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IMPACT OF INDUSTRIAL PROXIMITY ON THE PLANTS AND AGRICULTURAL SOIL IN TALOJA INDUSTRIAL AREA OF RAIGAD (M.S.), INDIA

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ABSTRACT

The present study is an attempt to determine the quality of the agricultural soil and the effect of pollution stress on the crops grown in Taloja industrial area of Raigad district of Maharashtra during 2020.

Randomly selected soil samples and plant samples from study area were investigated for physico-chemical characteristics and macro and micro-nutrients content. Health of soil was found to be degraded with respect to major nutrients, such as organic carbon, nitrogen, phosphorus and potassium which were found to be 0.44%, 235.67 kg ha^{-1}, 6.76 kg ha^{-1}, 206.5 kg ha^{-1} respectively. Lack of minor nutrients such as Mn, Zn, Cu and B in samples evidenced the low fertility of the soil. Soil quality index was computed by conventional weightage summation method. The results showed that the soil in this region has poor suitability for farming.

The effect of air pollutants released by industries on the physiology of the selected crops (*Dolichos lablab* L.) was also studied. Decrease in level of total chlorophyll (0.336 mg g^{-1}) and increase in ascorbic acid (0.387 mg g^{-1}), free proline (3.751 mg g^{-1}), soluble sugar (9.267 mg g^{-1}) and relative water content levels as compared to the control were seen in samples collected from industrial region. An increase of 8.90-14.15 % of APTI at industrial sites indicates the pollution stress on the crops in this region. The study suggests undertaking appropriate agricultural management practices to improve the quality of the crops.

(Key words: Agricultural soil; soil quality index, plants, air pollution tolerance index, Industrial region)

INTRODUCTION

The past few decades are witnessed rapid industrial growth around the world which is accompanied by severe environmental pollution. Dust, smoke, fumes, toxic gases and hazardous chemical emissions cause irreparable damage to the ecology and environment. Land deterioration, extinction of species, damage to human health and climate change raise a question on sustainable development due to industrialization [Zinck and Frashad, 1995, Hurni, 1997, Patnaik, 2018]. Industrialization associated environmental changes and their impact on biodiversity is studied extensively worldwide [Ellis *et al.,* 2011,Mgbemene *et al.,* 2016].

In India, a major part of the population (66%) is depending upon agriculture for livelihood, [Anonymous, 2019]. Soil is by far the most biologically diverse part of Earth and acts as a medium and nutrient reserve for plant growth. However, inappropriate agricultural practices, industrial development, construction and mining activities are deteriorating the productivity of the soil [Bhattacharya *et al*., 2015, Punekar *et al.,*2017].

Soil Quality Index (SQI) is considered to be the most appropriate for quantitative assessment of soil quality in terms of its 'fitness for use' [Triantafyllidis *et al.,* 2018, Thombe *et al.,*2020]. According to Karlen *et al.*(1997), chemical, biological and physical properties of soil interact incomplex ways to give soil quality. Thus, the soil quality is determined in terms of its measurable properties. The soil properties can get altered due to industrial activities which may get resulted in the lowering of soil quality and thus its productivity.

However, in an industrial region, poor soil quality is not only the reason for low agricultural output but the other stresses including air pollution stress also affect plant growth [Klumpp *et al.,* 2000]. The primary receptor of air pollutants is the leaves of the plants. The leaves provide a large surface area for absorption and accumulation and hence act as a sink to accumulate pollutants [Liu and Ding, 2008].One of the most common impacts of air pollution is the gradual disappearance of chlorophyll and thus,a decrease in the capacity for photosynthesis. The impact of air pollution on plants is expressed in Air Pollution Tolerance Index (APTI). [Chauhan and Bafna, 2011]. Air pollution tolerance index (APTI) is measured by using four parameters such as relative water content (RWC), total chlorophyll content (Tchl), leaf extract pH and ascorbic acid content (AA) in leaves to ascertain the response of plants biochemically and physiologically [Singh and Verma, 2007].

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Higher APTI values indicate more tolerance of plants to air pollution than those with low APTI values. Hence, APTI assessment of the trees is an important tool for evaluating plants' response to air pollutants.

A plethora of research is carried out by researchers and environmentalists to study the impact of industrial development on the agriculture sector [Bharati *et al.,* 2018]. Many reports have shown that in industrial regions, the various types of pollutants such as chemicals, particles, ionizing radiation and acoustic may cause acute or chronic detriment to the health of soil and plants. [Saha *et al.,*2017, Panwar *et al.,*2010, Govil *et al.,*2001]

MIDC Taloja is the huge industrial area of Raigad district adjacent to India's financial capital, Mumbai and a part of major industrial regions of India. This fully developed industrial area is dominated by chemical, pharmaceuticals, fertilizers, paints, petrochemicals, food and fish processing, dairy products, and engineering industries.Though the industrial growth opened new horizons for the residents, it impacted badly the agricultural production. The industrial discharges, landfill seepage, solid waste seepage, and faulty agricultural practices altogether damage soil quality and thus crops taken in such contaminated soil. The impact of polluted air is equally contributing to the devastation of biodiversity. Consequently, the local communities are being deprived of their means of livelihood as the land under cultivation is declining.

This study is an attempt to assess the quality of agricultural soil from the industrial region and evaluation of the impact of industrial proximity on the plants grown in the MIDC Taloja region.

MATERIALS AND METHODS

Description of study site and sampling

MIDC, Taloja at latitude 19.06 °N and longitude73.12 °E are identified as the industrially polluted zone in Raigad District (Fig 1). This investigation was designed to study the impact of industrial pollution on soil and crop quality within agricultural areas. The villages such as Chindhran, Dhansar, and Wavanje which are vicinity to the industrial region were selected as sampling sites (Table 1).

Table 1. Description of sampling stations in study area

Sampling station	Location	Description
S1	19.0726 °N, 73.1571 °E	Chindhran Village
S2	19.7515 °N, 75.7139 °E	Dhansar Village
S3	19.033 °N,73.0297 °E	Wavanje Village
Control	19.0072°N,73.1533 °E	Harigram Village

Major crops grown in this area are rice, grams, a variety of beans, vegetables etc. For this study, the hyacinth bean (*Dolichos lablab* L.) plant was selected. The soil samples and leaf samples of the hyacinth beans were collected from the randomly selected agricultural fields of the sampling stations. The results obtained were compared with the hyacinth bean plant grown in a non-polluted region (control).

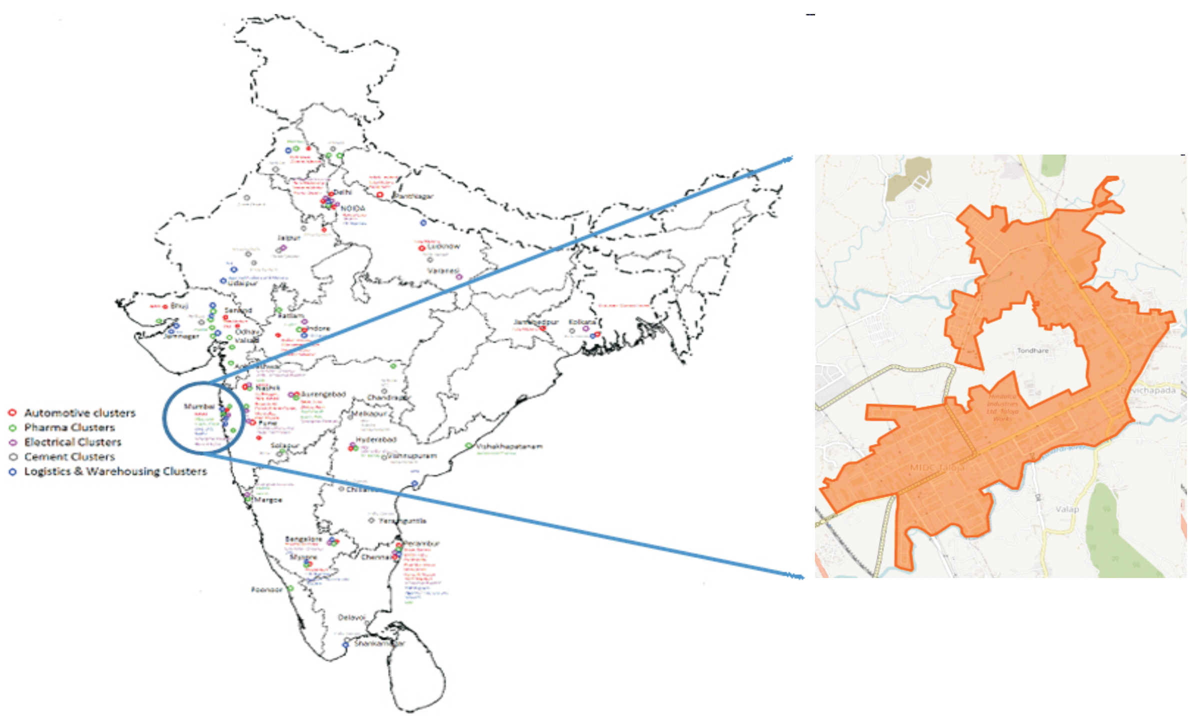

Figure 1. Study Area (Courtesy: Umrikar, 2014)

Sampling and analysis of sample

Nine soil samples were collected in the month of December 2020 from the selected fields to the depth of about 0 to 15 cm from the surface, using a shovel. Every sampling point is spatially separated by 15-20 m within the same physiographic unit. About 500 g of composite soil was collected from each unit. The samples were air-dried and sieved to remove foreign materials like roots, stones, pebbles and gravel. The sample size was reduced by Coning and Quartering method and stored into thick polythene bags.

All collected soil samples were analysed for various physical and chemical parameters. pH of soil:water (1:2.5) was measured using glass electrode and the electrical conductivity of soil:water (1:2.5) using conductometer (Equiptronics, EQ 661) [Jackson, 1973], organic carbon (%) [Walkley and Black,1934], total available nitrogen[Kjeldahl, 1889], total available phosphorus [Bray and Kuriz, 1945], and available potassium by flame photometry [Jackson, 1973].The Calcium was determined by titrimetric method [Balázs *et al.*,2005]. The nutrients such as Mg, Fe, Zn, Mn, Cu and B are determined by the ICP-OES method.

The soil quality index was determined by developing a minimum data set (MDS) of selected quality indicators based on expert knowledge of local soil conditions and soil-crop response. Soil quality is evaluated by the conventional method based upon the relative soil quality index (RSQI) [Pawar *et al.*,2018, Mandal *et al.*,2013, Sharma and Arora, 2010].

Data regarding MDS indicators and their weights were decided in relation to soil fertility which are given in Table 2. The sum of all the weights is normalized to 100%.Each of the indicators was divided into four classes: Class I, most suitable for plant growth; Class II, suitable with few limitations; Class III, suitable with more serious limitations; and Class IV, suitable with severe limitations to plant growth. According to the suitability, classes are rated as 4, 3, 2, and 1.

Soil quality index (SQI) was then calculated by the formula used by Kundu *et al.*(2012).

$$SQI = \sum W_i I_i$$

Where W_i is the weight of indicators and I_i is the rate of the indicator

Theoretically, SQI is ranged from 100 to 400 that is the minimum value of SQI is 100 and the maximum value of SQI is 400.

Table 2. Rating chart for soil test values (Kundu *et al.*, 2012)

Indicator	Weight	Class I	Class II	Class III	Class IV
Texture	15	Loam	Sandy or Clay loam	Clay or sand	Grit
pH	8	6-7.5	5.0-6 & 7.5-8.0	4.5-5.0 & 8.0 -8.5	< 4.5 & > 8.5
Electrical conductivity (mmhos/cm)	10	< 1	1-2	2-3	>3
Organic Carbon (%)	15	>0.75	0.5-0.75	0.21-0.5	<0.20
Available N ($kgha^{-1}$)	15	>560	280-560	141-280	< 140
Available P ($kg\ ha^{-1}$)	15	>25	10-25	5-10	<5
Available K ($kg\ ha^{-1}$)	15	>280	120-280	50-120	<50
Calcium ($cmol^{(+)}kg^{-1}$)	7	>10	5-10	1-5	< 1

The relative soil quality index (RSQI) was determined by comparing SQI value with the maximum theoretical value. Based on RSQI, the soil is categorized as in Table 3 [Singh, 2007].

Table 3. Category of soil quality based on relative soil quality index (RSQI)

RSQI (%)	Category
> 90	Very Good
80-90	Good
70-80	Medium
60-70	Moderately poor
< 60	Poor

Sampling and analysis of plant leaves

Fresh, fully grown plant leaves of hyacinth beans (*Dolichos lablab* L.) were collected as a sample from the selected fields.All leaves were cleaned thoroughly with distilled water and blotted dry. The weight of the fresh samples was recorded and stored in the refrigerator for further analysis. Some of the leaves were air-dried for the study of parameters like free proline and total soluble sugar. Fresh leaves were analysed for the determination of biochemical parameters such as relative water content, leaf extract pH, total chlorophyll and ascorbic acid.

Relative water content: The fresh leaves were cut from the petiole and their weight was recorded. Turgid weight and dry weight were recorded after keeping them overnight in water and drying in a hot air oven at 70°C till constant weight respectively. Relative water content is then determined by using the formula

$$\text{Relative water content} = \frac{\textit{Fresh weight - Turgid weight}}{\textit{Turgid weight - Dry weight}}$$

Total Chlorophyll : Chlorophyll a, chlorophyll b and total chlorophyll content was determined by Dimethyl

Sulfoxide (DMSO) method spectrophotometrically. [Shinano *et al.,* 1996]

pH : The pH of the leaf extract was recorded using a pH meter (EQ-621 Equiptronics) by homogenising 4 g of leaves in 10 cm^3 of distilled water.

Ascorbic acid : Ascorbic acid per dry weight of leaves was determined by the spectrophotometric method described by Bajaj and Kaur (1981).

Air Pollution Tolerance Index (APTI): APTL was calculated using the formuladescribed in Molnar *et al.*(2020)

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

Where A= Amount of ascorbic acid (mg g^{-1}); T = Total chlorophyll content (mg g^{-1}); P= pH of leaf extract; R= RWC(%)

Free proline : Free proline was determined spectrophotometrically according to Bates *et al.* (1973) method.

Total Soluble sugar : Soluble sugar was determined spectrophotometric method using phenol-sulphuric acid [Hellebust and Craigie, 1978].

Every analysis was carried out in Triplicate for each sample. The average values of every measurement were used for the calculation of APTI.

RESULTS AND DISCUSSION

Physicochemical properties of soil samples

Table 3 represents the physical and chemical properties of the surface soil samples (0-15 cm) collected from different sampling stations. As the sampling stations are located in the industrial region, the considerable variation in the soil attributes is clearly seen in Table 4. It is difficult to comprehend the effect of industrial proximity onoverall soil quality as a large number of variables were considered at a time. However, the impact on soil fertility can be studied on the basis of variations in the individual attributes.

The soil in this region was found to have sandy clay loam texture. The pH of samples was found slightly acidic to neutral with electrical conductivity >1 indicating all the soil samples are suitably good.

The fertile soil is a reservoir of the essential plant nutrients and supplies them to plants in adequate and suitable proportion for their optimal growth. The essential elements include C, N, P, K, Ca, Mg and S as macronutrients and Fe, B, Zn, Cu etc. as micronutrients. A large variation was found in major nutrients of the soil samples. Organic carbon content was found 0.18-0.86% with an average value of 0.44%. Typically, organic carbon is an indicator of the fertility of the soil, however, this study shows that the samples in the specified industrial area contain a poor level of organic carbon. Degradation of N, P and K levels were also observed in the samples. Total available N was found to contain ranging from 156.88-301.21 kg ha^{-1} with an average value of 235.67 kg ha^{-1}. Total available P and K were found in the range of 4.19-14.72 kg ha^{-1} (average = 6.76 kg ha^{-1}) and 81.54 - 405.07 kg ha^{-1} (average = 206.50 kg ha^{-1}) respectively which evidences the deficiency of the major nutrients. Also, Calcium level was recorded to very low to a high level with an average of 6.61cmol$^{(+)}$kg^{-1} ranging from 4.05-10.12 cmol$^{(+)}$ kg^{-1}. Calcium provides soil aeration and is essential for plant growth especially building strong cell walls and membranes. Level of Mg was found to be ranging from deficiency to adequacy (below detection limit to 10.28 mg kg^{-1}). The samples from Dhansar (S2) were found to have a magnesium deficiency.Fe content was found in the range of 0.05-0.072 mg kg^{-1}. The micronutrients such as Mn, Zn, Cu and B were determined by using ICP-OES which were found below the detection limit indicating low fertility of soil.

Table 4. Characteristics of soil samples collected from study area

Indicator	S I			S II			S III		
	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3	Sample 1	Sample 2	Sample 3
Texture	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam	Sandy Clay loam
pH	5.98	6.2	6.84	6.45	6.32	6.05	6.42	6.35	6.33
Electrical conductivity (mmhoscm^{-1})	0.625	0.73	0.791	0.720	0.702	0.738	0.366	0.433	0.36
Organic Carbon (%)	0.69	0.30	0.36	0.60	0.18	0.86	0.21	0.36	0.42
Available N(kg ha^{-1})	288.66	175.7	251.01	225.90	213.35	219.63	288.66	301.21	156.88
Available P (kg ha^{-1})	8.09	14.72	4.41	5.34	4.19	5.28	3.43	5.89	9.57
ailable K (kg ha^{-1})	81.4	115.9	150.6	190.02	405.07	324.43	202.8	116.13	272.13
Ca (cmol$^{(+)}$kg^{-1})	10.12	8.10	6.75	4.05	6.75	8.10	5.40	4.72	6.01
SQI	295	273	273	281	251	318	251	266	273
RSQI	73.75	68.25	68.25	70.25	62.75	79.50	62.75	66.50	68.25
Suitability for cropping	Medium	Mod-erately Poor	Mod-erately Poor	Medium	Mod-erately Poor	Medium	Mod-erately Poor	Mod-erately Poor	Mod-erately Poor

Soil Quality Index (SQI):

The soil quality index (SQI) of each sample was computed and soil was categorized as very good, good, medium, moderately poor and poor suitability for cropping. Soil quality indicators selected were simple and easy to quantify. Previous studies by Kundu *et al.*(2012), Buennemann *et al.* (2018), Mahajan *et al.*(2020) and Rajendiran *et al.*(2021) have been effectively used this approach to classify the soil quality based on nutrient availability.

The soil quality of the MIDC, Taloja was found to be moderately poor suitability for cropping. None of the samples were found to have good quality. The depleted levels of nutrients and organic matter need to be improved using appropriate soil management practices and optimum use of fertilizers.

Apart from the soil quality, there are many factors that affect crop yield as well as the quality of the crop. Water availability, contamination of water, air quality, infestation equally contributes to the yield and quality of the crop. Thus, the present study also addresses the impact of air pollution on the crop of hyacinth bean (*Dolichos lablab* L.) which is commonly grown in this area.

Effect of industrial emissions on the crops

The effect of the industrial emissions on the crops grown in the sampling site was also studied. The previous studies have shown that not only soil pollution but air pollutants, fly ash and dust particulates also severely affected the health of the plants. Thus, they are considered as an indicator of air quality [Ashden and Williams 1980,Seyyednejad *et al.,*2011, Molnár *et al.,*2020]. The quality of the crops in selected sites was expressed in terms of the air pollution tolerance index (APTI) formulated by Singh (1993). The other parameters such as free proline, total soluble sugar were also determined. The observed values are presented in Table 5.

Table 5. Attributes of plant leaves collected from study area and APTI

Sampling station / Parameter	Control	S1 Chindhran	S2 Dhansar	S3 Vavanje
Total Chlorophyll (mg g^{-1})	0.532	0.293	0.374	0.342
Ascorbic acid(mg g^{-1})	0.159	0.339	0.342	0.481
pH	6.65	6.00	6.45	6.34
RWC (%)	80.93	88.21	86.98	90.7
Free proline (mg g^{-1})	0.955	3.668	3.910	3.675
Total soluble sugar (mg g^{-1})	1.07	9.33	8.42	10.05
APTI	**8.2**	**9.03**	**8.93**	**9.39**
% Increase in APTI	-	10.12%	8.90%	14.51%

The major part of industrial emissions constitutes Sulphur dioxide (SO_2), nitrogen oxides (NOx), CO_2, fly ash as well as suspended particulate matter. When the plants get exposed to the pollutants above the normal physiologically acceptable range, the photosynthetic activity of the plants gets inactivated by reducing the concentration of chlorophyll and carotenoid pigments. [Giri *et al.,*2013]. In this study, samples were found to contain total chlorophyll in the range of 0.293-0.374 mg g^{-1} with an average value of 0.336 mg g^{-1}, whereas the control collected from the industrially non-polluted region have found total chlorophyll content 0.532 mg g^{-1}. These results were in agreement with the findings of Giri *et al.* (2013) and Manjunath and Reddy (2017),who reported decrease in photosynthetic pigments due to air pollution.

Ascorbic acid is an antioxidant that provides resistance to plants in a stressed condition. With the increase in pollution, ascorbic acid content also increases to combat the stressed condition [Bharti *et al.,*2018]. An appreciable increase in ascorbic acid content in the leaves collected from the industrial region (0.339-0.481 mg g^{-1})is observed as compared to the control (0.159 mg g^{-1}). This result is consistent with the previous studies that indicated increased production of ascorbic acid in polluted region [Meerabai *et al*., 2012, Chaudhary *et al.,*2021].

When the pH of the leaf extract is equal to or greater than 7 indicates that plants are more tolerant to air pollution.According to Singh *et al.*(1991) if pH is less than 7 affects the total chlorophyll concentration. The pH of leaf extracts in this study ranged from 6.00-6.45 which were slightly acidic as compared to the control.

RWC of all the samples were found almost same (80.93 – 90.7%). High RWC may be due to the dry season cultivation of these crops or the air pollution stress [Shrestha *et al.,*2021].

It is well established that an increased level of proline protects the plant from all kinds of stress [Hayat *et al.,*2012]. In this study, the proline level was found 3.668-3.910 mg g^{-1} at industrial sites which were higher than the control (0.955 mg g^{-1}). Similar findings by Tankha and Gupta (1992) reported increased level of free proline due to exposure of plants to SO_2 gas. Sanaeirad *et al.* (2017)also reported highest content of proline in polluted zone than clean zone.

The level of soluble sugar is an indicator of the ability of plants to survive under stress. High soluble sugar content provides osmotic protection to adapt the plant to environmental stress. The previous studies by Koochak and Seyyednejad (2010)reported an increased level of soluble sugar in polluted regions, however, the reports by Tripathi and Gautam (2007) and Rai (2015) indicated the depletion of sugar level in plant leaves in an industrial region. The investigations by Kameli and Losel (1993),Ludlow (1993) revealed that the more resistant species plants to the air pollution as compared to sensitive species showed more concentration of soluble sugar. In the present study, the observed increase in the concentration of soluble sugar in *Dolichos lablab* (L.)may be attributed to osmoregulation and tolerance contributing to plant survival.

Air Pollution Tolerance Index (APTI):

According to Meerabai *et al.*(2012)APTI expresses the tolerance of plants toward air pollution and the biochemical parameters that are responsible for the resistance to environmental stress. In this study, the considerable difference in APTI at the control site and sample site was observed which describes the air quality in the industrial region and its impact on the plants. These results are similar to the previous studies by Meerabai *et al.* (2012). APTI was found to be positively correlated with pH, total chlorophyll content, and relative water content and negatively correlated with ascorbic acid as described by Chaudhary *et al.* (2021).APTI has also, been used to identifying tolerance levels of plant species [Singh *et al.,*1991]. According to Shrestha *et al.* (2021), APTI value (~ 9) suggests that *Dolichos lablab* (L.) is a pollution sensitive species.

Soil quality and the effect of air pollution on crops grown in the Taloja industrial area were assessed. The present study showed the loss of organic carbon, nitrogen, phosphorus and potassium. Also, the soil samples were found to have a deficiency of essential nutrients such as Fe, Mn, Zn, Cu and B which suggests the low fertility of the soil. Soil health was assessed by calculating the soil quality index by weightage summation method. All the soil samples were found to have moderately poor suitability for cropping.

Impact of air pollutants on the cultivations in this region is expressed in terms of the air pollution tolerance index (APTI). APTI was found to be increased by 8.90-14.51% in the industrial region than in the non-industrial region. Elevated levels of free proline and total soluble sugar which contributes to the defence mechanism of plants were also observed in the industrial region compared to the control site.

All the results confirm that the farming activities in Taloja industrial region are highly influenced by industrial pollution. Proper soil management practices are recomm-ended.

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