# Study on variability of Physico-Chemical properties in Soils and Weeds of waste dumping yards of Visakhapatnam, Andhra Pradesh

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***Abstract***
*Soil is the predominant source for the existence of life (flora and fauna) on earth as it consists of rich minerals and nutrients. Over the years, due to globalization, urbanization, industrialization across the globe, huge quantity of waste is being generated. Domestic wastes, which serve to be the majority of the composition, are being dumped in specified areas for further treatment. Various contaminants from such domestic waste dumping areas are a source of contamination. Hazardous contaminants possess adverse impacts on environment and public health, of which soil fertility reduction is the prime. In view of this, the current study proposed to study the variability of soil fertility in Visakhapatnam, an emerging urban centre. The samples were collected from Kapuluppada (DY-1) and Bheemunipatnam (DY-2) which serve as domestic waste dumping areas whereas Yendada (CA) a residential area and control site of Visakhapatnam, Andhra Pradesh. The samples collected were analysed for the physico-chemical properties of soil.*

*Analytical results have shown slight variability in physico-chemical properties among the study areas. Further, as per the nutrient index, DY-1 and DY-2 waste dumping yard area soils seems to be 'medium fertile' and CA residential area soil seems to be 'low fertile'. As per this assessment, irrespective of soil contamination, the fertile nature of waste dumping yard soil seem to be more when compared to residential area soil because of continuous waste decomposition activities. However, contamination of waste dumping yard soil needs to be studied further to ensure whether contaminants are posing more threat to those soils.*

**Keywords**: Physico-Chemical properties, Contamination, Waste dumping yards, Nutrient index.

## Introduction

The superficial layer of earth is termed as soil and it is formed by breaking down of rock into smaller pieces and this breakdown of rock is termed as weathering. Soil is formed by thousands and lakhs of years of rock weathering and it is a continuous process. Rock is weathered by two types of processes like mechanical and chemical weathering. Soil consists of approximately 40-50% minerals, 1-10% organic and biological matter (flora, fauna, living and dead, macro, microscopic) and 50% pore space (which is filled with air and water)[45].

Soil is a key part of the eco system sustainability as soil is a habitat provider for billions and trillions of organisms (live and dead), helps for biodiversity, carbon recycling of globe, helps in removal of greenhouse gases, acts as nutrient recycler, stores the water and filters the wastewater, disposes / decomposes the waste etc.[3] Soil, which is a life linked aspect, is becoming polluted day-by-day because of rapid modernization, industrialization, urbanization, changes in agriculture etc. Soil pollution is nothing but contamination of soil by unwanted substances (termed as soil pollutants) like heavy metals, toxic chemicals, pesticides, biologically active pathogens, plastic waste etc.[33,36]

The above said soil pollutants will have an adverse impact on soil quality which in turn have adverse health impact on living beings (finally human beings) on earth as these pollutants transform from soil to human beings through bio magnification phenomenon. Urbanization is one of the major causes of soil contamination as urbanization results in a lot of domestic solid waste generation and such domestic solid waste may alter the physico-chemical properties of the soil[37,46]. Now, in this perspective, a study was carried out to understand the variability of soil fertility at domestic waste dumping areas (DY-1, DY-2 dumping yards) and control area (CA residential area) of Visakhapatnam.

In this regard, soil samples were collected from DY-1, DY-2 domestic waste dumping areas and CA residential area of Visakhapatnam, Andhra Pradesh and were analysed for physico-chemical properties. The DY-1 domestic waste dumping yard area is selected as it is bigger (approximately 105 acres) and widely used dumping area of Visakhapatnam from almost 20 years. The DY-2 waste dumping yard area is also selected as it is one more near-by waste dumping yard which is smaller in size (approximately 15 acres) and is being used from almost 12 years.

## Material and Methods

**Study Area:** The present study was undertaken in Visakhapatnam, a rapidly growing coastal metropolitan city located in the State of Andhra Pradesh, India. Positioned along the eastern coastline of the Bay of Bengal, Visakhapatnam has experienced accelerated urbanization, industrial development and population growth over the past few decades. This urbanization has consequently seen high solid waste generation with a significant portion of it being disposed of in the form of open dumping in allocated peripheral areas. The study focused on three distinct locations within the city: DY-1, DY-2 and CA, each representing varying degrees of anthropogenic influence and land use characteristics.

DY-1, one of the prime dumping yard in the city is situated on the northern outskirts of the city (approximately 19° N, 84° E) and receives an extremely high proportion of household waste daily, resulting in continuous organic matter decomposition and potential leachate infiltration into the surrounding soil. DY-2, located around 25 kilometres northeast of the city centre, borders both urban and semi-urban environment. This place serves to be the dumping spot for refuse from the area's households, industries and varied businesses. Despite the city renewal initiatives, the scars of the past activities of the municipal waste continue to reverberate on the environment of the present neighbourhoods.

In contrast, CA is predominantly a locality of residential properties with increasing housing development and urban infrastructure, but with no direct waste dumping activities. It was used as the standard or control area to measure soil nutrients under conditions of minimum pollution or contamination. The contrasting characteristics of these three sites ranging from high intensity waste disposal zones to urban residential areas furnish a basis to examine the variability in soil fertility and contamination across different land use types in emerging urban environments.

**Soil sampling and analysis:** The soil samples were collected within 0-15 cm depth from the domestic waste handling site of DY-1, DY-2 waste dumping areas and CA residential area. The collected samples were composite in nature and were air-dried for 07 days followed by sieving (using 10 mesh; ~2 mm) and were ground to fine powder.

**Physico-chemical Analysis:** The dried, sieved and grounded soil samples were studied for various physico-chemical characteristics as per standard methods as depicted in table 1.

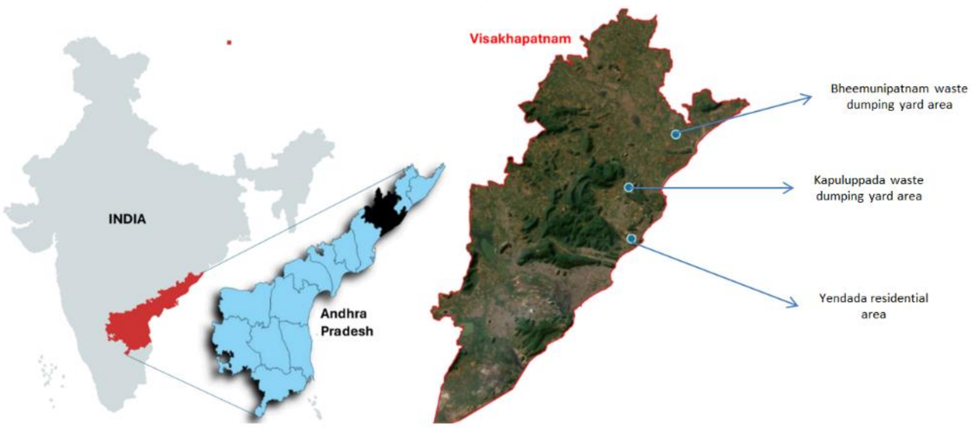


**Fig. 1: Map of the study areas DY-1 and DY-2 waste dumping yards, CA residential area of Visakhapatnam of Andhra Pradesh, India**

**Table 1**
**Methodology adopted for the estimation of physico-chemical properties**

| Physico-Chemical testing parameters of soil (with applicable units) | Testing Method |
|---|---|
| pH | pH Meter |
| Electrical Conductivity (us/cm) | Conductivity Meter |
| Organic Carbon (%) | Wet Oxidation Method (Walkley and Black) |
| Total Nitrogen (mg/kg) | Alkaline Potassium Permanganate (Kjeldhal distillation apparatus) |
| Potassium (mg/kg) | Neutral normal Ammonium Acetate extraction followed by Flame photometric method |
| Phosphorous (mg/kg) | Olsen's extraction followed by Spectrophotometric method |
| Calcium (mg/kg) | Complexometric titration EDTA |
| Magnesium(mg/kg) | Complexometric titration EDTA |
| Sodium (mg/kg) | Flame photometry |
| Chlorides (mg/kg) | Argentometry |
| Sulphur (mg/kg) | Spectroscopy |

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**Table 2**
**Total results of Physico-Chemical properties of soil**

| Soil Parameters | DY-1 waste dumping yard area | | | DY-2 waste dumping yard area | | | CA waste dumping yard area | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Range** | **Mean** | | **Range** | **Mean** | | **Range** | **Mean** |
| pH | No. of samples =06 | 7.35 to 7.9 | 7.76 | No. of samples =06 | 7.63 to 8.2 | 7.96 | No. of samples =06 | 6.5 to 7.34 | 6.87 |
| EC | | 0.75 to 1.03 | 0.92 | | 0.6 to 0.75 | 0.65 | | 1.73 1.92 | 1.79 |
| Calcium Carbonate | | 123.22 to 181.11 | 154.31 | | 97.66 to 137.6 | 110.44 | | 234 301 | 264.82 |
| Calcium | | 179.16 to 239.08 | 206.54 | | 158.57 to 211.54 | 184.29 | | 291.4 388.57 | 337.55 |
| Magnesium | | 150.7 to 262.5 | 215.46 | | 160.4 to 280.7 | 235.53 | | 160 293.52 | 239.33 |
| Chloride | | 775.71 to 893.76 | 841.16 | | 840.56 to 968.26 | 903.05 | | 107.03 123.32 | 115.24 |
| Sodium | | 17.74 to 57.67 | 42.27 | | 15.34 to 49.87 | 36.94 | | 13.8 44.9 | 33.24 |
| Potassium | | 110.1 to 140.25 | 126.74 | | 132.3 to 163.49 | 149.47 | | 8.15 10.58 | 9.55 |
| Sulphate | | 0 to 1.24 | 0.72 | | 1.54 to 3.98 | 2.39 | | 0 0.98 | 0.55 |
| Nitrogen | | 160.23 to 315.21 | 265.78 | | 176.58 to 328.71 | 274.09 | | 102.94 230.22 | 180.91 |
| Phosphate | | 9.68 to 12.79 | 11.01 | | 8.52 to 11.5 | 9.66 | | 12.89 17.01 | 14.11 |
| Org. Carbon | | 0.96 to 1.61 | 1.32 | | 0.64 to 0.84 | 0.73 | | 0.33 0.6 | 0.52 |
| Microbial Respiration | | 12.32 to 13.26 | 12.67 | | 8.9 to 10.2 | 9.54 | | 7.29 7.6 | 7.39 |

**Nutrient Index:** This soil nutrient index was used in this study to compare the soil fertility using physico-chemical properties of the soils collected from DY-1, DY-2 waste dumping areas and CA residential area. A comparative index was established to compare the soil nutrients level in areas through a soil nutrient index. As per soil nutrient index, soils fertility is classified as low (below 1.67), medium (1.67 to 2.33) and high fertile (above 2.33). Soil nutrient index is calculated as per the following formula:

$$\text{Nutrient index (NI)} = \{(1xA) + (2xB) + (3xC)\} / TNS \quad (1)$$

where A is No. of samples falling under low category, B is No. of samples falling under medium category and C is No. of samples falling under high category[41].

## Results and Discussion

**Physico-chemical properties analysis:** In order to assess the fertility status and contamination levels of the collected soil samples, a comprehensive set of physico-chemical parameters was analysed using standard laboratory procedures. Soil pH was measured with a calibrated digital pH meter and EC, expressed in micro-Siemens per centimetre (μS/cm), determined using a conductivity meter[18]. Organic carbon (OC) content was estimated using wet-oxidation method, as described by Walkley and Black[53]. The estimation of total nitrogen was analysed using Kjeldahl digestion and distillation as given. Available potassium was measured by a neutral normal ammonium acetate solution and a flame photometer, while available phosphorus was estimated using the Olsson's extraction method followed by spectrophotometric analysis.

The concentrations of calcium and magnesium were estimated via titration using EDTA as chelating agent. Sodium concentration was analysed by flame photometry and Cl levels were determined by the argentometric titration method. The estimation of sulphur was carried out using the turbidimetric method via spectrophotometry. These standard analytical protocols provided a robust framework for evaluating nutrient variability and soil fertility status across the study locations.

**pH:** Soil pH is one of the vital factors which enhance the chemical process by ensuring the availability of elements and nutrients. Elements and nutrients availability vary with pH i.e. variation in acidic, alkaline and neutral pH has severe impact on availability of element and nutrients. In this assessment, it is observed that soil pH in DY-1 waste dumping yard ranges between 7.35 to 7.9, DY-2 waste dumping yard ranges between 7.63 to 8.2 and 6.5 to 7.34 in CA residential area.

As per this study, DY-2 waste dumping yard area seems to be slightly alkaline when compared to DY-1 waste dumping yard and DY-1 waste dumping yard area seems to be slightly alkaline when compared to CA residential area. This slightly higher alkalinity in DY-2 waste dumping yard area > DY-1 waste dumping yard area might have a significant impact on nutrients uptake of plants. Contamination might be one of the reasons for slightly higher alkalinity in these DY-2 and DY-1 waste dumping yard areas.

**Electrical Conductivity:** EC is one of the important factors which enable us to understand the fertility of soil. The ideal EC ranges between 0.2 to 1.2 mS/cm. EC lower than 0.2 mS/cm indicates that soil is lacking adequate nutrients and EC higher than 1.2 mS/cm indicates that soil consists of a higher number of salts. In this assessment, it is observed that EC value in DY-1 waste dumping yard area ranges in between 0.75 to 1.03 mS/cm, DY-2 waste dumping yard area ranges in between 0.6 to 0.75 mS/cm and 1.69 to 1.92 mS/cm in CA residential area. As per this study, DY-2 waste dumping yard area and DY-1 waste dumping yard area soils seem to be with good EC range because of absorption of various types of dumped waste. CA residential area soil seems to be having higher salt content as it might be nearer to the sea.

**Calcium Carbonate and Calcium:** Calcium carbonate shows impact on pH level of the soil which in turn impacts the solubility of nutrients. Usually, higher calcium carbonate results in higher pH but in this assessment, it is observed that calcium carbonate in DY-1 waste dumping yard area ranges between 123.22 to 181.11 mg/kg, DY-2 waste dumping yard area ranges between 97.66 to 137.6 mg/kg and 234 to 301 mg/kg in CA area.

Calcium is the major component which helps the plant to grow effectively by promoting cell growth. It also helps in absorbing other nutrients in the plant[17]. In this assessment, it was observed that calcium in DY-1 waste dumping yard area ranges in between 179.16 to 239.08 mg/kg and DY-2 waste dumping yard area ranges in between 158.57 to 211.54 mg/kg and 291.42 to 388.57 mg/kg in CA residential area. As per this study, calcium and calcium carbonate seem to be higher in CA area only when compared to DY-1 and DY-2 waste dumping yard areas.

**Magnesium and Sodium:** Magnesium is one of the key minerals which helps plant growth by enhancing chlorophyll synthesis, enzyme activation and synthesis of several proteins. In this assessment, it is observed that Magnesium in DY-1 waste dumping yard area ranges in between 150.7 to 262.5 mg/kg, DY-2 waste dumping yard area ranges in between 160.4 to 280.7 mg/kg and 160 to 293.52 mg/kg in CA residential area. There is no much difference in magnesium availability in soils within CA residential area and DY-1, DY-2 waste dumping yard areas.

Sodium is one of the elements which helps the plant to maintain cell osmotic pressure within. Excess sodium may harm the plant and may kill the sensitive plants[25]. As per this assessment, it was observed that sodium level in DY-1 waste dumping yard area ranges in between 17.74 to 57.67 mg/kg and DY-2 waste dumping yard area ranges in between 15.34 to 49.87 mg/kg and 13.8 to 44.9 mg/kg in CA area. Sodium levels are slightly higher in DY-1 waste dumping yard area when compared to DY-2 waste dumping yard area and CA residential area.

**Chloride and Potassium:** Chlorides within the soil at an adequate level help in maintaining ionic balance within the cells of the plant tissues, higher and lower chloride levels within soil will adversely impact the plant growth[9]. As per this assessment, it is observed that chlorine level in DY-1 waste dumping yard area ranges in between 775.71 to 893.76 mg/kg and DY-2 waste dumping yard area ranges in between 840.56 to 968.26 mg/kg and 107.03 to 123.32 mg/kg in CA residential area. Chloride levels are very much higher in DY-2 waste dumping yard area when compared to DY-1 waste dumping yard area. Chloride levels are very low in CA residential area when compared to waste dumping yard areas.

Potassium is one of the primary nutrients and key element to ease optimal plant growth by enhancing enzymes, carbon metabolism and photosynthesis[55]. As per this assessment, it is observed that potassium level in DY-1 waste dumping yard area ranges in between 110.1 to 140.2 mg/kg and DY-2 waste dumping yard area ranges in between 132.3 to 163.49 mg/kg and 8.15 to 10.58 mg/kg in CA residential area. Potassium levels are higher in DY-2 waste dumping yard area when compared to DY-1 waste dumping yard area. Low potassium levels are observed in CA residential area soil when compared to waste dumping yard areas.

**Phosphate:** Phosphorus is one of the primary nutrients and a prime element which enhances the root growth and disease resistance within the plant[22]. As per this assessment, it is observed that phosphorus level in DY-1 waste dumping yard area ranges in between 9.86 to 12.79 mg/kg and DY-2 waste dumping yard area ranges in between 8.52 to 11.5 mg/kg and 12.89 to 17.01 mg/kg in CA residential area. The phosphorous level is slightly higher in CA residential area when compared to DY-1 and DY-2 waste dumping yard areas.

**Sulphur:** Sulphur is one of the important nutrients for plant growth. Sulphur helps in enhancing enzyme activity in case of regular metabolic process and even during stress condition[35]. As per this assessment, it is observed that sulphur level in DY-1 waste dumping yard areas ranges in between 5 to 1.24 mg/kg. DY-2 waste dumping yard area ranges in between 1.54 to 3.98 mg/kg and 0 to 0.98 mg/kg in CA residential area. Sulphur availability is higher in DY-2 waste dumping yard area when compared to DY-1 waste dumping yard area and CA residential area respectively.

**Organic Carbon and Organic matter:** Organic carbon has positive impact on growth of the plant as it has retention capability of nutrients/minerals in soil. Organic carbon in soil is termed SOC (Soll Organic Carbon). SOC is formed by decomposition of organic matter in soil with the help of microbes. Soil with high SOC has higher retention capability of nutrients. In this assessment, it is observed that SOC in DY-1 waste dumping yard area ranges in between 0.85 to 1.61% DY-2 waste dumping yard area ranges in between 0.46 to 0.84% and 0.33 to 0.8% in CA residential area. SOC levels are higher in DY-1 waste dumping yard area when compared to DY-2 waste dumping yard area. CA residential area has lower SOC when compared to waste dumping yard areas. Higher levels of SOC at waste dumping yard areas might be because of massive decomposition activity at dumping area.

**Total Nitrogen:** Nitrogen is one of the primary nutrients and is an essential element to enhance plant growth. Nitrogen is a key component of chlorophyll and building blocks like amino acids and proteins. As per this assessment, it is observed that nitrogen level in DY-1 waste dumping yard area ranges in between 160.23 to 315.21 mg/kg. DY-2 waste dumping yard area ranges in between 176.58 to 328.71 mg/kg, 102.94 to 230.22 mg/kg in CA residential area. Slightly higher nitrogen levels are observed in DY-2 waste dumping yard area than DY-1 waste dumping yard area. In CA residential area, lower levels of nitrogen is observed when compared to DY-2 and DY-1 waste dumping yard area and this might be because of waste decomposition activities at dumping yards.

**Physio-chemical characteristics of soils:** This study helps to identify the quality of soil i.e. fertile nature of the soil can be known. It is observed that soil samples collected from DY-1, DY-2 waste dumping yard areas seem to be 'Moderately Alkaline' and CA residential area is 'Neutral' in nature. 'Moderately Alkaline' nature at DY-1 and DY-2 waste dumping yard areas clearly indicates that solid waste contamination might be the reason for alkalinity. Electrical Conductivity levels are at 'Medium' level in DY-1, DY-2 waste dumping yard areas and 'High' level in CA area. It is also observed that primary nutrients like nitrogen and phosphate levels are almost similar (Medium level) in DY-1, DY-2 waste dumping yard areas and CA area whereas potassium levels are at 'Medium' levels in both DY-1, DY-2 waste dumping yard areas and 'Low' level in CA area.

Other nutrients / minerals like calcium and calcium carbonate are at 'Very low' level in DY-1, DY-2 waste dumping yard areas and CA area. Chloride levels are at higher side in DY-1, DY-2 waste dumping yard areas and are at lower side at CA area. Magnesium is at 'Medium' level in DY-1, DY-2 waste dumping yard areas and CA area. Sodium is at 'Low' level in DY-1, DY-2 waste dumping yard areas and CA area. Sulphate is at 'Medium' level in DY-2 waste dumping yard area and 'Low' level in DY-1 waste dumping yard area and CA area.

Apart from the above, organic carbon and microbial respiration seem to be 'Higher' in DY-1 waste dumping yard area and of 'Medium' level in DY-2 waste dumping yard area and CA area (DY-2 waste dumping yard area seems to be slightly on higher side when compared to CA area.

**Nutrient Index:** The soil nutrient index (SNI) is one of the most efficient soil fertility assessment tools, as it considers the content of the most demanded macro elements, as well as secondary elements. Results of a soil fertility comparison at study sites, from DY-1, DY-2 and CA showed a clear connection between the existing land use patterns, organic recycling activities and the level of anthropogenic influence on the soil[28]. The pH of the soil across all three sites ranged from nearly neutral at CA to the level of moderately alkaline at DY-1, DY-2, which is good for the overall development and plant growth. However, it may affect the micronutrient availability in the alkaline range[1].

The soil EC was at the moderate level at both DY-1, DY-2, being higher at CA, which may be caused by the urban runoff or salts accumulated and it may interfere with nutrient uptake. The most prominent component of organic carbon in DY-1 was the result of decomposed organic waste, stating that it was the highest of the three locations reflected the presence of moderate soil activity and organic matter in DY-2 and in CA. Nitrogen, phosphorus and magnesium were classified as a medium level at all stations, suggesting that growing plants in this area should encounter no problems in sourcing required essential nutrients[50].

Meanwhile, the potassium levels noted in the topsoil by CA were on the lower side, hence implying that the crops produced in this area may perform poorly or that the nutrient uptake is also ineffective. A critical observation is the consistently very low calcium levels in all three locations, pointing to a widespread deficiency of this vital secondary nutrient, probably due to leaching of soils. The sulphate levels varied, being low in DY-1 and CA, but at moderate levels in DY-2, depicting about sulfur cycling dynamics and availability. Across all areas, there was a low amount of sodium that would be considered hazardous salinity to crops as shown in table 3.

The overall fertility status suggests that dumping yard soils, despite waste accumulation, retain moderate nutrient potential due to organic matter inputs. In contrast, residential soils like control are of nutrient depletion and ionic imbalance due to the absence of natural replenishment and exposure to urban contaminants. Uniform calcium deficiency across all the sites calls for immediate attention through soil amendment strategies.

**Table 3**
**Rating of soil based on soil nutrient index**

| Soil parameters to conclude soil nutrient levels | DY-1 waste dumping yard area | DY-2 waste dumping yard area | CA residential area |
|---|---|---|---|
| pH | Moderately Alkaline | Moderately Alkaline | Neutral |
| EC | Medium | Medium | High |
| Organic Carbon | High | Medium | Medium |
| Nitrogen | Medium | Medium | Medium |
| Phosphate | Medium | Medium | Medium |
| Potassium | Medium | Medium | Low |
| Sulphate | Low | Medium | Low |
| Calcium | Very Low | Very Low | Very Low |
| Magnesium | Medium | Medium | Medium |
| Sodium | Low | Low | Low |
| **Soil Nutrient Index** | **Medium Fertile** | **Medium Fertile** | **Low Fertile** |

Enhancing organic carbon, correcting potassium and sulfur deficiencies and managing EC levels can collectively improve the SNI and can support sustainable soil health across the studied regions.

## Conclusion

Upon studying the physico-chemical characteristics of soils in DY-1, DY-2 waste dumping yard areas and CA area, based on nutrient index assessment, it is concluded that soil in DY-1 and DY-2 waste dumping yard area seems to be 'Medium Fertile' and CA area soil seems to be 'Low Fertile' irrespective of solid waste contamination in both DY-1 and DY-2 soils. Because of continuous solid waste decomposition activity, soil consists of high moisture content, microbial respiration and nitrogen availability and this might be the reason for effective withholding of available nutrients / minerals within the soil and making the soil slightly more fertile in DY-1 and DY-2 waste dumping yard areas than CA residential area soil.

However, this can be studied further by carrying out experimentation. Irrespective of fertile nature, as per primafacie assumption, hazardous contamination at waste dumping yard soil needs to be studied to ensure whether contaminants are posing more threat to those soils, eco system and spreading further.

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