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Research Article

Impact of coal dust handling on mangrove ecosystem around Kandla Port, Gujarat, India.

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Abstract: The present study aims to identify the impacts of port-led coal activities on mangroves and its ecosystem. Duration of the study was 6 months. Study was conducted at two different locations viz. Kandla Port and the Vadinar site which was selected as pristine located in Marine National Park. To identify the coal impact, soil and water samples were assessed as per the CPCB standards which included heavy metal assessment also. Samples collected from 3 different locations with 0-3 km radius from the Port. For assessing, mangrove health, Dust load assessment in leaf, Carbon content estimation in leaf, Relative leaf water content, Chlorophyll, Stomata density and morphological observation were also recorded. To identify the impacts of coal dust on mangrove, obtained the holistic approach by studying not only mangrove physiology but the physicochemical indicators (soil & water) and heavy metal assessment too. Results of soil and water samples' analysis revealed that the samples collected around Kandla Port showed highest variation in the physicochemical properties of soil and water. Heavy metal contamination was observed in all sample sites including pristine location too. However, Physicochemical analysis of soil and water carried out for the mangrove ecosystem showed contamination of different types but only correlating it with coal as its major source cannot be established since there are various other development activities taking placed around the Port which could have contributed to the pollution.

Key words: Coal Dust, Dust load, Heavy Metal Contamination, Kandla Port, Mangroves ecosystem, Physicochemical analysis

Introduction

Gujarat, situated on the Western Coast of India, is the principal maritime State endowed with strategic port locations. There are 41 ports, of which Kandla is a major port. Out of the remaining 40 ports, 11 are intermediate ports and 29 are minor ports under the control of Gujarat Maritime Board. Gujarat ports (including Kandla) account for 41% of traffic in the total National port traffic, which is more compared to any other State in India. Crude oil and coal are leading commodities imported at non-major ports of Gujarat, where share of coal import stands at 29% of total imported commodities (Gujarat Maritime Board, 2015). The areas near the ports and harbours, dealing with coal handling, are prone to such fugitive emissions causing stressful environment for the nearby ecology. Around 18 million tons of coal is consumed in Gujarat State annually, mostly accounted for power generation. None of this coal is produced in the State but comes mostly from Madhya Pradesh & about 4 million tonnes are imported (SoER, 2012, Government of Gujarat).

Status of Mangroves in Gujarat:

In-terms of area under mangrove cover, Gujarat ranks second after Sunderbans, West Bengal with an estimated area of 1107sq km under the mangrove, accounting for 23.91 percent of India's total mangrove vegetation. Gujarat has the longest coastline where majority of the mangroves are concentrated on the Gulf regions i.e. Gulf of Kutch and Gulf of Khambhat. The notified area of mangrove forest is of 1,326.43 sq km, of which 1,142.5 sq km is in Kutch and Jamnagar districts (Forest Survey of India in 2013). Out of this, majority (77 percent) of mangrove cover belongs to Kutch district, encompassing an approximate area of 786 sq km (Forest Survey of India, 2015). This study takes a deeper review on mangroves and marine ecosystems in context of post development activities with explicit focus on coal handling activities.

Materials and Methods

Study area Description: Two sites were selected at different locations for comparing and assessing results of coal dust impact on mangroves and its ecosystems. i.e: 1) Kandla Port and 2) Pristine site, located at Vadinar near Marin National Park, Jamnagar.

About Kandla Port:

Kandla Port is one of the major ports among the 13 declared major ports of India; the port is located on the shores of Kandla Creek in Kutch District. Presently, Kandla Port handles cargo at its ten general cargo berths and through barges at *Bunder* Basin and *Tuna*. Both these facilities have a combined capacity of 46.28 Million Metric tonnes per annum, which includes dry handling capacity of

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33.28 MMTPA and liquid cargo handling capacity of 13.0 MMTPA. In 2003, Coal storage area of Kandla was reported 41 Ha which reached at 137 Ha in 2015. Including Coal, another major commodities exchanged at Kandla Port are, POL and acids, crude oil, edible oil, fertilizers, scrap, steel coils, wooden logs and coal, Food grains, Salt, Coated/Steel Pipes etc. Study conducted within the 3 Km of buffer from the port area (Fig. 1: Location of sample collection from Kandla Port Site).

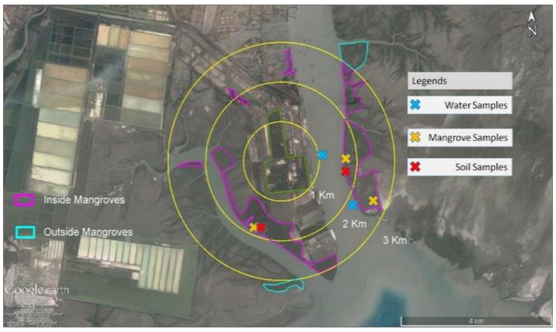

Figure 1. Location of Sample collection from Kandla Port site

Pristine Site:
One pristine site has been selected for comparative assessment. The site has been selected at Vadinar district, located 18 km east from Marine national park and nearer to Narara, situated on the southern shore of the Gulf of Kutch in the Jamnagar District of Gujarat State. GPS coordinates of the site was N: 22^0 27' 48.05" and E: 69^0 43' 2.67"

Methodology
The approach of the study is designed to identify the stress elements on mangroves and its ecosystem. There are various factors that interact with an ecosystem likewise and playing crucial role in the sustenance of mangrove ecosystems. The study was undertaken for the 3(Oct-Dec, 2016) months for observing pilot results. Methodology adopted for the pilot study is divided into 3 different segments which are as followings:

1. **Secondary data assessment and trend analysis:** Secondary data of soil and water quality, Mangrove Density, Coal handling and Heavy metals have been collected from the respective Government Departments (2010-2013) for the further analysis of trends and to use as the baseline information.
2. **Primary Data collection:** To assess the impacts of coal dust, major focus has been laid on primary data and ground level assessment. Number of samples and locations has been chosen based on GIS map and port locations. It has been ensured that collected samples would represent aqueous system. In order to collect the representative and homogenous samples, site assessment has been done though GIS mapping. Three buffer areas of 1KM, 2KM, and 3 KM were mapped putting centre in port locations. Samples have been collected from buffer areas, to understand spatial effect of coal dust on surrounding areas. Soils and Water samples were assessed in the Gujarat laboratory, Ahmedabad for Physicochemical Analysis and Heavy metal assessments. Analyses of the samples were made as per the CPCB standards and Guideline of assessments.
3. **Mangrove Assessment:** For studying direct impact of coal dust on mangroves, following methodology was adopted:

Estimation of Chlorophyll content and other pigments: Collected leaf samples placed into Lab in airtight bag and washed in fresh water. This extract was prepared and further analysed by using required concentration of menthol and acetone which is based on Mckinney's work and measuring its absorbance using Single Beam UV/vis Spectrophotometer at $\lambda = 663$ nm and $\lambda = 645$ nm for Chlorophyll (a,b) and Carotene estimation.

Estimation of Carbon content in Coal dust particles: Collected dust from leaves was weighed then to calculate prices dust load per cm 2 areas, total 50 leaves were cut in area of 1 x 1 cm and burned them through heat until burning of total Carbon. Residue was weighted as the incombustible ash. Difference in weight was calculated which resulted as the fixed Carbon content.

Estimation of Dust loads on leaves: Leaf sample was collected randomly in the early morning from the lower branches at the height of 2-4 m and analysed within 24 hours of harvesting. The amount of dust was calculated by taking the initial and final weight of beaker in which the leaf samples were washed. It was calculated by using the formula:

$$[W=W2-W1/A]$$

Where, W = Dust content (mg/cm2), W1 = Weight of beaker without dust, W2 = Weight of beaker with dust A = Total area of leaf in cm^2

Relative Leaf Water Content (RWC):
The method described by Liu and Ding, was followed to determine RWC based on the formula, RWC= (wf – wd) x 100 / (wt – wd) Where, wf fresh wt of the leaf, wt-turgid weight of the leaf after immersing into water overnight and wd-dry weight of the leaf. Fresh weight (wf) of the leaf was increased when leaf pieces were weighed after immersing in water overnight to get turgid (wt). The leaf pieces were then blotted to dryness and placed in a dryer at 115^0C (for 2 hr.) and reweighed to get dry weight.

Mangrove Density: Mangrove density survey was carried out to assess the vegetation status of mangroves around coal storage sites at each port. The vicinity area was taken around 1km, 2km and 3 km of coal handling site. Mangrove density assessment was carried out using quadrate

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methodology. 10 m *10 m size of quadrats was laid down randomly at the site to quantify number of plants. Mangrove vegetation was classified based upon the height of the plant and all plants were accounted based upon the category. Classification of mangrove plants based upon the height for density study was defined as Class I: 2m & above, Class II: 1m -2m, Class- III: 60 cm- 1m, Class-IV: 0 cm-60 cm.

Stomata Density: Leaves section collected and analysed through electron microscope.

Results and Discussion

Secondary Data Assessment

Secondary Data collected from various relevant Departments (GPCB & CPCB) specifically related to coal handling, Mangroves, Water and Soil quality and Heavy metal contamination for the study site (Kandla Port) and pristine location (Vadinar). Considering secondary data assessment, quality of soil and water fallen within the permissible limit and there was no contamination of heavy metals. Data used for the assessment was from 2010-11 and 2012-13 as there was no latest data published by the respective authentic sources. Assessment of Data is as following:

- pH of Water recorded between the range of 7.8 and 7.6 during the year 2010-11 and 2012-13
- During the year 2010-11, BOD level recorded as 11.8mg/l which significantly raised up to 21.89mg/l in 2012-13
- COD values recorded during 2010-11(56.5mg/l) and 2012-13(74.8mg/l) are within the standard limit of CPCB (below 250mg/l)
- DO recorded little higher in the year 2010-11(5.2mg/l) and 2012-13(5.6mg/l) than the permissible limit of CPCB (5mg/l)
- Limit of Suspended Solid exceed the permissible limit as fixed by the CPCB (100mg/l) and recorded 170mg/l in 2010-11 and 190mg/l in 2012-13
- Concentration of Chloride recorded beyond the permissible limit (1000mg/l) viz.25351mg/l in 2010-11 and 23978mg/l in 2012-13
- Concentration of Sulphates also recorded very high (permissible limit 1000mg/l) in 2010-11 (2272mg/l) compared to the 2012-13 (603mg/l)
- Concentration of Phosphate recorded 0.33mg/l in 2010-11 which was decreased up to 0.11 in the year 2012-13 respectively and under the permissible limit of CPCB (3mg/l)
- Concentration of Nitrate found within the permissible limit during 2010-11(2.2mg/l) and 2012-13(1.0mg/l)

Primary Data Assessment for Pristine Location:

Water and Soil samples were collected and assessed for comparative assessment. Results are as following:

Physicochemical Analysis of Water:

- Water samples collected at pristine location had pH of 8.1.
- The amount of dissolved solids and suspended solids was 8025 and mg/l and 50mg/l respectively.
- Dissolved solids content exceeded the permissible limits (2100mg/l) while the suspended solids was found within the limits.
- The turbidity of water (i.e. an account of the clarity of the water) at pristine location was 10 NTU which was within the permissible limits and the water samples showed a clean visibility when collected.
- The chemical oxygen demand for the water samples (225mg/l) collected was within the permissible limits of 250mg/l while the Biological Oxygen Demand (40mg/l) exceeded (the permissible limit of 30mg/l). Dissolved Oxygen content in the water must be maintained above 5mg/l for ecologically important locations and it was found under control, as the samples had 5.8mg/l of DO in water.
- Nitrate, phosphate, sulphates and fluorides were within the permissible limits at pristine location where nitrate was around 70mg/l (permissible limits: 100mg/l), phosphate was not detected or was below the detection level of 0.1mg/l, sulphate content was around 152mg/l (permissible limits: 1000mg/l) and fluoride was around 2mg/l (permissible limits: 15mg/l).

Physicochemical Analysis of Soil:

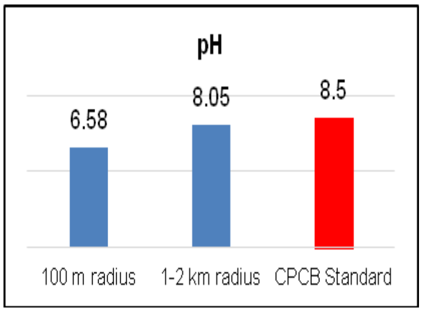
- The soil sample collected at pristine location showed that the soil was alkaline with pH of 8.1.
- Electrical Conductivity of the Soil was around 1.88 to 1.46 and the Cation exchange Capacity was around 6.9% to 7.3%.
- The nutrient content of the soil measured by the content of Nitrogen, Phosphorus and Potassium which recorded 0.16% in the surface layer and 0.21% at 30 cm for nitrogen, 0.26% in the surface layer and 0.21% at 30 cm depth for phosphorus and 0.29% in the surface layer and 0.31% at the 30 cm layer for Potassium content.

Primary Data Assessment of Kandla Port:

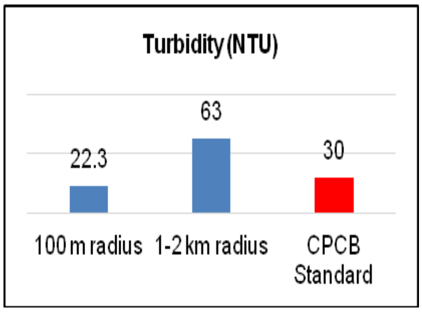
Sediments play an important role for mangrove ecosystems (McManus, 1998). Considering the facts, Samples for soil, water and Mangroves health assessment were collected from following GPS locations at the Kandla Port Site and the pristine during the month of October-December, 2016:

1. N 22 58.5 07, E 0.70 13.07 (Within 1 km)
2. N 22 58 18.0,E: 0.70 13.16 (Within 1 -2kn radius)
3. N 22 59.45 9, E 0.70 12.22 (within 2-3 km radius)

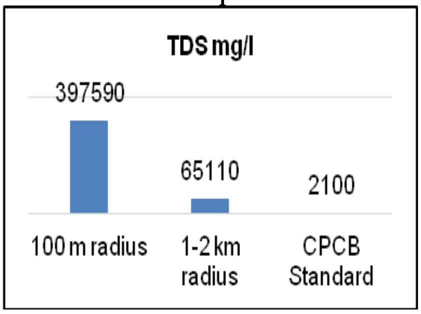
Physicochemical assessment water:



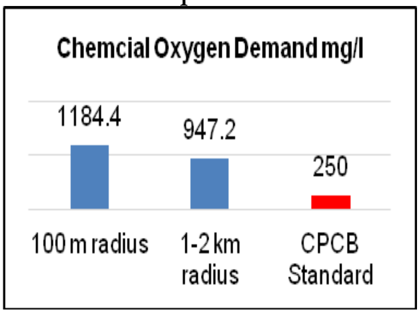
Graph 1a



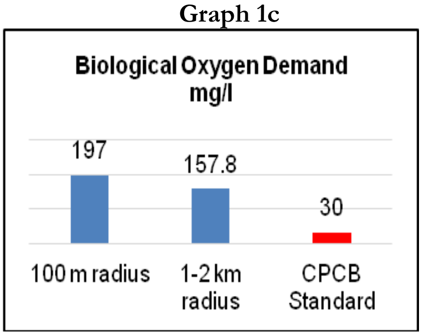
Graph 1b



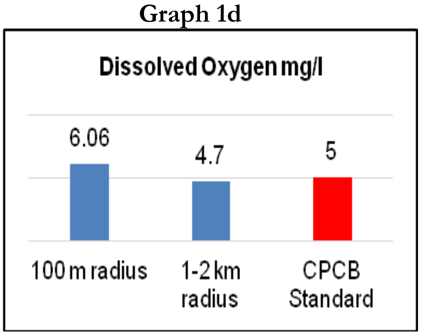
Graph 1c



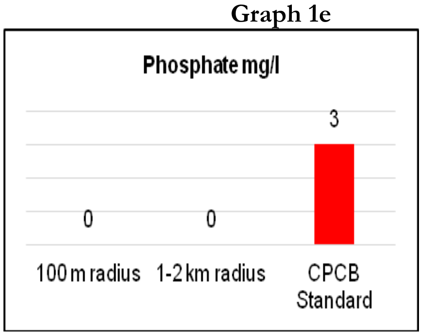
Graph 1d



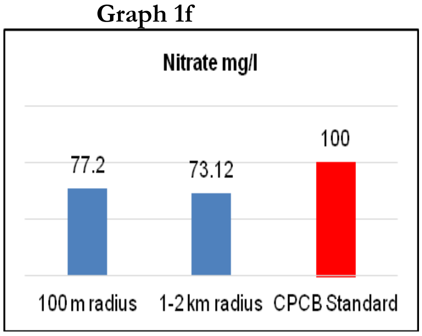
Graph 1e



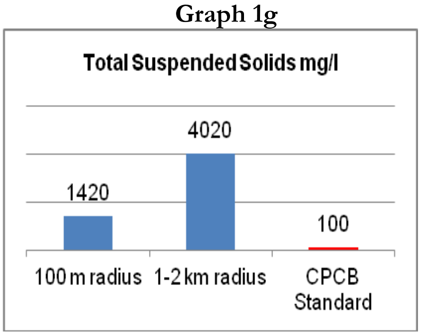
Graph 1f



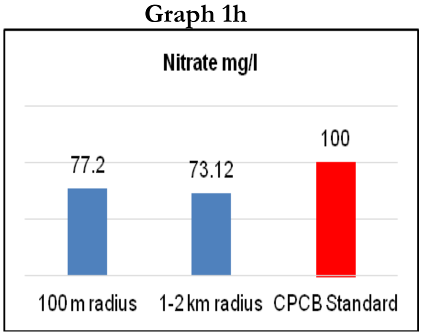
Graph 1g



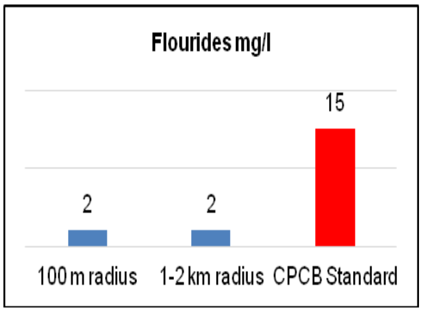
Graph 1h



Graph 1i



Graph 1j



Graph 1k

- pH value found within 100 m from coal storage area was 6.58 and at 2-3km range, it was 8.05 **(Graph 1a)**
- Turbidity recorded varied for both the sample sites which found 22.3 NTU within 100 m radius and 63 NTU within 1-2 km radius **(Graph 1b)**
- TDS recorded at both sites (within 100 m and 1-2 km) showed very steep rise compare to permissible limit (2100mg/l) **(Graph 1c)**
- The water samples collected at both the sites showed elevated levels of COD compared to the permissible limits **(Graph 1d)**
- BOD at both locations is higher than the standards which signifies a higher requirement of oxygen which considered as a negative sign for the health of the marine ecosystem **(Graph 1e)**
- Amount of DO within the 100 km radius was little high than the permissible limits while samples within 1-2 km radius, amount of DO found under the permissible limit **(Graph 1f)**
- Phosphate content in water was not detected at any of the sample sites. Hence the concentration of phosphate was significantly low **(Graph : 1g)**
- Concentration of Sulphate particles in water for the sample sites was considerably low compared to the permissible limit (1000mg/l) **(Graph : 1h)**
- Total suspended Solids recorded much higher at both the sites than the permissible limits **(Graph 1i)**
- Amount of Nitrate recorded well within the permissible limits from both sample sites **(Graph 1j)**
- Fluoride contents recorded negligible (2mg/l) and within the permissible limit **(Graph 1k)**

Heavy Metal Assessment:

Heavy metals are elements having relatively higher atomic numbers and are metallic in nature, often considered as a polluting agent for the environmental studies. Information on trace elements in coal has been reviewed comprehensively by Swaine (1990) and Swaine & Goodarzi (1995), including environmental aspects during mining and combustion.

Heavy Metal Assessment for Water Samples:

Water samples analysis for the presence of heavy metal showed no significant presence of any heavy metal in the water. Hence heavy metal assessment not proved any significant contamination in the water at all the identified sites. The information about the detection levels for all the heavy metals that were assessed mentioning in Table 1. (Table 1. Heavy Metal assessment of water samples of Kandla Port)

Table 1. Heavy Metal assessment of water samples of Kandla Port

Parameters	Detection levels	Test Method
Selenium (mg/l)	0.01	IS:3025(P-56):2003
Iron (mg/l)	0.08	IS:3025 (P-53):2003
Cadmium (mg/l)	0.0005	IS:3025(P-41):1992
Mercury (mg/l)	0.005	IS:3025 (P- 48):1994
Copper (mg/l)	0.04	IS:3025 (P-42):1992
Chromium (mg/l)	0.03	IS:13428:2005
Arsenic (mg/l)	0.005	IS : 3025(p-37):1998 3737)37):1998
Zinc (mg/l)	0.01	IS:3025(p-49):1994

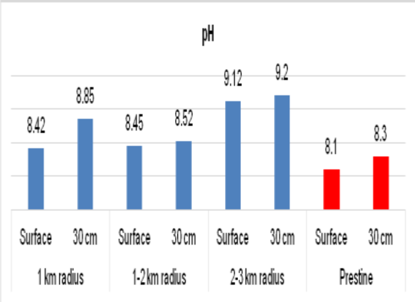
Heavy Metal Assessment for Soil Samples:

The results of heavy metal analysis of soil showed contamination of 4 different heavy metals in the soil. All soil samples including the pristine location showed presence of lead, zinc, copper and iron. Presence of heavy metal like selenium, cadmium, mercury and arsenic were not found in any soil samples or the concentration was below detection levels. This segment discusses the presence of heavy metal in the soil as described in Table 2 (Table 2. Comparable assessment of Heavy Metal):

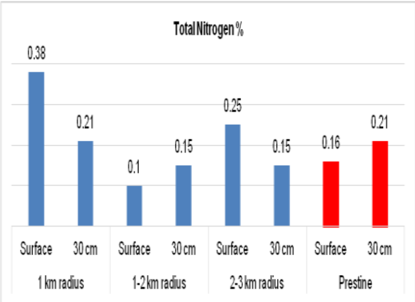
Table 2. Comparable assessment of Heavy Metal

Heavy Metals listed	Kandla		Pristine	
	Surface	30 cm	Surface	30 cm
Lead (ppm)	6.4	6.8	3.12	3.05
Zinc (ppm)	81.04	70.62	71.21	72.24
Copper (ppm)	7.2	6.1	2.11	2.09
Iron (ppm)	5.24	5.8	3.25	3.21
Chromium (ppm)	nil	nil	nil	nil
Nickel (ppm)	nil	nil	nil	nil

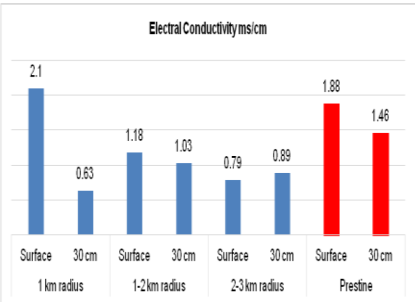
Physicochemical assessment soil:



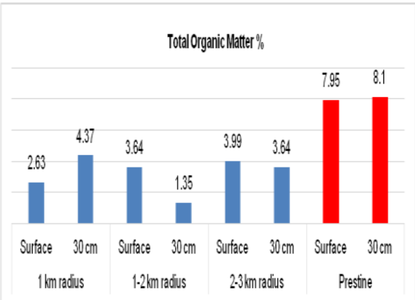
Graph 2a.



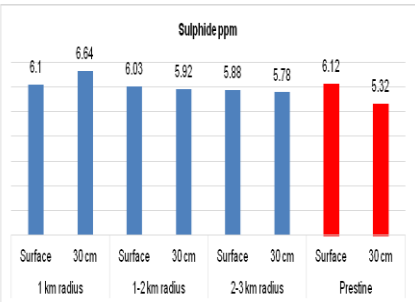
Graph 2b.



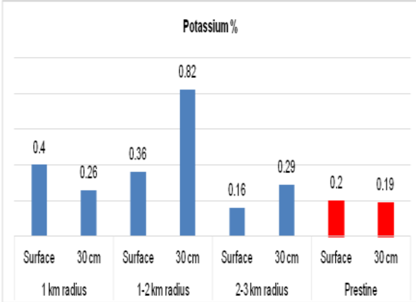
Graph 2c.



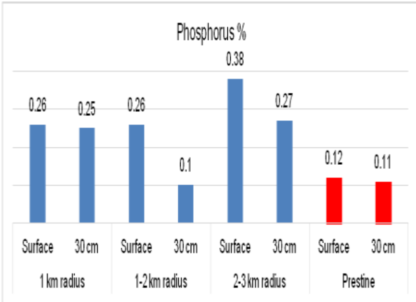
Graph 2d.



Graph 2e.



Graph 2f.



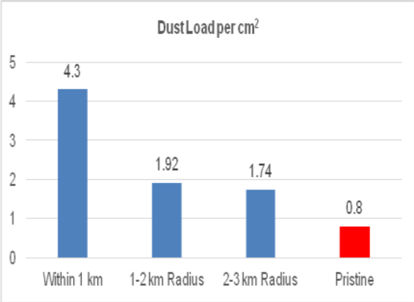
Graph 2g.

- pH of soil at all sample locations found alkaline (8.42 – 9.2) and alkalinity gradually increased towards the coal storage facility of port (**Graph 2a)**
- Nitrogen content found higher at the coal storage site and degreased within 1 km radius while gradually increased at the distance of 3 km **(Graph 2b)**
- The electrical conductivity was observed maximum at the surface of the soil near the sample sites which decreased gradually at the increasing of distance **(Graph 2c)**
- Organic matter at 30 cm depth, recorded higher which found at closer location to sample site at port whereas the distance of 3 km, presence of organic matters found dip **(Graph 2d)**
- Concentration of sulphide observed maximum at the location, closer to the coal storage facility **(Graph : 2e)**
- Concentrations of Potassium in soil samples were not uniform and no clear pattern or observations were noticed **(Graph 2f)**
- Phosphorus content at surface observed maximum at the farthest distance from the coal storage facility while found uniform up to 2 km radius **(Graph 2g)**

Mangrove Health Assessment:

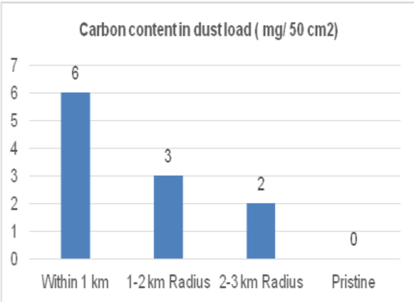
Coal Dust Load: Dust load has negative impact on growth of leaf and load on the surface of leaf alerts its optical properties (Eveling, 1969), hence it interferes with the normal functioning of the leaf. The coal dust load on the leaf shown around 4.3 mg/ cm^2 within 1 km and 1.92 mg/cm^2 between 1-2 km radius **(Graph 3a)**

http://dx.doi.org/10.21746/aps.2018.7.6.5



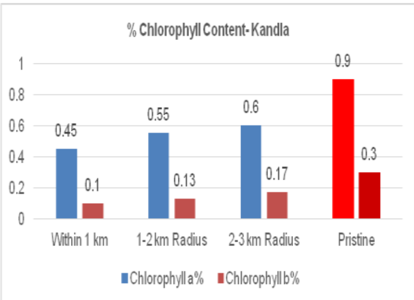
Graph 3a.

Presence of Carbon Contents: Presence of Carbon contents in leaf reduces the respiratory functioning of the leaf by blocking the stomata (Reddy, 1998). Carbon content estimation in dust load for Kandla represented very high carbon contents in the dust load which was around 6 mg/ 50 cm² within 1 km. **(Graph 3b)**



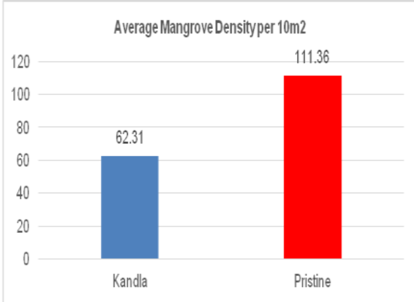
Graph 3b.

Leaf Chlorophyll content: Chlorophyll is the principal photoreceptor in photosynthesis and any reduction in content corresponds directly to plant growth (Wagner, 1998). The Leaf Chlorophyll Content found within the acceptable limit. **(Graph 3c)**

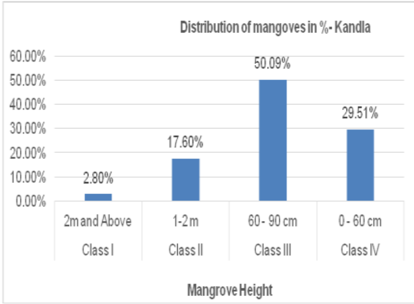


Graph 3c.

Average Mangrove Density & Distribution of Mangroves: Average mangrove density at Kandla recorded 62.31 trees/10m², considerably lesser then mangrove density of pristine location. Considering mangrove distribution pattern, Class III type trees were observed covering highest surveyed area with 50.09%, followed by class IV with 30.49% of surveyed area. Matured tree with height above 2 m have lowest share at 2.8% coverage area. **(Graph 3d, 3e)**

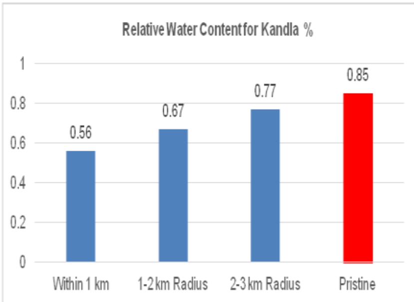


Graph 3d.



Graph 3e.

Relative Leaf Water Content: According to Eveling, 1969, dust particles have triggered an increased loss of water from the leaves. Relative leaf water content parameter showed more than 40% decreased in moisture content on leaves due to excessive coal dust deposition. The sites closer to the coal storage had maximum dust load hence the impact of the dust load can directly be observed on the leaf water content. **(Graph 3f)**



Graph 3f.

Morphological Observations:

Leaf samples collected from the closer to coal handling sites had a poor quality as compared to the greater distance and blackening of leaf was observed very clearly. This was due to the prolonged deposition of coal dust on leaves. (Fig. 2: Leaves collected from 100 m distance of the port)

Fig. 2: Leaves collected from 100 m distance of the port

Anatomical Observation:

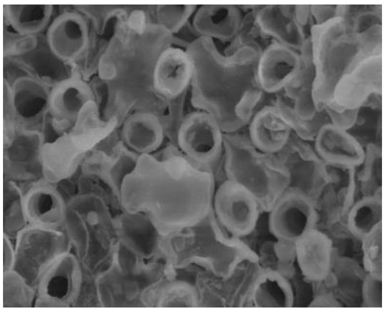
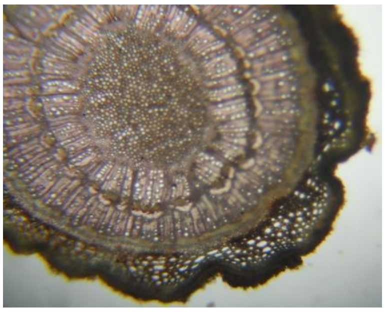


Fig. 3: Leaf section of lower epidermis for stomatal observation of Kandla

Considering anatomical observations, stomatal density was measured with the help of electron microscope. The assessment revealed that the count of stomata increased in the areas that are nearer to the coal handling sites, compare to samples collected from the pristine site. Stomata density was more (24) for the samples which had more dust cover on the leaves compared to the pristine location (11) (Figure 3. Leaf section of lower epidermis for stomatal observation of Kandla).



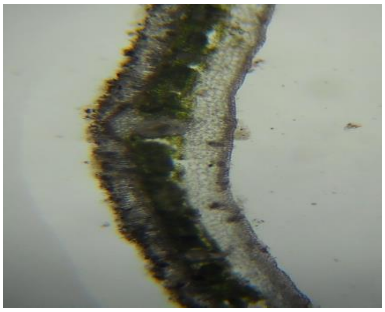
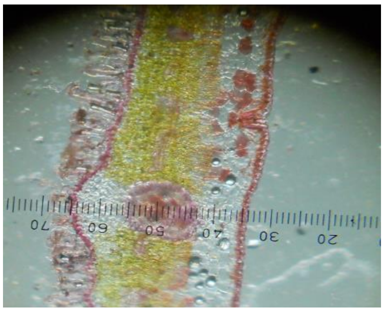


Fig. 4: T.S. of stem collected from port site
Fig. 5: T.S. of leaf collected from port site

Transverse Sections of Stems and Leaves were also taken for better understanding of coal dust deposition from the Kandla Port and the pristine location. The section of stem shows slight variation in pith but do not show any direct impacts. The variation can be due to other environmental factors.



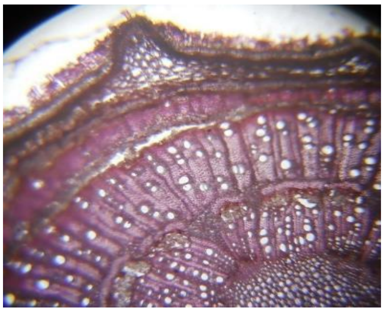


Fig. 6a: T.S. of Stem collected from Pristine
Fig. 6b: T.S. of leaf collected from Pristine

Transverse section of leaf exhibits prominent coal dust deposition on upper and lower leaf surface. Coal dust deposition on leaf hair blocks the stomata, which hampers Photosynthetic process of plant (Naidoo G, Chirkoot D, 2004) (Figure 3a: Transverse Section of mangroves Stem, Figure 3b: Transverse Section of mangroves leaf)

Discussion

- The present study aimed at understanding the impacts of coal dust on the mangrove ecology.
- Considering Soil Sample analysis, Nitrogen Content observed higher at the location closer to the coal storage site of port while decreased at the distance of 1 km and further increased at the distance of 3 km, thus showing fluctuation in trend.
- Sulphide level at Kandla is almost at par with the pristine location with marginal variations.
- Physicochemical and heavy metal analysis shows signs of environmental pollution around the port. Physiological analysis of mangrove samples revealed a high degree of impact in Kandla. The impact focused and observed maximum up to 1 km periphery from coal handling site at port, the impact intensity decreased as the distance from the port increased. Beyond 3 km periphery, the impact observed very low.

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- The amount of dust load decreased significantly as the distances increased from the coal handling sites. The comparative analysis with pristine site revealed that the dust accumulation was very high closer to coal handling site at port areas as compared to the pristine site.
- The amount of carbon deposition observed on the leaf had a direct relationship with its distance from the coal storage sites as the maximum amount of carbon was found on samples collected from the location adjacent to coal storage units which decreased with increasing of distance.
- The amount of carbon deposition observed on the leaf had a direct relationship with its distance from the coal storage sites as the maximum amount of carbon was found on samples collected from the location adjacent to coal storage units which decreased with increasing distance.
- The relative water content of mangrove leaves was recorded lowest at Kandla (43%) whereas chlorophyll content analysis indicated the lowest content in samples collected from Kandla (45%)

Conclusion

Results of soil and water samples' analysis revealed that the samples collected around Kandla Port showed highest variation in the physicochemical properties of soil and water. Heavy metal contamination was observed in all sample sites including pristine location.

Impacts observed at Kandla can't be explained solely due to the coal dust contamination as the port extension activities also have impact on the mangrove cover around the port too.

The direct impacts of coal dust on mangrove were visible and derived further by observing the physiological and anatomical state of mangrove. But such observation may vary since it's completely dependent on the geographical locations and time/season of sample collection. Moreover, the role of coal dust in overall impacts on mangrove cannot be ascertained since there are other natural and anthropogenic factors affecting the mangrove physiology. Additionally, the mangrove natural regeneration was observed at all sample sites. Since mangrove has bioremediation characteristic, it tends to absorb the additional nutrient flow (containing heavy metal) which may have led to its proliferation. Environmental status plays a very important role in understanding the health of any particular ecosystem. Physicochemical analysis of soil and water carried out for the mangrove ecosystem showed contamination of different types but correlating it with coal as its major source cannot be established since there are various other development activities taking placed around the Port which could have contributed to the pollution too.

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