Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 3 (2023)

Bioavailability of Heavy Metals in Soils and their Uptake by Paddy (*Oryza sativum*) – An Empirical Study

[1*]G. Saraswathy, [2] [3]P.N. Sudha [4]G. Lavanya, [5]T.N. Balaji, [6]K.S.Venkatesh

[1]Department of Chemistry, Government College of Engineering, Bargur, Tamil Nadu, India
saraswathirumal@yahoo.co.in.
[2] Department of Physiology, Saveetha Dental College & Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai -600077, Tamil Nadu, India
[3] Department of Chemistry, DKM College of Women, Vellore, Tamil Nadu, India
[4] Department of Chemistry, Saveetha Engineering College, Thandlam, Chennai-602105
[5] Department of Chemistry, PERI Institute of Technology, Mannivakkam, Chennai-48.
[6] Department of Physics, PERI Institute of Technology, Mannivakkam, Chennai-48

*Corresponding Author E-mail: drparsu8@gmail.com

Abstract: Heavy metals, such as Cadmium, copper, lead and chromium are the most toxic, persistent, and widespread environmental pollutants, particularly in areas with high anthropogenic pressure. Dissolved or suspended metals in soil and water, even in traces can degrade water quality and soil fertility and become available to plankton, nekton which in turn alters the normal biogeochemical cycling. Crop plants growing on heavy metal contaminated medium can accumulate high concentrations of trace elements which cause serious health risks to consumers. The toxicity of heavy metals at high levels of exposure is well known but a major concern is the possibility that continual exposure to relatively low levels of these heavy metals through the consumption of the vegetables and food crops may entail adverse health effects. Only bioavailable metals in soil are able to exert toxic action. Bioavailable metals cannot be measured directly through chemical analysis-only living organisms determine bioavailability. An experimental study was carried out to better understand the bioavailability and extent of toxicity of heavy metals on the growth of paddy plant in the heavy metal contaminated soil samples of Ranipet industrial area. Results show that Chromium and Zinc were recorded in higher concentration in all the four study areas. The heavy metal Cr concentration was in the order MGR Nagar > Vannivedu > Bharathi Nagar >Vanapadi. Germination studies of *Oryza sativam* in the metal contaminated soil medium was carried out with the finally extracted soil and the germination time and extent of growth were studied. The result reveals that the percentage of seed germination is in the order Bharathi Nagar (90%) > Vanapadi (75%) >MGR Nagar (55%) > Vannivedu (50%) respectively.

Keywords: Heavy metals, industrially polluted soils, *Oryza sativam*, germination studies, bioavailablity and bioaccumulation**.**

1. Introduction

Agricultural and industrial activities release several organic pollutants, drugs, and large quantities of inorganic pollutants as heavy metals (Malidareh et al., 2014; Briffa et al., 2020). They enter in environment from several sources, both natural and anthropogenic sources (Zazouli et al., 2010; Wenga and Gwenzi, 2022). Anthropogenic rare earth elements in aquatic environments: Occurrence, behavior, and fate. In *Emerging Contaminants in the Terrestrial-Aquatic-Atmosphere Continuum:* (pp. 87-102). Elsevier.). These activities can cause severe pollution of highly toxic heavy metals (such as Cu, Cr, Cd, Hg, Pb, and As) in aquatic and terrestrial ecosystems, and even to the atmosphere (Leung et al., 2006). Heavy metals are non-biodegradable, thus persisting for long periods in environmental ecosystems, may be fatal to living organisms.

Crops in close to contaminated sites can uptake and accumulate these metals, and then exert potential risk to humans and animals (Gupta and Gupta, 1998; Jarup, 2003; Cheng et al., 2014). The major route for heavy metals exposure to humans is mainly through the soil-crop-food pathway. Bioaccumulation is the accumulation of a chemical via all routes available to the organisms. Heavy metal accumulation and bioavailability in both soil and water have to be considered to obtain a better understanding of environment–animal interactions. Metal association with soil matter and availability strictly depends upon their chemical form. The readily soluble fraction of metals is generally considered to be phytoavailable. Bioaccumulation of metals by biota in surface water and by plants and animals in the terrestrial environment can adversely affect humans (Kaur and Sharma, 2021).

Excessive accumulation in cultivated soils may result not only in soil contamination, but has also consequences for quality and safety. Food consumption, in fact, is the main source of human exposure to heavy metals (over 90%) when compared to respiratory or dermal exposures (Loutfy et al. 2006).

According to the Food and Agricultural Organization (FAO) (2004), rice nearly provides 30% of the dietary energy supply around the world. Rice (*Oryza sativa*) is a commonly used food and, it is in the second rank in the world for consumption (Zhuang et al., 2016). Rice supplies two-thirds of calories to Asiatic consumers (Van Tran, 1998; Hoogenkamp et al., 2017). It has been estimated that over 50% of the world's population consumes rice. Global production of rice was around 483.1 million tons in 2016 (WRP, 2017).

From soil and water, all plants have the ability to accumulate heavy metals which are essential for their growth and development. These metals include Mg, Fe, Mn, Zn, Cu, Mo, and Ni (Peterson, 1983). High levels (500ppm) of hexavalent Cr in soil reduced germination up to 48% in the bush bean *Phaseolus vulgaris* (Parr and Taylor, 1982; Islam et al., 2014). Peralta et al. (2001) found that 40ppm of Cr(VI) reduced by 23% the ability of seeds of Lucerne (*Medicago sativa* cv. Malone) to germinate and grow in the contaminated medium. The reduction germination of seeds under Cr stress could be a depressive effect of Cr on the activity of amylases and on the subsequent transport of sugars to the embryo axes (Zeid, 2001; Medda and Mondal, 2017).

Soil sequential extractions are employed to isolate and quantify metals associated with different fractions. Selective extraction is based on the procedure used by Tessier et al., (1979). After sequential extraction, the soils are expected to contain only residual metals.

As rice is a staple food for daily consumption in India, especially in the region of the present study site, there is an increasing requirement for the knowledge of metal levels in food crops growing on heavy metal contaminated medium. Crop plants growing on heavy metal contaminated medium can accumulate high concentrations of trace elements which cause serious health risks to consumers.

In the present study, experimental work was carried out on germination studies of *Oryza sativam* in the metal-contaminated soil of Ranipet Industrial area, Tamilnadu, India. The extent of heavy metal contamination and its effects on plant growth were investigated in the agricultural soils collected from typical industrial areas of Ranipet.

2. Materials and Methods

2.1. Site description and samplings

Ranipet industrial area ranks fifth in the Top Ten Most Polluted Areas in the world (Blacksmith Institute, New York, 2006). The study area, Ranipet Industrial Town is one of the biggest industrial towns with a large number of industries established by Government Enterprises like SIPCOT and SIDCO. Ranipet industrial area has vast agricultural lands, in the uncultivable condition due to heavy metal and other pollutions. Hence, in the present study, an attempt has been made the analyze physico-chemical factors and heavy metals in the soils of various industries like Malladi drugs and pharmaceuticals, Tirumalai Chemicals Limited, a dyeing unit, and tanneries.

Soil samples, topsoil up to 15cm depth, and subsoil from 15-30 cm depth were collected from the uncultivated agricultural lands of MGR Nagar, Bharathi Nagar, Vanapadi Village, and Vannivedu village of Ranipet industrial town. Control soil was collected from fertile agricultural lands of Kaniyambadi village, Vellore District. The samples were brought to the laboratory and were analyzed within 6 hours of sample collection.

2.2. Sample analysis

Physicochemical factors such as pH, Electrical conductivity (EC), Moisture, Porosity, Specific Gravity, Calcium, Nitrogen, Phosphorus, Potassium (NPK Values), and heavy metals such as Cadmium, Chromium, Copper, Cobalt, Lead, Nickel, and Zinc were analyzed for both top and sub soils as per the method of Jackson (1958).

Heavy metal concentrations in the topsoil and subsoil of MGR Nagar, Bharathi Nagar, Vanapadi, and Vannivedu agricultural lands were measured. The heavy metals (Cd, Cr, Cu, Co, Pb, Ni, and Zn) concentrations were analyzed using Atomic Absorption Spectroscopy (Varian AAA 220 FS). The whole analysis was conducted in a clean-air room of class 10000 (APHA 1990).

2.3. Germination studies

Seed germination is the first physiological process affected by heavy metals. The ability of a seed to germinate in a medium containing heavy metals would be indicative of the level of tolerance of the heavy metal.

Hence the seeds of *Oryza sativam* were sown in the residual forms of metal-containing soil samples and experiments on seed germination, seedling growth, and chlorophyll content of *Oryza sativum* were carried out as per the methods of Sadasivam and Manickam (2022).

2.4. Statistical analysis

All the data were analyzed and expressed as the mean of six individual observations. Standard Error (SE) and student's "t" test were calculated as per the method of Pillai and Sinha (1968). ANOVA tests were carried out to trace interspecific variation between and within four different soil samples. The correlation analysis was conducted by Pearson correlation. The correlation was significant at a 0.05 level.

3. Results and Discussion

3.1. Physico-chemical factors of soils

Trace elements originating from various sources may finally reach the surface soil, and their further fate depends on the soil's chemical and physical properties and especially on their speciation. Table 1 shows the salient observations of the physico-chemical properties of soil samples collected from four different sites: MGR Nagar, Bharathi Nagar, Vanapadi, and Vannivedu agricultural lands of the Ranipet industrial area.

Table 1 : Analysis of physico-chemical factors of top and subsoil samples from MGR Nagar, Bharathi Nagar, Vanapadi, and Vannivedu, Ranipet.

Parameters	**MGR Nagar**		**Bharathi Nagar**		**Vanapadi**		**Vannivedu**	
	Top soil	***Sub soil***	***Top soil***	***Sub soil***	***Top soil***	***Sub soil***	***Top soil***	***Sub soil***
pH	7.9 ± 0.09	7.7 ± 0.09	8.0 ± 0.002	7.9 ± 0.003	7.8 ± 0.06	7.6 ± 0.05	7.8 ± 0.05	7.8 ± 0.07
Electrical Conductivity (μmhos/cm^2)	4.21 ± 0.008	3.84 ± 0.008	4.612 ±0.006	4.116± 0.001	2.814 ± 0.07	2.712 ± 0.06	4.842 ± 0.65	4.312 ± 0.05
Moisture %	36 ± 0.07	40 ± 0.09	36 ± 0.001	31 ± 0.001	35 ± 0.1	34 ± 0.3	36 ± 0.3	33 ± 0.1
Porosity	4.91 ± 0.09	4.12 ± 0.07	4.921 ± 0.09	4.662 ± 0.09	3.612 ± 0.08	3.512 ±0.09	3.521 ± 0.98	3.112 ± 0.08
Alkalinity mg/Kg	346.2 ± 0.6	314.1 ± 0.7	346.2 ± 0.6	312.4 ± 0.6	440.1 ± 0.19	380.2 ± 0.21	492.2 ± 0.11	441 ± 0.21
Salinity mg/Kg	49.2 ± 0.07	38.6 ± 0.09	42.1 ± 0.07	36.1 ± 0.07	58 ± 2.4	52 ± 2.1	426.4 ± 2.5	391.8 ± 2.3
Organic matter %	4.6 ± 0.02	4.1 ± 0.03	6.66 ± 0.01	5.92 ± 0.01	3.1 ± 0.01	3.1 ± 0.02	9.1 ± 0.18	8.8 ± 0.21
Nitrite mg/Kg	1024.1 ± 0.007	998.2 ± 0.006	268 ± 0.006	206 ± 0.006	1624 ± 0.007	1612 ± 0.007	774.3 ± 0.21	714.2 ± 0.22

Ammonia mg/Kg	39.2 ± 0.01	35.0 ± 0.72	41 ± 0.06	36 ± 0.05	31.2 ± 0.06	30.4 ± 0.06	38.2 ± 1.8	31.1 ± 2.4
Nitrate mg/Kg	1341.2 ± 0.007	1268.0 ± 0.007	924.1 ±0.007	914.2± 0.006	2416 ± 0.07	2012 ± 0.09	2014.1 ±0.27	1912.1 ± 0.23
Total Nitrogen mg/Kg	2404.5 ± 0.7	2301.2 ± 0.03	1233.1 ±0.08	1156.2 ± 0.08	4071.2 ±0.07	3654.4 ± 0.07	2826.6 ± 1.3	2657.4 ± 1.7
Phosphorous mg/Kg	102.1 ± 0.9	99.2 ± 0.07	176.2 ± 0.07	151.2 ± 0.02	702 ± 0.07	612 ± 0.06	342.2 ± 1.1	322.6 ± 1.2
Potassium mg/Kg	92.6 ± 0.03	89.6 ± 0.06	1240 ± 0.72	1120 ± 0.74	142 ± 0.076	106 ± 0.76	246.1 ± 0.06	228.1 ± 0.07
Sodium mg/Kg	246.1 ± 0.04	309.8 ± 0.03	720 ± 0.08	660 ± 0.07	41 ± 0.09	32 ± 0.07	1011.2 ± 1.3	962.6 ± 1.5
Calcium mg/Kg	10421.2 ± 0.01	9100.1 ± 0.02	8200 ± 0.75	7962 ± 0.74	12260 ± 0.74	11120 ± 0.73	12912.3 ±0.77	11261.2 ± 0.76

Values expressed as mean ± SE of six individual values

The pH value range for proper plant growth is 5.5 – 7.0. However, MGR Nagar, Bharathi Nagar, Vanapadi 2nd Street, and Vannivedu soils were exceptional with pH values of 7.9, 8.0, 7.8, and 7.8 respectively showing slightly alkaline soil properties, BIS (2004).

Alkaline soils owe their unfavourable physico-chemical properties mainly to the dominating presence of sodium carbonate, which causes the soil to swell. The above result also reveals the significantly higher concentration of sodium in MGR Nagar (246.1mg/kg), Bharathi Nagar (720mg/kg) and Vannivedu(1011.2mg/kg) except Vanapadi (41mg/kg) with moderate sodium level. The salinity of Vannivedu soil (426.4mg/kg) was recorded high when compared to other sites. Sometimes these soils are also referred to as alkaline sodic soils.

Plants require at least sixteen elements for normal growth and completion of their life cycle. They need relatively large amounts of nitrogen, phosphorous, and potassium referred to as primary nutrients (Tisdale, 1993; Rashid et al., 2016). The three secondary elements Ca, Mg, and S are virtually required in smaller amounts. The micronutrients consist of seven essential elements which are boron, copper, chlorine, iron, manganese, molybdenum, and Zinc (Ajibola and Rolawanu, 2000). From **Table-1**, rank order of essential elements N, P, K in the sites under study were, for total nitrogen (N) the order: Vanapadi > Vannivedu > MGR Nagar > Bharathi Nagar; for phosphorous (P): Vanapadi > Vannivedu > Bharathi Nagar > MGR Nagar and for potassium (K): Bharathi Nagar >Vannivedu >Vanapadi > MGR Nagar respectively.

Soil organic matter is considered to be the most important parameter controlling heavy metal content in soils, (Kabata and Pendias, 2001; Stefanowicz, et al., 2020). The organic matter content in the soil samples was in the order Vannivedu (9.1%) > Bharathi Nagar (6.66%) > Vanapadi (4.6%) > MGR Nagar (3.1%) respectively. This may be because, in Vannivedu, the type of Industries are purely tannery-related industries. In tanneries, during the pretanning process, the skins and hides are cleaned and washed, and subjected to various other chemical processes. Hence the flesh, protein, and collagenous parts are washed out. That's the reason for the higher organic content of Vannivedu soil. The same is the reason for the higher salinity of this soil as it NaCl is used for preserving the skins and hides which are washed during pretanning process.

The soil samples were rich in metals such as Sodium, Potassium, and Calcium. This may be due to the discharge of untreated tannery effluent directly in the agricultural lands. The tannery effluent also contains high concentrations of ions like N and K and organic pollutants like oil and grease, tannin, and lignin (Manonmani et al., 1991; Thambavani and Prathipa,, 2011). The result predicts that calcium concentration varied between 7691mg/kg to 10421mg/kg respectively.

3.2. Heavy Metal Concentration in Soil.

Table – 2 reveals the extent of soil contamination attributable to higher levels of heavy metals in the top and sub-soil samples of the Ranipet industrial area. Metals accumulated in soils are depleted slowly by leaching, plant uptake, erosion, or deflation. The first half-life of heavy metals, as calculated by Iimura et al., (1977) for soils in Iysimetric conditions, varies greatly – for Zn, 70 to 510 years; for Cd, 13 to 1100 years; for Cu, 310 to

1500 years and for Pb, 740 to 5900 years. From the compilation of data given by Bowen, (1979) the following residence time of trace elements in soils of temperate climate can be estimated; for Hg, 500 to 1000 years; and for Ag, Au, Ni, Pb, Se, and Zn, 1000 to 3000 years. In tropical Rainforests, the rate of leaching of the elements is much shorter and is calculated at about 40 years.

Table 2: Analysis of heavy metals (mg/kg) in the top and sub soil samples from MGR Nagar, Bharathi Nagar, Vanapadi, and Vannivedu, Ranipet.

Metals (mg/kg)	MGR Nagar		Bharathi Nagar		Vanapadi II street		Vannivedu	
	Top soil	*Sub soil*	*Top soil*	*Sub soil*	*Top soil*	*Sub soil*	*Top soil*	*Sub soil*
Cadmium (Cd)	0.201 ± 0.006	0.182 ± 0.007	0.312 ± 0.005	0.284 ± 0.002	0.26 ± 0.005	0.211 ± 0.007	0.512 ± 0.005	0.492 ± 0.004
Chromium (Cr)	6942.1 ± 0.07	6114.2 ± 0.06	384.6 ± 0.06	342.1 ± 0.05	46.8 ± 0.05	41.2 ± 0.04	6126.4 ± 0.09	5984.1 ± 0.14
Cobalt (Co)	5.9 ± 0.03	5.5 ± 0.02	10.12 ± 0.02	8.91 ± 0.06	11.4 ± 0.01	10.1 ± 0.04	19.4 ± 0.12	15.1 ± 0.11
Copper (Cu)	47.21 ± 0.006	44.31 ± 0.005	74.1 ± 0.006	71.6 ± 0.003	76.2 ± 0.004	61.8 ± 0.003	76.2 ± 0.11	71.4 ± 0.14
Lead (Pb)	4.96 ± 0.007	4.32 ± 0.007	8.01 ± 0.006	6.07 ± 0.004	13.81 ± 0.007	11.12 ± 0.005	19.62 ± 0.12	15.1 ± 0.11
Nickel (Ni)	61.2 ± 0.03	51.2 ± 0.06	44.29 ± 0.03	41.3 ± 0.01	42.88 ± 0.02	41.1 ± 0.03	49.26 ± 0.03	43.2 ± 0.11
Zinc (Zn)	112.1 ± 0.002	94.86 ± 0.001	724.1 ± 0.002	711.4 ± 0.001	74.8 ± 0.002	71.3 ± 0.001	1421 ± 0.11	1240 ± 0.21

Values expressed as mean ± SE of six individual values

The investigation results reveals that the levels of heavy metals in top soil was found to be higher when compared to sub soil i.e. Top soil > Sub soil in all study areas. Almost all the metals were recorded high in Vannivedu soil sample. In general, Chromium and Zinc were recorded high when compared to other metals under study.

Table – 2 shows that the concentration of Chromium in soil samples was found to be significantly higher than the permissible limit (100 mg/kg) recommended by WHO (1996) except Vanapadi site. The existence of Cr concentration was in the order: MGR Nagar (6942.1 mg/kg) > Vannivedu (6126.4 mg/kg) > Bharathi Nagar (384.6 mg/kg) > Vanapadi (46.8 mg/kg) respectively. Since MGR Nagar and Vannivedu sites were surrounded by a large number of tanneries and leather processing units, the level of Cr was significantly high. The pointedly higher concentration of Cr in MGR Nagar may be due to Tamilnadu Chromate and Chemicals Ltd which was shut down in 1996 after the regulating activity by Tamilnadu Pollution Control Board (TN PCB). Even though the industry was not operating, the chromium leaching from the hazardous waste dump cannot be ruled out, as the groundwater samples (yellowish–green colour) collected have reported the presence of chromium (CPCB, Chapter IV, 2002). When compared to other sites, the Vanapadi soil sample was recorded with a low concentration of Cr.

The maximum level of Cd in the soil as per the WHO (1996) is 0.8 mg/kg. Soil samples from four sites under study were recorded below the target value. The concentration of Copper and Ni in soil samples was between the ranges 47.21 mg/kg – 76.2 mg/kg and 41.1 mg/kg – 61.2 mg/kg respectively (Table 2). The recommended limit for Cu and Ni by WHO standard (1996) is 36 mg/kg and 35 mg/kg. Since this area is surrounded by chemical industries, heavy metals like Cu, Co, and Ni were found to be high. Chemical industries use metals like Cd, Cu, Ni, etc. as catalysts and reducing agents in various steps of preparation.

From the result (Table – 2), the level of Pb in soil samples was found below (between the range 4.96 mg/kg – 19.62 mg/kg) the recommended value (85 mg/kg), WHO (1996).

Almost all the four soil samples exhibited high concentrations of Zinc when compared to the recommended limit (50 mg/kg) by WHO (1996). Bharathi Nagar and Vannivedu sites recorded significantly higher levels of Zn with 724.1 mg/kg and 1421 mg/kg respectively. Even though Zn is an essential element, at higher concentrations, Zn becomes toxic, Jain et al, (2013).

3.3. Heavy Metal Concentration in Different Plant Parts and their impact on plant growth.

Plants are good indicators of the health of the soil in which they are growing Ogundele DT, (2015). Seed is the first phase in the plant life cycle. The germination studies of *oryza sativam* in the extracted metal medium will help us in understanding the uptake of pollutants and phytotoxicity. Metal salt and pot studies conducted in the laboratory greatly overestimated the phytotoxicity and bioavailability of metals.

Germination studies of *Oryza sativam* were carried out with the finally extracted residual soil of the four experimental sites and seed germination, seedling growth, and chlorophyll content were investigated. Table 3 shows that the percentage of seed germination was in the order of Bharathi Nagar (90%) > Vanapadi (75%) > MGR Nagar (55%) > Vannivedu (50%) respectively. The maximum germination of *Oryza sativam* in Bharathi Nagar and Vanapadi may be due to the presence of higher concentrations of phosphorus, Potassium, and Nitrogen which are essential nutrients for plant growth (Table – 1). To grow and complete the life cycle, plants must acquire macronutrients such as Nitrogen, Potassium, Phosphorous, Sulphur, Calcium, and Magnesium (Barber, 1984). Organic matter plays a key role in governing heavy metal availability in the soil. The Bharathi Nagar soil sample was recorded with a higher percentage of organic matter (**Table – 1)** which leads to lesser bioavailability of heavy metals and thus maximum plant growth in the above two sites. In Vannivedu, even though the organic matter of the soil sample has a significantly higher percentage of organic matter (9.1 %), a considerably high concentration of Cr inhibits plant growth. Similarly, MGR Nagar soil sample also was recorded with a significantly higher level of Cr (**Table – 2)** and hence resulted in 55% seed germination.

Table 3: Percentage seed germination, Seedling growth and Chlorophyll content of *Oryza sativam* exposed to residual soil of the four experimental sites.

Site		MGR Nagar	Bharathi Nagar	Vanapadi	Vannivedu
Percentage seed germination (%)		55 ± 0.12	90 ± 0.15	75 ± 0.21	50 ± 0.32
Seedling Growth (cm)	Shoot	4.36 ± 0.14	6.22 ± 0.15	5.97 ± 0.13	2.1 ± 0.03
	Root	4.0 ± 0.21	5.64 ± 0.33	6.61 ± 0.12	1.89 ± 0.54
Chlorophyll content (mg/kg)		34.9 ± 0.32	60.2 ± 0.14	47.0 ± 0.22	32.1 ± 0.18

All the values were subjected to statistical analysis and found to be statistically significant.

The seedling growth in Bharathi Nagar (shoots – 6.22 cm and root 5.64 cm) and Vanapadi (shoot – 5.97 cm and root 6.61cm) soil samples were found to be comparatively more than MGR Nagar (shoot – 4.36 cm and root 4.0cm) and Vannivedu (Shoot – 2.1cm and root 1.89cm) soil samples. Among the four sites, poor seedling growth was recorded in Vannivedu soil samples. Even though the Vannivedu soil sample was rich in N, K and P (Table – 1), negative factors like high sodicity and salinity lead to poor plant growth. From Table -1, it was clear that Vannivedu soil sample was recorded with a significantly higher concentration of Sodium (12912.3 mg/kg) and Salinity (426.4 mg/kg). The presence of competitive cations can also affect the uptake of vital nutrients. Except Ni, all other heavy metals Cr (6126mg/kg), Pb (19.62mg/kg), Co, Cd and Cu were recorded with higher levels in Vannivedu soil sample than other sites. The ability of a seed to germinate in a medium containing Cr would be indicative of its level of tolerance to this metal (Peralta et al., 2001).

Moreover, Vannivedu soil sample was recorded with a significantly higher Zn concentration with the value of 1421 mg/kg Organic matter improves Zn's availability by releasing Zn with time and through changes in the physicochemical properties of the soil, which increases its uptake by roots (Cakmak, 2009). The most obvious symptoms of Zn toxicity reported in plants are the inhibition of growth, and chlorosis of young leaves (probably the consequence of lower uptake of $Fe2+$ and $Fe3+$), and can lead, in some cases, to cell death (Habiba Balafrej et al., 2020). For most crops, the typical Zn is a key nutrient that creates chloroplasts for photosynthesis. Jain et al, (2013) demonstrated that in *A. thaliana*, treatment with 0.075 mM of Zn did not affect plant development, whereas, at concentrations above 0.1 mM, Zn became toxic. Salinity also affects photosynthesis mainly through a reduction in leaf area, chlorophyll content, and stomatal conductance.

Metals can also be complexed and sequestered in cellular structures (eg. Vacuole) becoming unavailable for translocation to the shoot (Lasat et al., 1996; 1998; Adhikary, 2015). Studies of Tuteja et al., (2013) and Liu et al., (2018) also reveal that salinity inhibits seed germination and seedling growth of rice, reduces photosynthesis and ultimately reduces rice production. The low salinity, sodicity, and higher organic matter of Bharathi Nagar Soil is responsible for better seed germination and chlorophyll content of the rice plant's better growth. As per Cüneyt Uçarlı, 2020, salinity may adversely influence seed germination by decreasing the amounts of seed germination stimulants such as GAs, enhancing ABA amounts, and altering membrane permeability and water behavior in the seed. Similarly, Soil organic matter and environment had significant effects on seedling emergence as shown in the study of the effect of soil organic matter on the seedling emergence of sunflowers by Önemli (2004).

Thus, from the above studies it is understood that along with the various factors like the soil physico chemical factors, the readily available heavy metals are the one which can be made available by simple biogeochemical mechanisms affect the plant growth and increase the metal accumulation in the feed plants.

4. Conclusion

The above results and discussion reveal that the soil is irreversibly polluted with significant levels of heavy metals. Thus, the speciation study is an important technique to find the nature of the heavy metals and predict their bioavailability form for suitable remediation. From the results and discussion of heavy metal accumulation in plants, it is clear that the heavy metal accumulation are toxic at different degrees at different stages of plant growth and development and also that toxicity is concentration and medium dependent. Solutions for many of our pollution problems can be found either in an improved technology, more personal responsibility or better environmental management. By environmental management it is to see whether air is fit to breath, water to drink and soil and food resource, etc., is fit to provide all needs. In the environmental field, an ultimate goal might be to determine accurately, the human health or ecological risks posed by the heavy metal species discovered and quantified at a site and redirect this understanding into the design, selection, optimization and monitoring of remediation strategies applied to clean up the site, if necessary.

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