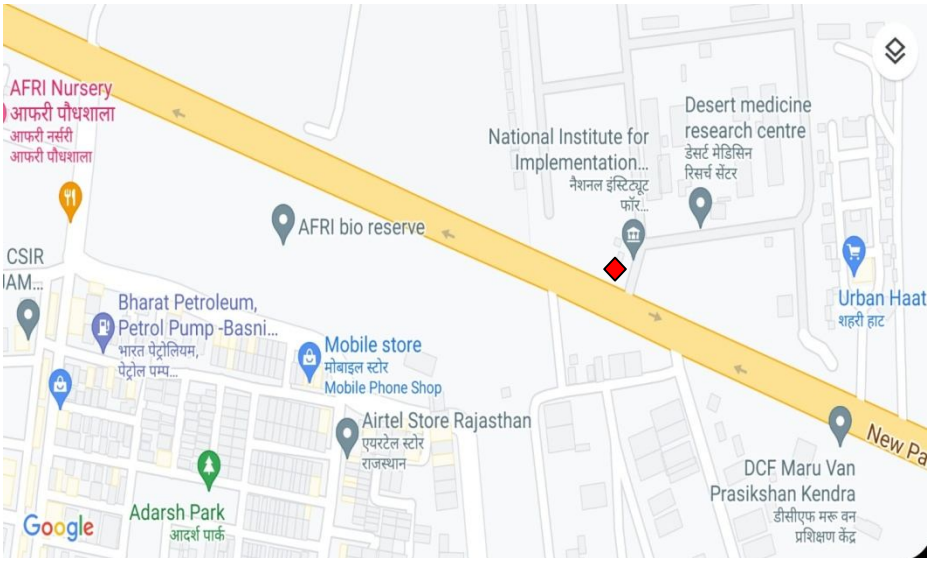

Fig 3:Highway side sampling site.

Sampling Procedure

Two plants, which were common to all three sampling sites were selected for APTI analysis. These were Neem (*Azadirachta indica*) and Eucalyptus (*Eucalyptus* spp). Mature leaves of the plants, about 2 meters from ground were collected once a month, in morning hours (between 08:00 to 09:00 AM) at each sampling site from June 2021 to November 2021. These freshly collected leaves were sealed in polyethylene bag to prevent loss of moisture, brought to lab and subjected to Total Chlorophyll, Ascorbic acid, Relative water content and pH estimation in their fresh form, to avoid variation in results by the following methods – pH by pH meter (Systronics water analyzer Model371), analysis of total chlorophyll was performed according to method described by [6], titrimetric estimation of Ascorbic acid was performed using 2, 6 Dichlorophenol indo phenol dye, Relative water content and APTI calculation were performed according to method described by [7].

The parameters mentioned above were calculated using formulas:

Total Chlorophyll:

$$\text{Total Chlorophyll } (\text{mg}/g) = \frac{20.2 * (A_{645}) + 8.02 * (A_{663}) * 25(V)}{1000 * 1\ (W)}$$

Where, A=Absorbance of the extract at the wavelength (nm), V=total volume of the chlorophyll solution (ml), and W=weight of the tissue extract (g).

Ascorbic Acid:

Ascorbic acid content of the samples were analysed by titrimetric method using 2,6- Dichlorophenol Indo phenol Dye.

Relative Water Content (%):

$$\text{Relative water content (\%)} = \frac{F - D}{T - D} * 100$$

Where, F=Fresh weight (gm), T=Turgid weight (gm), D=Dry weight (gm)

pH:

pH was measured using pH meter.

Air Pollution Tolerance Index:

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

Where, A=Ascorbic Acid content (mg/g), T=TotalChlorophyll content (mg/g), P=pH of leaf extract andR=Relative Water content of leaf (%).

Classification of plants was done according to APTI value[8] (Table 1)

APTI value	Air pollution tolerance status
Less than 1	Highly sensitive
Between 1 - 16	Sensitive
Between 17-29	Intermediate tolerant
Between 30 -100	Tolerant

Table 1: Classification of plants according to APTI values.

RESULTS AND DISCUSSION

The results were obtained as follows:

Total chlorophyll

Month	Residential (mg/g)	Industrial (mg/g)	Highway side (mg/g)
June, 2021	0.28	0.17	0.19
July, 2021	0.39	0.38	0.29
August, 2021	0.37	0.29	0.23
September, 2021	0.36	0.25	0.27
October, 2021	0.38	0.27	0.48
November, 2021	0.36	0.38	0.36

Table 2: Total chlorophyll content of Neem at three sampling sites.

Month	Residential (mg/g)	Industrial (mg/g)	Highway side (mg/g)
June, 2021	0.45	0.38	0.11
July, 2021	0.30	0.25	0.15
August, 2021	0.47	0.32	0.17
September, 2021	0.24	0.21	0.12
October, 2021	0.40	0.21	0.21
November, 2021	0.46	0.24	0.20

Table 3: Total chlorophyll content of Eucalyptus at three sampling sites.

Total chlorophyll content is sum total of photosynthetic pigments chlorophyll A and chlorophyll B [26]. Its content depends upon photosynthetic rate and soil nutrients [9]and has important role in growth and development of plant [10].

Average values for total chlorophyll in both Neem (0.36mg/g) and Eucalyptus (0.39mg/g)were found higher at Residential area, which is consistent with [11].

For Neem (Table 2), it was observed that average values for Highway side (0.30mg/g)and Industrial area sampling site(0.29mg/g) had marginal differences, but a larger difference was observed for Eucalyptus (Table 3) at Highway side (0.16mg/g) and Industrial area sampling site (0.27 mg/g).

Results obtained in this study are in agreement with the study held by [12] on Eucalyptus, where they found that vehicular emissions negatively affect chlorophyll concentration, which directly effects plant growth as an instant decrease in plant productivity is observed [13].

[10, 14,13, 15, 16]mentioned several reasons for decrease in chlorophyll level, of which particulate deposition on leaves, blockage of stomatal pores explains the low levels of total chlorophyll observed for Eucalyptus at Highway side sampling site, where sand kicking, fuel exhaust by moving vehicles is prevalent.

[17] have mentioned water stress conditions in chloroplast as one of the causes for chlorophyll content reduction. They have also mentioned tolerance to air borne pollution being relevant with high chlorophyll content, which could provide an explanation to higher total chlorophyll content observed at Industrial area sampling site, despite higher levels of pollution[18].

Ascorbic acid

Month	Residential (mg/g)	Industrial (mg/g)	Highway side (mg/g)
June, 2021	0.20	0.22	0.11
July, 2021	0.15	0.28	0.24
August, 2021	0.23	0.30	0.25
September, 2021	0.37	0.09	0.22
October, 2021	0.24	0.12	0.20
November, 2021	0.22	0.20	0.35

Table 4: Ascorbic acid content of Neem at three sampling sites.

Month	Residential (mg/g)	Industrial (mg/g)	Highway side (mg/g)
June, 2021	0.25	0.26	0.18
July, 2021	0.18	0.30	0.30
August, 2021	0.21	0.27	0.22
September, 2021	0.29	0.11	0.24
October, 2021	0.27	0.23	0.22
November, 2021	0.29	0.26	0.20

Table 5: Ascorbic acid content of Eucalyptus at three sampling sites.

Ascorbic acid content of plant has been given utmost importance among all the biochemical parameters used for calculating APTI, due to its antioxidant, reductive and Reactive Oxygen Species scavenging properties - thus, increasing tolerance level of plants and ultimately, APTI value of a plant [12, 10,14, 18,19,13, 11,20,21,22,23].

Ascorbic acid is the only variable that multiplies during APTI calculation as "ascorbic acid concentration rises when overall chlorophyll levels fall to fight stress" and "preserves the integrity of the chloroplast membrane and the breakdown of chlorophyll" [13, 21,22].

Average Ascorbic acid content fractionally differed for Neem (Table 4) at Residential area (0.24mg/g) and Highway side sampling site (0.23mg/g), while a slight difference was observed at Industrial area site (0.20mg/g).

For Eucalyptus (Table 5), marginal differences were observed as (Residential area =0.25mg/g, Industrial area = 0.24mg/g, Highway side = 0.23 mg/g).

Almost similar levels of ascorbic acid content in leaves of Neem and Eucalyptus at three different area with ideally different pollution levels, do point towards polluted status of Jodhpur city's air. Study by [17] mentions that lower Ascorbic acid levels are associated with sensitive nature of plants towards automotive exhaust, this can be observed in findings of this study as well, as Industrial area and Highway side sampling side cater heavy traffic load as compared to Residential area.

[14] mention dependency of Ascorbic acid on pH levels of the plant, but suggested the "significance of PM accumulation on the leaf surface and in-wax" which can lead to varied ascorbic acid levels, irrespective of pH.

Relative water content

Month	Residential (%)	Industrial (%)	Highway side (%)
June, 2021	85.34	85.10	91.57
July, 2021	79.07	84.85	76.70
August, 2021	71.13	65.88	73.66
September, 2021	91.28	75.60	81.05
October, 2021	98.00	85.23	92.23
November, 2021	59.85	95.12	83.68

Table 6: Relative water content of Neem at three sampling sites.

Month	Residential (%)	Industrial (%)	Highway side (%)
June, 2021	86.04	86.32	83.25
July, 2021	48.99	83.88	83.65
August, 2021	41.65	79.75	84.98
September, 2021	68.20	88.04	89.95
October, 2021	99.00	88.93	85.77
November, 2021	97.87	98.48	96.26

Table 7: Relative water content of Eucalyptus at three sampling sites.

Relative water content of a plant helps maintain physiological balance [14]. It could vary with "atmospheric conditions, humidity and availability of moisture content in soil" [9].

Average values of Relative water content for Neem (Residential area = 80.78%, Industrial area = 81.96%, Highway side = 83.15%) and for Eucalyptus (Residential area = 73.62%, Industrial area = 87.57%, Highway side = 87.31%) indicate that Neem on Highway side and Eucalyptus in Industrial area are associated with high percentage of relative water content. The results obtained in present study can be explained by the works of [12] where they have mentioned high stress conditions caused due to air pollution,being associated with higher relative water content.[10] mentioned higher relative water

content in all plant species of Industrial area, which can be attributed to the fact that increased relative water content leads to increased physiological balance and tolerance capacity towards air pollution[17,18,19, 15,11].

pH

Month	Residential	Industrial	Highway side
June, 2021	6.23	6.73	6.75
July, 2021	6.15	7.08	6.8
August, 2021	6.02	6.15	6.21
September, 2021	6.25	6.57	6.45
October, 2021	6.53	6.4	5.7
November, 2021	6.13	6.75	5.2

Table 8: pH content of Neem at three sampling sites.

Month	Residential	Industrial	Highway side
June, 2021	4.5	5.83	5.65
July, 2021	5.07	8.3	7.3
August, 2021	5.23	5.39	5.68
September, 2021	5.5	5.47	6.11
October, 2021	6	5.64	6.02
November, 2021	5.39	4.82	6.3

Table 9: pH content of Eucalyptus at three sampling sites.

Acidic or lower pH value of cell sap is generally associated with the presence of SO_2 and NO_x in ambient air [17, 14, 18,19,13, 16,20,24]. It was further elaborated by [15] as they mention production of Reactive Oxygen Species during SO_2 to SO_3 photo-oxidation and conversion of diffused air pollutants like NO_2 CO_2, and SO_2 into acid radicals in the cell sap.

Average values of pH for Neem (Residential area =6.22, Industrial area = 6.61, Highway side = 6.19) and for Eucalyptus (Residential area =5.28, Industrial area = 5.91, Highway side = 6.18) indicate that acidic/ lowerpH level in leaves of both Neem and Eucalyptus are associated with increased pollution levels.

The results obtained are in agreement with findings of [12, 10,19,11,22] where they mentioned positive correlation of low pH levels with sensitivity of plant to air pollution, lower photosynthetic activity and APTI values.

APTI

Month	Residential	Industrial	Highway side
June, 2021	8.66	8.66	9.23
July, 2021	8.01	8.70	7.84
August, 2021	7.26	6.78	7.53
September, 2021	9.37	7.62	8.25
October, 2021	9.97	8.60	9.34
November, 2021	6.13	9.65	8.56

Table 10: APTI of Neem at three sampling sites.

Month	Residential	Industrial	Highway side
June, 2021	8.73	8.79	8.43
July, 2021	5.00	8.65	8.59
August, 2021	4.28	8.13	8.63
September, 2021	6.99	8.87	9.41
October, 2021	10.07	9.03	8.71
November, 2021	9.96	9.98	9.75

Table 11: APTI of Eucalyptus at three sampling sites.

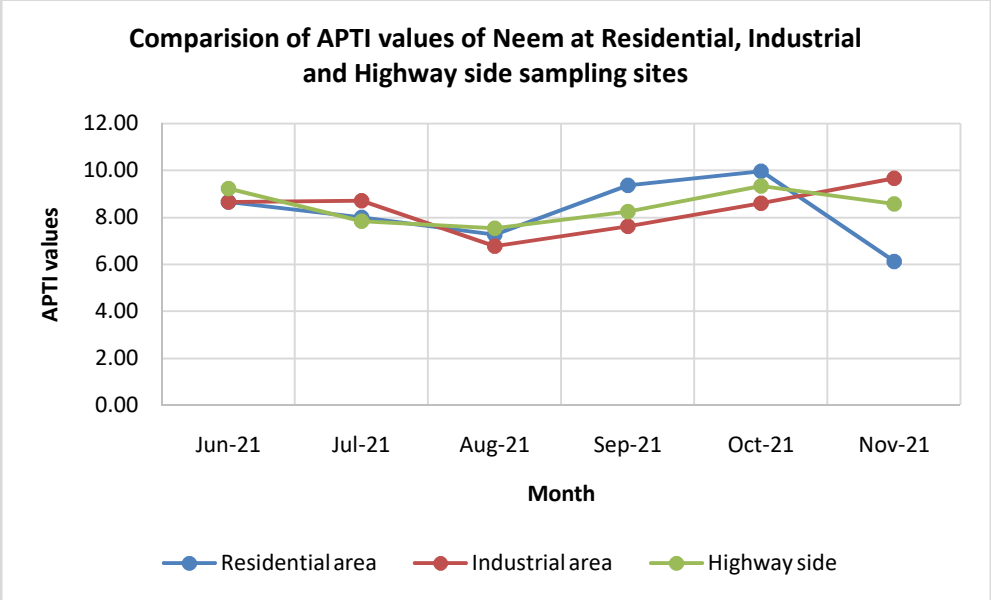

Fig 4: APTI of Neem at three sampling sites.

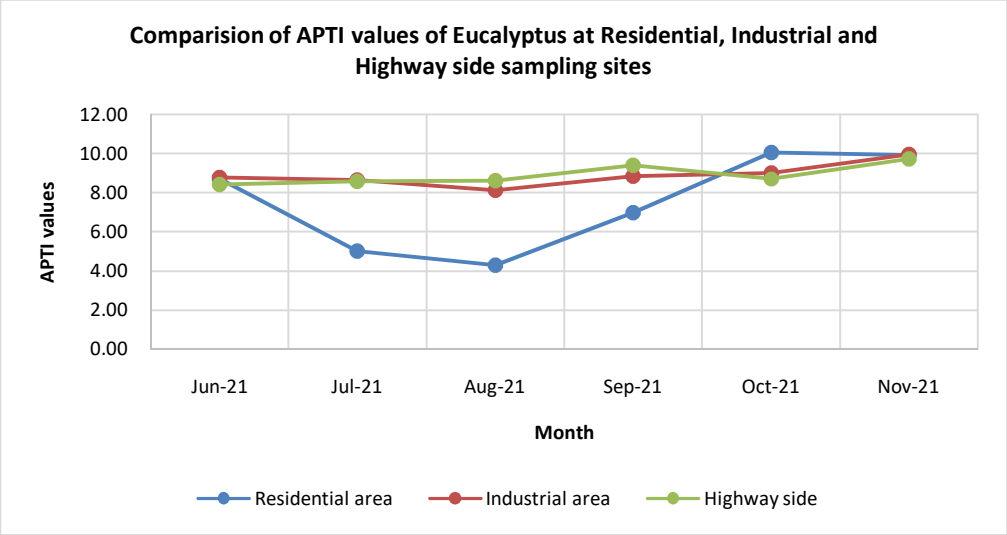

Fig 5: APTI of Eucalyptus at three sampling sites.

APTI is a value indicative of plant's tolerance to air pollution, which is calculated using biochemical parameters- ascorbic acid, total chlorophyll, relative water content and pH of plant's leaves under consideration.

Maximum values of APTI for Neem (Table 10) in ascending order Highway side < Industrial area < Residential area sampling site.Minimum values of APTI for Neem in ascending order Residential area < Industrial area < Highway side sampling site.

Maximum values of APTI (Table 11) for Eucalyptus in ascending order Highway side < Industrial area < Residential area sampling site.Minimum values of APTI for Eucalyptus in ascending order Residential area < Industrial area < Highway side sampling site.

It can be seen that average values of APTI for both Neem and Eucalyptus show the following trend in ascending order Residential area < Industrial area < Highway side sampling site.

The APTI values obtained for both Neem (Fig 4) and Eucalyptus (Fig 5) show a trend of having maximum APTI values (in month of October 2021),while minimum values (for Neem in month of November 2021 and for Eucalyptus in month of August 2021) at Residential area sampling site.

The average values of APTI for Neem (Residential area =8.23, Industrial area = 8.34, Highway side = 8.46) and for Eucalyptus (Residential area =7.50, Industrial area = 8.91, Highway side = 8.92) point that both Neem and Eucalyptus are relatively more tolerant at Highway side as compared to Residential area sampling site and is in agreement with findings of [17, 13, 25,24,22,26,27]

Tolerance of plant can be influenced by many factors, of which a few environmental parameters are temperature, relative humidity, water content and soil acidity [13]. But, [25] reported in their study that tolerance of plants drops significantly under extreme conditions, instead of increasing with pollution levels.

APTI values can indicate tolerance of plant to air borne pollution (according to the table), since APTI values in this study have ranged from 3- 10, it can be implied that both Neem and Eucalyptus are sensitive species and thus, have a potential to be utilised as bio- indicator of air pollution[10, 14, 19, 15,22].

CONCLUSION

It can be concluded that two common plants Neem and Eucalyptus have potential to be used as bio-indicator for air pollutiondue to their sensitivity towards air pollution, according to their APTI values.

Competing interests: The authors have no competing interests to declare that are relevant to the content of this article.

AUTHOR'S CONTRIBUTION:

Both authors (Punit Saraswat and Shuchita Singh) have equally contributed to the research paper.

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CITATION OF THIS ARTICLE

Punit Saraswat and Shuchita Singh. Comparative assessment of Air Pollution Tolerance Index (APTI) of two common plants in three differently polluted areas of Jodhpur. Bull. Env.Pharmacol. Life Sci., Vol 11 [11] October 2022 :77-85