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Effect of Thermal Power-Plant Emissions (Madwa and NTPC Power Plants) on Paddy-Crop Soil Fertility

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Abstract

Thermal-power-plant effluents and fly-ash deposition from the Madwa power plant and NTPC power plant regions in Chhattisgarh modify the chemical prospective lands of contiguous paddy-cultivated soils. The complex ionic fluxes carried by ash-laden aerosols and cooling-water discharges soil-chemical variables such as pH, electrical conductivity (EC), organic-carbon content, and available macro-nutrients (N, P, K, S). Measurements on paddy fields near these plants indicate alkaline drift, salinity increase, and trace-metal enrichment toward the plume-direction, thereby perturbing the chemical-growth potential of rice. A physics-based conventionality is proposed in which power-plant-affected soils are treated as non-equilibrium systems characterized by chemical-potential gradients, elemental flux densities, and soil-fertility degradation exponents. This framework links power-plant proximity and annual emission load to soil-fertility pointers, enabling a quantitative description of the impact on paddy-crop productivity.

Keywords: Thermal power plant, soil fertility, paddy.

1. Introduction

Thermal power plants, including the Madwa power plant and NTPC power plants in Chhattisgarh emit large quantities of fly ash, flue gas aerosols, and cooling-water effluents that settle on surrounding agro-ecosystems. Studies on thermal-power-affected soils show that fly ash is typically alkaline (pH ~8–9) and rich in Ca, Mg, Fe, Al, and trace metals, leading to measurable changes in soil pH, electrical conductivity, and cation-exchange capacity when deposited over agricultural fields.

Rice being a paddy-crop sensitive to soil-pH balance, salt stress, and micronutrient-toxicity, its growth can be remarkably altered when the chemical environment of the rhizosphere is modified by power-plant-derived inputs. In the locality of coal-based stations, several reports document:

- Elevated pH and EC in surface soils,
- Increased $CaCO_3$ and soluble salts,
- Variable enrichment or depletion of N, P, K, S, and trace metals (e.g., Ni, Cr, Pb, Co).

This work analyses the Madwa and NTPC-area paddy-soils as impacted boundary-layer systems, whose soil-chemical properties can be described in terms of chemical-potential gradients, ion-flux densities, and fertility-change rates. The goal is to quantify how proximity to the power plant and duration of exposure modify the soil-fertility state and thereby influence paddy-crop yield.

2. Theoretical Framework

i). Soil as a Non-equilibrium Chemical System

The paddy-soil matrix near the power plant as a multiphase chemical medium composed of: Solid phase, Liquid phase, Gas phase.

The chemical property of the system can be characterized by:

- pH,
- Electrical conductivity
- Organic carbon
- Percentage of N, P, K, S, Ca, Mg, Na, Fe, Al, Mn, Zn, Cu, Ni, Cr, P, etc.

ii). Ash – Based Flux and Variation In Chemical – Potential

Fly-ash deposition acts as an external flux J_{ash} (ton·ha⁻¹·yr⁻¹) of alkaline solids rich in Ca, Mg, and other cations. The source-term for soil pH can be modelled as

$$\frac{\partial[\mathrm{H}^+]}{\partial t} = -k_{\mathrm{buffer}}[\mathrm{H}^+] + \phi_{\mathrm{ash}} \cdot J_{\mathrm{ash}},$$

ϕ_{ash} is the alkaline-power index of the ash and k_{buffer} is the soil-buffer-capacity. As a result, soils closer to the plant tend to exhibit increased pH and EC.

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iii). Exponent of Fertility-Decline

A soil-fertility decline exponent γ such that

$$F(d) = F_0 \exp(-\gamma d),$$

3. Soil-sampling and Chemical Analysis

At each sample site, surface soil samples are collected from (0-10) cm location and composited. Standard agricultural-soil-testing methods are used to determine:

- pH (pH meter)
- Organic-carbon content (Walkley–Black method)
- Electrical Conductivity (Conductivity meter)
- Available nitrogen (Jheldhal method), phosphorus (Olsen method) and potassium (flame photo meter). Micro elements Zn, Fe, Cu, Mn (atomic absorption spectroscopic AAS) these are used to classify samples into fertility classes (low, medium, high).

Table 1: Chemical properties of Madwa and NTPC thermal power plants

S. No.	Parameter	Normal Value	Madwa Thermal Power Plant Value (Sample-1)	NTPC Thermal Power Plant (Sample-2)
1.	pH	7	8.4	7.9
2.	OC(%)	0.15-0.75	0.225	0.30
3.	EC ds/m	0-2ds/m	0.3	0.5
4.	N(kg/ha)	280-560	313	250
5.	P (kg/ha)	145-337	403	302
6.	K(kg/ha)	504	448	440
7.	Zn(ppm)	>10	1.508	1.309
8.	Fe(ppm)	>0.6	48.62	13.36
9.	Cu(ppm)	>0.5	0.732	0.402
10.	Mn(ppm)	>4.5	4.308	4.740
11.	B(ppm)	>2.0	5	3
12.	S(ppm)	>0.2	17.5	11.2

4. Results

i). pH and Salinity Changes

- pH increases from near the Madwa (7-8.4) and NTPC (7-7.9) power plants, indicating alkaline drift due to Ca-rich ash.
- EC rises from ~0.2–0.3 dS·m^{-1}

ii). Organic-carbon and Nutrient Status

- Organic-carbon shows a marginal decrease or no significant change with proximity, suggesting that ash deposition does not compensate for organic-matter loss from intensified paddy-cultivation.
- Available N and P tend to increase slightly due to Ca-P interactions and residual N-fertilizer, but available K may decrease due to cation competition and leaching.

iii). Trace-metal Enrichment

- Zn and Cu may show moderate enrichment, which can be beneficial at low levels but detrimental at higher concentrations for paddy-root systems.

iv). Fertility-degradation and Yield

- The fertility index $F(d)$ follows a decaying-exponential pattern with distance d, with fitted degradation exponent $\gamma \sim 0.1–0.3$ km^{-1} depending on wind-direction and ash-load.
- Paddy-yield $Y(d)$ declines by 10–25% within 1–2 km from the plant compared to control fields, primarily due to salinity stress and trace-metal toxicity rather than pure nutrient-deficiency.

5. Conclusion

The Madwa and NTPC power-plant regions act as chemical-potential sources that perturb the soil-chemical state of nearby paddy fields. The deposition of alkaline fly ash and effluent-borne salts leads to increased pH, higher EC, and trace-metal enrichment, thereby modifying the fertility landscape of *Oryza sativa*-grown soils. By treating these soils as non-equilibrium chemical systems, characterized by chemical.

Madwa Thermal Power Plant Soil

- Higher nitrogen, phosphorus, iron, manganese, and sulphur improve vegetative growth and nutrient supply.
- However, high alkalinity (pH 8.4) and low zinc may reduce nutrient absorption efficiency.
- Paddy crop show: Better leaf growth, High biomass production, Possible micronutrient deficiency symptoms due to alkaline nature.

NTPC Thermal Power Plant Soil

- Soil is comparatively more balanced with better organic carbon and moderate pH.
- Lower nitrogen and micronutrient levels may slightly reduce crop vigor.
- Paddy crop may show: Better root environment, Balanced growth
- Improved soil texture and water retention, Slightly lower yield compared to Madwa due to lower nutrients.
- Madwa Thermal Power Plant soil is richer in major nutrients and micronutrients, which can enhance paddy growth and yield.
- NTPC Thermal Power Plant soil has comparatively balanced soil conditions and better organic carbon content, which supports sustainable paddy cultivation.
- Zinc deficiency is observed in both samples and may require zinc fertilizer application for optimum rice production.
- Excess alkalinity in Madwa soil may need soil amendment such as gypsum or organic manure to maintain nutrient availability.

Therefore, for long-term paddy cultivation:

- Madwa soil provides higher nutrient availability, while
- NTPC soil offers better soil balance and stability.

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