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Heavy Metal Pollution Assessment in the Midland Paddy Field Soils of Kerala, South India

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ABSTRACT

The physico-chemical attributes of paddy fields in Chathannoor, kollam district of Kerala, South India were monitored before sowing and after harvest stages of the crop senson with an emphasis on the heavy metal content in paddy field soils. The average level of heavy metals in the paddy field soils before sowing is higher than that of after after havest. The essential micronutrients (S&B) are found deficient in both stages of the crop season. Direct application of chemical fertilizers to the soil before sowing and they use of pesticides duringthe growth stages of the paddy contributes to the elevated levels of heavy metals in the ground. The escalated levels of geo-accumulation index values for cadmium in all the study sites sites indicate moderate contamination of the soils. The chemical fertilizers like urea, calcium superphosphate, muriate of potash can act as sources of trace metal enrichment of agricultural farmlands. Enhanced better agrarian management practices and stringent laws should be enacted for the proper conservation of paddy fields in study are from further degradation, thereby maintaining the ecological integrity of the wethland ecosystem.

Keywords Metal, Paddy field, Geo-accumulation index, Contamination factor, Micronutrient.

INTRODUCTION

Havy metal is a metal having slightly higher density and is toxic at low concentrations. They occur naturally in the environment. Mining wastes, municipal wastewater, landfill leaches, urban runoff are the primary sources of the introduction of heavy metals into the almosphere (Ravindra et al. 2015). When soils contaminated with heavy metal used for crop production, it is probably toxic to crops, animals, and human beings (Wong et al. 2002). Soil is a specific component that acts as natural buffer in transporting elements and other substances to the atmosphere, hydrosphere, and living biota (Pendias 2011). In plants, iron is a primary component of many heme and non-heme iron enzymes. They are involved in nitrogen fixation, photosynthesis, and electron transfer. Zinc is an essential component of dehydrogenases, proteinases, and peptidase enzymes in plants. Cu is a constituent of cytochrome oxidase, ascorbic acid oxidase, and laccase enzymes (Stevenson and Cole 1999). Chromium is a heavy metal occurring natu-

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rally, found in animals, plants, rock, volcanic dust, and gases (USDHHA 2000)..

Krauskopf (1972) showed that the trace element obtained from contaminants in the soil, such as fertilizers, lime, pesticides, manures, and airbome particles from industrial processes, mining, and fossil fuel combustion. Boron, iron, and zinc deficiencies influenced by the addition of lime to acidic soils. Acute iron toxicity develops vomiting abdomen pain,, conjumetivitis, retinitis, and choroiditis (Baker and Brooks 1989). According to the degree of toxicity, heavy metals (arsenic, cadmium,chromium, lead, and mercury0 rank having public health significance. Cadmium is the non-essential element that is potentially toxic to human and soil-plant systems. The poisonous effect of non-essential element cadmium is the development of cadmium-induced renal failure, livr disease, and lung disorder. The soils with decreased cadmium concentration have high available zinc content (Stevenson and Cole 1999). Peroetuated use of varions pesticides results in heavy metal pollution in agricultural soils. High concentrations of heavy metals in agricultural soils may increase the potential uptake of these metals by plants. since rice is the staple food for a large part of the human population across the worid, it is essential to determine the concentration ofheavy metals in paddy field soils, and plant parts. Considering the problems of heavy metal in agriculture, the present study aims to assess the heavy metal pollution in the soils of selected midland paddy fields of Kerals, South India.

MATERIALS AND METHODS

Study area characterization

The present study looks into the selected midland paddy fields (Kurungal paddy sector) of Chathannoor in Kollam district, Kerala, South India (Fig. 1). The study area Chathannoor is about 14 km away from Kollam Railway station in kerala and is in the banks of the Iihikkara river. The water from the Ithikkara river used for irrigation of the paddy fields in this area. The study area geographically lies between north latitude N $08^0 52'29''$ and east longitude E $76^0 43'22''$. The average elevation is 14m—the exact location of the study sites marked by Global Positioning System (Garmin, USA). Chathannoor is bounded on the north and west by the Ithikkara river. Kaolinite or china clay is the primary mineral found in Chathannor. The inhabitants of the study area mainly depend on agri-

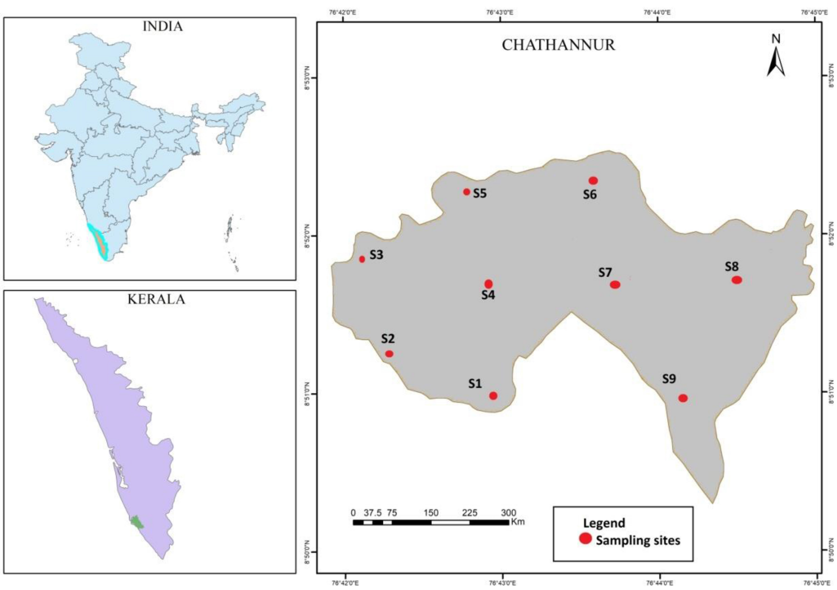

Fig. 1. Location map of study area ahowing sampling stations.

culture. Before sowing, the paddy fields plough with cow dung, neem cake, urea and muriate of potash.

Sample collection and preparation

A proportionate random sampling technique was adopted to select nine paddy field from the study area. Surface soil samples (depth of 0-15 cm) were collected from nine paddy fields before sowing and after harvest of the crop season and were labeled (S1 to S9). The soil samples collected were kept in clean, marked polyethylene bags and brought to the laboratory for analysis. Before the digestion of soil samples, each composite sample dried at 65^0C for 48 hours.

Physico-chemical characteristics of paddy field soil

The physico-chemical attributes of soil samples (ph, total nitrogen, phosphoruds, potassium, organic carbon) were determined following the standard procedures by Trivedi and goel (1986) respectively.

Heavy metal analysis

For the trace metal analysis, 05g of dried soil digested with 15 ml of hydrofluoric acid and 4ml of Perchloric acid in a Teflon crucible. After digestion, 5 ml of concentrated nitric acid added. Cooled and filtered the contents through Whatman No 42 filter paper and made up to 50 ml to a volumetric flask (Class A-borosil) with double distilled water (AOAC 2013). The heavy metals Cd, Cr, Pb, Cu, Zn, and Fe, were determined using an atomic Absorption Spectrophotometer (Pinnacle 500, perkin Elmer, Singapore) Hollow cathode lamps and EDL lamps at specific wavelengths (Zn-213.56, Pb-283.31, Cr-357.87, Cu-324.75, Cd-N9300107, and Fe-248-33) used.

For calibration of Atomic Absorption Spectrophotometer, the standards of the heavy metals Cd, Cr, Pb, Cu, Zn, and Fe prepared. Working standards were prepared from stock standard solutions (Pure grade, perkin Elmer standands of Cu-N9300114, Zn-N9300168, Cr-N9300112,Pb-N9300128, and Fe-N9300126) by dilution of 1000 mg/L stock solutions. The calibration curve for each heavy metal was linear, and a correlation coefficient of 0.995 obtained - all standards prepared by double distilled water. A reagent blank also made in the same manner for sample preparation. The heavy metal content in paddy soils were expressed on a dry weight basis in mg/kg.

Table 1. Degree of metal pollution in terms of seven classes.

I_{gro} value	I_{gro} class	Soil dust quality
>5	6	Extremely contaminated
4-5	5	Strongly to extremely contaminated
3-4	4	Strongly contaminated
2-3	3	Moderately to strongly contaminated
1-2	2	Moderately contaminated
0-1	1	Uncontaminated to moderately contaminated
<0	0	Uncontaminated

Heavy metal Pollution indices

The Geo-accumulation index, contamination factor, and pollution load index are the indices used for the unitary assessment of soil pollution with particular heavy metals.

Geo-accumulation index (I_{geo})

The Geo-accumulation index depicts the assessment of soil contamination with heavy metal referenced to a specified background value (Muller 1969). It is calculated by the equation

$$Igeo = Log\ 2 \left[\frac{Cn}{1.5\ Bn}\right] \quad (1)$$

where, Cn is the concentration of individual heavy metal, and Bn is the background value of each heavy metal. According to the degree of anthropogenic influence on the heavy metal concentration, it classifies into seven grades (Table 1).

Pollution Load Index

Pollution Load Index (PLI) is obtained from contamination factors (CF). contamination factor is the value obtained by dividing the concentration of each metal by its background value. Pollution Load Index of the sites calculated by obtaining the n-root from the nCFs obtained for the metals. The Pollution Load Index (PLI) developed by Varol (2011), which is as follows:

$$CF = \frac{C\ metal}{C\ background} \qquad (2)$$

$$PLI = \sqrt[n]{CF1xCF2xCF3x....CFn} \qquad (3)$$

where, CF – contamination factor, C_{metal} – concentration of metal, $C_{background}$- background value of the metal and n – number of metals. The PLI value>1 indicates pollution, whereas PLI value <1indicates no contamination.

RESULTS AND DISCUSSION

The results of the study on heavy metal (Cr, Zn, Fe, Pb, Cu, Cd) concentration in the paddy fields of the study area are given in Table 2.

Heavy metal content in paddy field soils.

Chromium (Cr) is the non-essential element that exists intwo oxidation states Cr^{3+} and Cr^{6+}. It brings about cell division, elongation of roots and shoot, and metabolic disorders in seed germination. The mean Cr concentration in the paddy field soils found to vary from 6.85 (S9) to 9.41 (S5) mg/kg before sowing and 0.72 (S6) to 2.86 (S2) mg/kg after harvest. The use of phosphate fertilizers in agriculture activities increases the chromium metal content in crops as the manure is manufactured from phosphate ore with a high amount of heavy metals such as chromium, lead, and iron (Saadia et al. 2016). Excessive concentration of chromium detected in the study hints the overuse of chemical fertilizers ures and muriate of potash (Mohiuddin et al. 2017).

Zinc, the essential element dissolves in aqueous acids or bases, forming hydrogen gas and zinc ion, respectively (Irwin et al. 1997). the concentration of zinc ranges from 38.08 (S9) to 66.8 (S5) mg/kg before sowing and 12.36 (S6) to 57.57 (S3) mg/kg after harvest, which was lower than the permissible limit (300-600 mg/kg) suggested by Awasthi (2000). The deficiency of zinc in the soils can overcome by the addition of $ZnSO_4$ @ 20 kg ha^{-1} recommended by DADFW (2018). The reports by Benson et al. (2014) and Nohiuddin et al. (2017) revealed the presence of relatively high concentration of trace metal zinc in commercially available inorganic fertilizers calcium superphosphage, muriate of potash and urea. Elevated levels of soluble zinc are present under well-oxidized conditiona at pH 5 to 6.5 (Gambrell et al. 1991).

The existence of dissolved organic matter decelerates the free oxidation of ferrous to ferric by stabilizing the Fe (II) state (Theis and Singer 1974), and this oxidation process accelerated by the presence of heavy metal (vuori 1995). Before sowing, the iron content in paddy field soils varied from 134.81 (S7) to 136.53 (S5) mg/kg and observed to range from 8.24 (S2) to 113.03 (S7) mg/kg after harvest.

Lead, the non-essential element exists insoil as Pb^{2+} and lead hydroxyl complexes. Accessible anthropogenic sources of lead include gasolic paint, pesticides, and ammunitions. The Pb content in paddy field soils vary from 1.45 (S1) to 2.3 (S4) mg/kg before sowing and 0.97 (S6) to 1.9 (S2) mg/kg after harvest which found to be lower than the permissible limit (250-500 mg/kg) suggested by awasthi (20000. Increased application of inorganic fertilizer urea and calcium superphosphate in soils to improve crop yield is the source of lead in the grounds (Bensonm et al. 2014).

Table 2. Descriptive statistics of heavy metals in paddy field soils. *SD-Standard Deviation.

Heavy metal (mg/kg)	Before sowing				After harvest			
	Min	Max	Mean	SD+	Min	Max	Mean	SD+
Chromium	6.85	9.41	8.25	0.82	0.72	2.86	1.7	0.67
Zinc	38.08	66.8	53.49	11.46	12.36	57.57	34.33	12.51
Iron	134.81	136.53	135.73	0.603	8.24	111.03	78.84	30.26
Lead	1.45	2.3	1.93	0.24	0.97	1.9	1.37	0.30
Copper	4.1	6.46	5.16	0.73	1.54	2.31	1.94	0.26
Cadmium (mg/kg)	1.45	2.43	1.86	0.29	1.09	2.01	1.60	0.30

The essential element, copper, exists in soil as Cu^{2+}. In natural forms, it mainly derved from parental rock-forming materials and when bound to silicates and oxides among primary minerals forms relatively immobilespecies (jenkins and jones 1980). Cu concentration in the soil samples moved on from 4.1 (S9) to 6.46 (S5) mg/kg before sowing and ranged from 1.54 (S6) to 2.31 (S8) mg/kg which is lower than the permissible limit (135– 270 mg/kg) suggested by Awasthi (2000). The deficient copper levels in paddy field soils of the study area can be solved by the application of CuS4 @ 2 kg ha^{-1} rate as recommended by DADFW (2018). The continual spraying of Bordeaux mixture [$Ca(OH)_2 + CuSO_4$] to control vine downy mildew was responsible for the long-term accumulation of copper in soils, reaching values commonly ranging from 100 to 1500 mg/kg.

Cadmium, the non-essential element exists in soil as Cd2+ found to vary from 1.45 (S7) to 2.43 mg/kg (S5) before sowing and 1.09 (s7) to 2.01 (S5) mg/kg, after planting that were lower than the permissible limit (3-6 mg/kg) suggested by Awasthi (2000). Anthropogenic imput of cadmium in soils occurs by aerial deposition and sewage sludge, manures, and phosphate fertilizer application. The fundamental cause of the toxicity of Cd is its higher affinity to thiol groups in enzymes and other proteins. The presence of Cd hence disturbs enzyme activity. In plants, excess Cd may also disrupt iron metabolism and cause chlorosis. The particular hazard with Cd is that the plants usually do not act as an indicator of levels toxic to humans and animals, because plants tolerate higher levels of Cd than animals (Liphadzi and Kirkham 2014). The primary source of cadmium in agricultural soils is the over-application of chemical fertilizers urea, muriate of potash, as reported by (Mohiuddin et al. 2017). Studies by Rogan et al. (2009) shows that heavy metal poliution in the soils is due to the anthropogenic activities like mining, waste disposal, and effluents primarily in agricultural lands.

Physico-chemical attributes of paddy field soils

The physico-chemical characteristies of the paddy field soils such as pH, total nitrogen, phosphorus, potassium, organic carbon, sulfur and boron content estimated before sowing and after harvest (Table 3) in the crop season of the period 2015-16.

Before sowing

The pH of the paddy field soil samples before sowing found to vary from 6.8 to 7.5, which comes under the neutral and slightly alkaline category. Total nitrogen in the paddy field soils ranged from 0.69 to 1.41 mg/kg, and phosphorus content varied from 0.59 to 0.94 mg/kg. Potassium concentrations in the paddy field soils ranged from 0.45 to 0.61 mg/kg. Organic carbon concentrations in the paddy field soils observed to vary from 0.76 to 1.79%. The soils in the paddy fields of study area come under Medium (≥0.7 to ≥1.5%) and High (>1.5%) category. The concentration of secondary nutrient sulfur in the paddy field soils noticed to range from 0.52 to 2.78 mg/kg, which comes under the deficient category (<5 mg/kg) suggested by DADFW (2018). They recommend the addition of sulfur at the rate of 25 kg ha^{-1}. The micronutrient boron in the paddy field soils before sowing ranged from 0.79 to 2.66 mg/kg, which comes under the deficient category (<5mg/kg) suggested by DADFW (2018). The recommend the addition of borax at the rate of 10 kg $ha^{-1.}$

Table 3. Descriptive statistics of varicus soil quality parameters. *SD-Standard Devistion.

	Before sowing				After harvest			
Parameter	Min	Max	Mean	SD*	Man	Max	Mean	SD*
pH	6.8	7.5	7.19	0.26	7.4	7.7	7.51	0.11
Nitrogen (mg/kg)	0.69	1.41	0.90	0.23	1.61	2.93	2.35	0.49
Phosphorus (mg/kg)	0.59	0.94	0.72	0.12	0.98	2.13	1.68	0.36
potassium (mg/kg)	0.45	0.61	0.53	0.05	0.97	1.88	1.48	0.35
Org Carbon (mg/kg)	0.76	1.79	1.33	0.30	1.0	3.21	1.85	0.77
Sulfur (mg/kg)	0.52	2.78	2.03	0.78	1.31	3.46	2.11	0.7
Boron (mg/kg)	0.79	2.66	1.98	0.56	2.04	3.14	2.60	0.36

Table 4. Correlation matrix for different soil quality parameters before sowing. *Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

	pH	N	P	K	OC	S	B	Cr	Zn	Fe	Pb	Cu	Cd
pH	1												
N	-557	1											
P	-518	857**	1										
K	.186	-503	-170	1									
OC	.408	.382	.283	-104	1								
S	.293	-329	-.160	.566	-.088	1							
B	.291	.102	-.015	-.136	.629	-.541	1						
Cr	-.705*	.652	.434	-.354	.006	-.407	.208	1					
Zn	-.792*	.522	.266	-.421	-.167	-.612	.207	.907**	1				
Fe	-.112**	.755*	.564	-.357	.000	-.221	-.056	.930**	.837**	1			
Pb	-.351	.609	.708*	-.009	.384	-.489	.357	.201	.231	.222	1		
Cu	-.700**	.768*	.474	-.431	.088	-.349	.130	.948**	.865**	940**	.235	1	
Cd	-.482	.669*	.398	-.484	.192	-.621	.249	.498	.582	.489	.665	.580	1

After harvest

The pH of the paddy field soil samples after harvest found to vary from 7.4 to 7.7, which comes under the slightly alkaline category. total nitrogen in the paddy field soils ranged from 1.61 to 2.93 mg/kg, and phosphorus content varied from 0.98 to 2,13 mg/kg. Potassium concentrations in the paddy field soils ranged from 0.97 to 1.88 mg/kg. Organic carbon concentrations in the paddy field soils observed to vary from 1.72 to 3.21%. The paddy field soils of study area come under Medium (≥0.7 to ≤1.5%) and high (>1.5%) category. The concentration of secondary nutrient sulfur in the paddy field soils noticed to range from 1.31 to 3.46 mg/kg, which comes under the deficient category (<5mg/kg) suggested by DADFW (2018). They recommend the addition of sulfur at the rate of 25 kgha^{-1}. The micronutrient boron in the paddy field soils before sowing ranged from 2.04 to 3.14 mg/kg, which comes under the deficient category (<5mg/kg) suggested by DADFW (2018). They recommend the addition of borax at the rate 10 kgha^{-1}. The results of the physico-chemical characteristics of paddy field soil samples before and after harvest are in agreement with Lakshmy and Jaya (2007).

Correlation analysis of soil quality parameters

The association of heavy metals with soil quality characteristics was studied using correlation analysis. The study reveals that during before sowing (Table 4), P exhibits a significant positive correlation with N (r =0.857**) at 0.01 significant levels. This association is in agreement with Alzubaidi et al. (1990) that adding nitrogen and phosphorus fertilizers together produced better positive interaction than when added separately. There is a significant negative correlation between pH and Cu (r = -0.700*), which shows that soil pH has a marked inpact on the migration and biological effects of Cu. This result is in agreement with Li et al. (2013). Cr exhibits highly significant positive correlations with Zn (r =.907**), Fe (r =.930**) and Cu (r=.948*). Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present.

After harvest, K exhibits a highly significant positive correlation (r =.810**) at 0.01 significant levels (Table 5). This finding is in agreement with Bhattacharya et al. (2015) that the interaction between N and P is the single most nutrient interaction that affects the adsorption and phosphorus desorption capacity in the soils. Sulfur also exhibits a positive, highly significant positive correlation with organic carbon (r= .869**), which goes along with Subhashis et al. (2016) that the addition of organic matter influences sulfur mineralization. Pb exhibits highly positive correlations with CR (R = .821**) and Zn (r= .881**) significant at 0.01 levels.

Identification of prominent factors by Factor Analysis

Factor analysis during before sowing hs extracted

Table 5. Correlation matrix for different soil quality parameters after harvest. *Correlation is significant at the 0.05 level (2- tailed). *Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2- tailed).

	pH	N	P	K	OC	S	B	Cr	Zn	Fe	Pb	Cu	Cd
pH	1												
N	-.225	1											
P	-.173	.311	1										
K	-.207	.659	.810**	1									
OC	.477	-.508	.002	-.130	1								
S	.689*	-.397	.181	-.013	.869**	1							
B	.192	-.049	.032	.069	.781*	642	1						
Cr	-.412	.196	.138	.103	.120	-.197	.164	1					
Zn	-.116	-.307	.016	-.379	.249	.040	.084	.718*	1				
Fe	-.391	.228	.077	.402	.003	.214	-150	-.411	-.724*	1			
Pb	-.404	-.296	-.041	-.282	.254	-.135	.176	..821**.	.881**	-.749*	1		
Cu	.042	.030	.593	.278	.408	.494	.292	.501	.530	-.053	.324	1	
Cd	-.579	-.300	-.299	-.484	-.208	-.339	-.030	.087	.235	-.598	.362	-.175	1

three principal components (Table 6), viz., F1, F2, and F3 are explaining the variance of 40% , 21%, and 19% respectively after considering eigen values more significant than one and varimax rotated. The factor loading chart highlighted F1 loading concerning N, P, Cr, Zn, Fe, Pb, Cu, and Cd along with significant negative loading forK, OC, S and B. F2 fraction mainly constitutes Pb as the principal component. The prominent factor determining the source of pollution is the organic matter, bonding with the heavy metals Forstner and Wittmann (1981).

Factor analysis during after harvest has also extracted three principal components (Table 7), viz., F1, F2, and F3 are explaining the variance of 30%, 27%, and 22%. Here, the factor loading chart highlighted F1 loading about P, Cr, Zn, Cu, Pb, and Cd. The F2 fraction comprises mainly OC and S with the maximum negative loading of N. Accordingly, the influence of different sources in controlling soil chemistry revealed that it is agricultural sources of pollution.

Identification of sources of pollution

Cluster analysis is to find subgroups within a large

Table 6. Components explaining different factor loads (before sowing)

Component	F1	F2	F3
pH	-.905	-.137	.174
N	.611	.727	.124
P	.408	.838	-.159
K	-.418	.003	-.521
OC	-.332	.660	.412
S	-.331	-.096	-.833
B	-.182	.230	.863
Cr	.883	.139	.239
Zn	.904	-.029	.365
Fe	924	-251	-.007
Pb	.131	.829	.237
Cu	.882	.233	.201
Cd	.507	.437	.459
Total	5.290	2.762	2.449
% of Variance	40.694	21.247	18.840
Cumulative %	40.694	61.941	80.782

Table 7. Components explating different factorloads (before sowing).

Component	F1	F2	F3
pH	-.507	.672	-.172
N	-.153	-.428	690
P	.104	.103	.840
K	-.188	-.082	.939
OC	.144	.944	-.093
S	-.161	.966	.035
B	.176	.688	.071
Cr	.833	-.006	.310
Zn	.889	.213	-.122
Fe	-.795	.122	.317
Pb	.954	.069	-.130
Cu	.460	.514	.537
Cd	.456	-.368	-.513
Total	3.850	3.414	2.887
% of Variance	29.613	26.262	22.211
Cumulative %	29.613	55.875	78.086

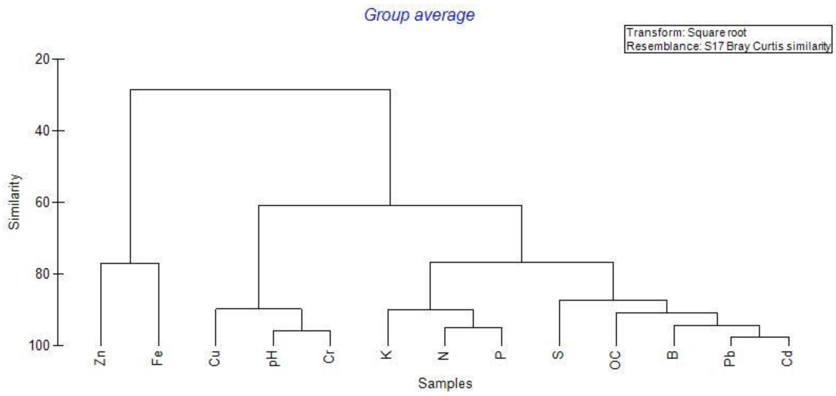

Fig. 2. HCA dendrogram during before sowing.

group and form a tree-like structure form called a dendrogram. hierarchical agglomerative clustering commonly used, which supplies the instinctive similarity relationships between anyone sample and the entire data set (massart and Kaufman 1983) hierarchicalcluster analysis (HCA) performed for the nine samples and 13 variables during before sowing and after harvest for identifying the source of pollution of heavy metals (Figs. 2 and 3). HCA dendrogram employed for soil quality variables formed two distinctive groups of clusters before sowing and after harvest (Cluster 1 and Cluster 2). The study also reveals that Zn and Fe form a separate cluster (Cluster 1).

In contrast, remaining parameters formed another cluster (Cluster 2) in both before sowing and after harvest stages of the crop season. The distinctive group (Cluster 1) invariably indicates that two factors are responsible for the determination of soil quality in the study area. These Zn and Fe emanating from the widespread application of chemical fertilizers and pesticides are accountable for the contamination of paddy field soils in the study area. Enhanced trace metals in inorganic fertilizers could constitute a threat to human health and the sustainnability of farming practices.

Assessment of heavy metal pollution using indices

The geo-accumulation index (Igeo)calculated for

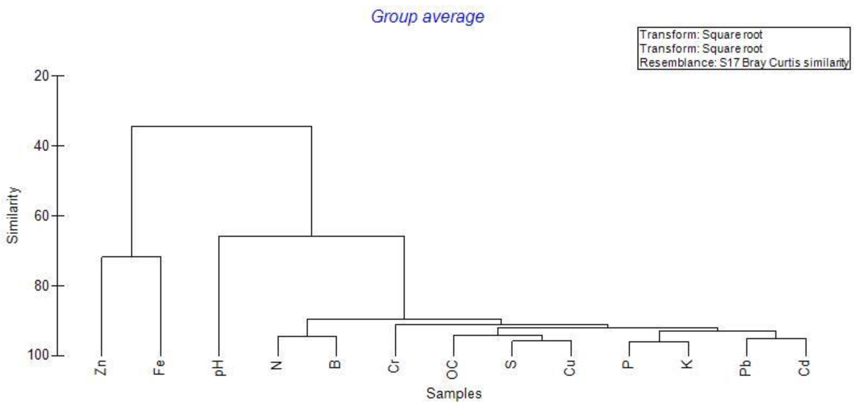

Fig. 3. HCA dendrogram during after harvest.

the heavy metals Cr, Zn, Fe, Pb, Cu, and Cd. The I_{geo} values before sowing extends from uncontaminated to moderately contaminated categories. I_{geo} values for Cr and Pb come under "Class 0" for all sites indicate the uncontaminated sediment quality. Igeo values for Zn, Fe, and Cu comes under "Class 1". It shows that the sites are in uncontaminated to moderately contaminated category. The Igeo values for Cd come under "Class 2", showing the site as moderately contaminated. After harvest, the Igeo values for Cr, Pb, and Cu designated as uncontaminated, leaving in Class '0', The Igeo values for Zn and Fe come under "Class I", indicating the uncontaminated to moderately contaminated quality of the sediments in all sites. after harvest also, Igeo values for Cd come under "Class 2," indicating moderate contamination.

The pollution load index (PLI) provides an easy way to prove the deterioration of the soil conditions as a result of the accumulation of heavy metals. The results of the present study showed that the contamination factor for the metals Cr, Zn, Fe, Pb, Cu and Cd are low (<1). The pollution load index found to be generally low in all the studied sites of the paddy fields.

CONCLUSION

This study revealed that there is heavy metal (Cr, Zn, Fe, Pb, Cd and Cu) contamination in the midland paddy fields of Kerala. The paddy field soils are high in heavy metal content before sowing than after harvest. unscientific and unethical use of agrochemicals significantly contributes to the heavy metal pollution in the paddy field soils of the study area. Considerable increase in Igeo values for Cd in all sites, both before sowing and after harvest periods was due to rampant agricultural practices. Adopting the best agricultural management practices and nutrient management plans after convincing the farmers about the ill effects of agrochemicals is necessary to reduce heavy metal accumulation in the paddy field soils and paddy.

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