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Indian
Journal of Advances in
Chemical Science

Indian Journal of Advances in Chemical Science **4(4)** (2016) 386-393

Physico-chemical Parameters and Fertility Status in Selected Soils of Agastheeswaram, Kalkulam and Vilavancode Taluk's of Kanyakumari District, Tamil Nadu, India: A Study

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Received 18th July 2016; Revised 28th September 2016; Accepted 30th September 2016

ABSTRACT

An assessment of variation in physico-chemical parameters, concentration of macronutrients, and trace elements was undertaken during the two major seasons of Kanyakumari district to determine the fertility status of the soil. The available macronutrients such as N, P, and K were analyzed by quantitative analysis, colorimetric analysis, and flame photometer, respectively. The available trace elements concentration was determined using atomic absorption spectrophotometer. The analyzed results indicated that both in the wet and dry season, macronutrient, potassium, and trace elements such as Zn, Fe, and Mn were insufficient range other than available nitrogen and available copper. Among the five sampling locations, sampling location S_5 showed stronger acidic nature and had a higher content of organic carbon, available P, Fe, and Mn during both the seasons.

Key words: *Macronutrients, Trace metals, Fertility, Concentration.*

1. INTRODUCTION

Soil can be defined as "a natural body consisting of generally unconsolidated layers of horizons of minerals and organic constituents of variable thickness which differ from parent rock, in morphological, physical, chemical, and mineralogical properties [1]. Soil is composed of mineral constituents, organic matter (humus), living organisms, air, and water and it regulates the natural cycles of these components [2]. It is a valid component medium of unconsolidated materials, which forms the life support component of biosphere [3]. Plant growth and development are mostly governed by the chemical environment of the soil [4].

Soil health is the foundation of productive farming practices. Fertile soil provides essential nutrients in plants. Important physical characteristics of soil - like structures and aggregation allow water and air to infiltrate, roots to explore, and biota to thrive. Diverse and active biological communities help soil to resist physical degradation and cycle nutrients at rates to meet plant needs. Soil health and soil quality are terms used interchangeably to describe soil that are not only fertile but also possess adequate physical and biological properties to "sustain productivity, maintain environmental quality, and promote plant and animal health " [5].

Soil fertility is only one of the determinant components of soil quality. Fertile soils are able to provide the nutrients required for the growth of the plant. They are the chemical components of soil. Some plants need certain nutrients in large amounts, such as nitrogen, phosphorous, and potassium, which are called macronutrients. Other nutrients, such as boron and manganese, are needed in minute quantities. In high - quality soil, nutrients are available at rates high enough to supply plants needs, but low enough that excess nutrients are not leached into groundwater or present at high levels toxic to plants and animals.

Good agricultural practices maintain or improve soils. Soil is fundamental to agriculture, and a well-managed soil improves performances of crops and livestock. However, soil becomes less productive if eroded by wind and water, compacted from improper use of machinery on the land, or damaged by inappropriate fertilization or irrigation. Eroded soil also creates a problem in water sources and is a major cause of eutrophication and siltation.

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The increasing human population is placing greater pressure on soil and water resources that threaten our ability to produce sufficient food, feed, and fiber. As a result, there is a growing consensus within our global community for the protection of natural resources and implementation of environmentally and economically sound agricultural practices with utmost priority.

The basic physical, chemical, and biological properties of soils must be considered for maintaining sustainable agricultural practices. Through the study of soil science, the importance of this heterogeneous assemblage of minerals, organic matter, organisms, air, and water as a key component of our global environment becomes self-evident. Soil provide a wide range of important ecosystem services such as a filter for water, a sink for carbon, a regulator of atmospheric gases, and a medium for plant growth, which helps to sustain all life on this planet.

Global industrialization and human social and agricultural activities have an effect on environmental pollution and global ecosystem. This corruption of the ecosystem has a negative effect on human health and all living organisms. Growing industrialization and environmental pollution from technology have started to affect human health [6]. The dramatic increase in public awareness and concern about the state of global and local environments which has occurred in recent decades has been accompanied and partially prompted by an ever growing body of evidence on the extent to which the pollution has caused severe environmental degradation. The introduction of harmful substances into the environment has been shown to have many adverse effects on human health, agricultural productivity, and natural ecosystems [7]. Environmental pollution of toxic metals has increased dramatically since the onset of industrial revolution [8].

Trace metals is a general collective term which is applied to a group of metals and metalloids with atomic density >4 g/cm^2 or five times or, greater than water [9]. Their pollution to the environment, even at low levels and the resulting long-term cumulative health effects are the leading health concerns all over the world. Soil pollution by heavy metals, such as cadmium, lead, chromium, and copper, is a problem of concern. Some heavy metals such as arsenic, cadmium, and lead have reported to have no known bioimportance in human biochemistry and physiology and consumption even at very low concentrations can be toxic [10,11]. When agricultural soils are polluted, these metals are taken up by plants and consequently accumulate in their tissues [12]. Animals that graze on such contaminated plants and drink from polluted waters, as well as marine lives that breed in heavy metal-polluted waters also accumulate such metals in their tissues and milk if lactating [13].

There is a growing concern about the possibility of soil contamination resulting in uptake by plants and the introduction of the elements in the vital food chain which affect the food safety. Thus, the knowledge of built up of nutrients in the soil of cultivated areas is an important criterion to recognize potential ecological problems. The situation is even more worrisome in the developing countries where research efforts toward monitoring the environment have not been given desired attention by the stakeholders, hence the need for the present study, which was carried out to determine the levels of trace metals - Pb, Cr, Cd, Ni, Zn, Mn, Cu, and Fe in the agricultural lands in three different taluks of Kanyakumari district and to assess if their levels are sufficient to pollute the soil environment.

2. METHODOLOGY

2.1. Study Area

Kanyakumari is one of the smallest districts in Tamil Nadu state having an area of 1584 km^2. The district lies between 77° 05’ and 77° 36’of the Northern latitude. The district has four taluks, namely, Thovalai, Agastheeswaram, Kalkulam, and Vilavancode. Among the four taluks, soils samples were collected only from the agricultural lands of Agastheeswaram and Kalkulam taluks. The soils of these taluks are of sandy loam type with low gravel content.

2.1.1. Sampling

Pazhavilai (S_1), Peycode (S_2), Thalakulam (S_3), Bethelpuram (S_4), and Midalakadu (S_5) were selected as sampling locations as shown in Figure 1. Samples were collected during the rainy season of 2012 and in the dry season of 2013 in the agricultural lands which were 5 km away from the coastal areas of Kanyakumari district. At each sampling location, about 2 kg of soil was collected at the surface levels (0-15 cm in depth) at a distance 1 m away from the road. Soil samples were prepared by collecting small portions of surface soil. A “V” shaped cut of 0-6 inch depth at random locations was made in each sampling site, and one inch of soil on either side of pit was scraped and collected in polythene bags. Quartering technique was adopted to reduce the size of the sample to the required mass. The collected soil samples are then assigned with identification number and were processed, analyzed by selecting standard procedures which are appropriate for soils of the study area.

Three samples were collected in each sampling point, crushed and sieved with 2 mm mesh before storing it in labeled polythene bags before analysis.

2.1.2. Determination of pH

The pH of soil samples was determined with deep vision, digital pH meter, model: 111/101, according to the following analytical procedure.

The pH meter was calibrated using pH 7 buffer solution. Then, the meter was adjusted with known pH

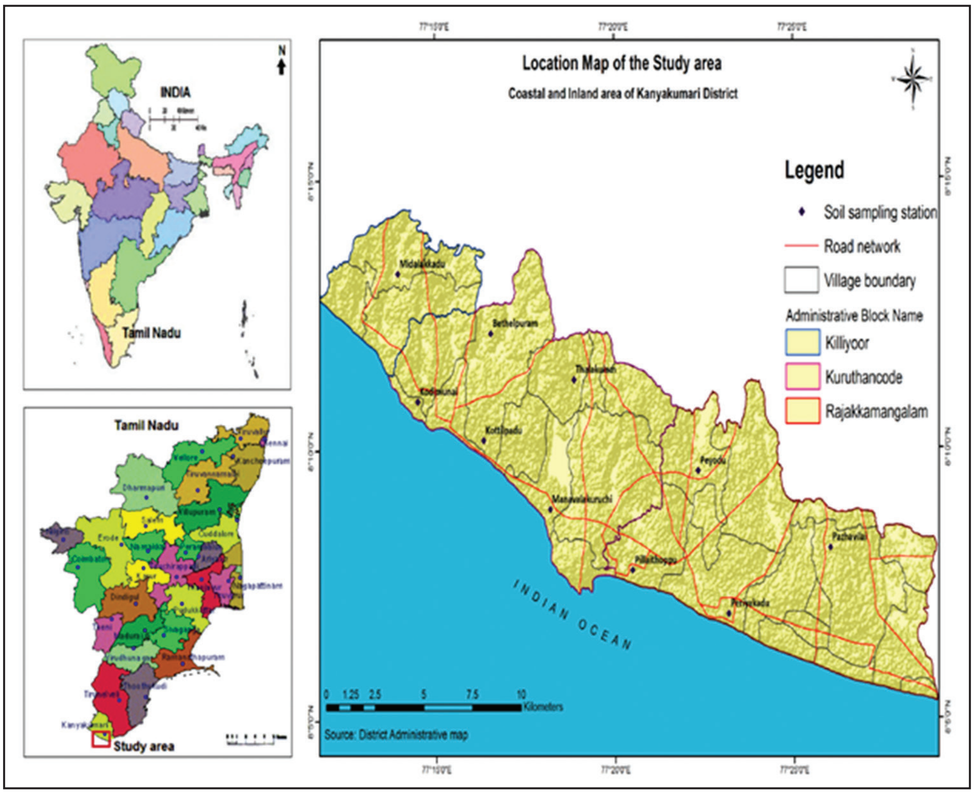

Figure 1: Location map of the study area.

buffer solution 4.0-9.2. 20 g of soil was weighed and transferred into 100 ml beaker. The 40 ml of distilled water was added and stirred well with a glass rod. This was allowed to stand for ½ h with intermittent stirring. To the soil suspension in the beaker, the electrode was immersed, and the pH value was determined from the automatic display of the pH meter.

2.1.3. Determination of organic carbon

Organic carbon was determined using chromic acid oxidation method (Walkey and Black, 1934).

About 1 g of soil was weighed into a 500 mL Erlenmeyer flask. 10 mL of 1N potassium dichromate solution was added to it. Then, 20 mL of sulfuric acid was added and mixed gently by shaking for 1 min. Then, it is allowed to stand for 30 min. This is diluted to 200 ml with deionized water. With this 10 mL phosphoric acid, 0.2 g of ammonium fluoride and 10 drops of diphenylamine indicator were added. This was titrated against 0.5 N ferrous ammonium sulfate solution until the color changed from dull green to turbid blue. The titration was continued until the end point was reached. The endpoint was the shift from color to brilliant green. A blank titration was carried out in the same manner.

% Organic matter = {10[1(S÷B)]*0.67}

S → Sample titration

B → Blank titration.

2.1.4. Determination of available nitrogen

Available nitrogen was determined by alkaline permanganate method. Transfer 20 g of sieved soil into 1litre round bottom flask. Then, add little quantity of distilled water with the help of jet in such a way that the particles of soil do not remain stuck to the sides of the flask. Add 2-3 glass beads to present bumping and 1 mL of liquid paraffin to prevent frothing. Add 100 mL of potassium permanganate and 100 mL of sodium hydroxide solution to the flask (both the solutions should be prepared fresh). Distill and collect the distillate in a beaker containing 20 mL of boric acid working solution. Collect approximately 150 mL of distillate. Titrate the distillate with standard H_2SO_4 - 0.02 N till the color changes from green to red and record the burette reading. The blank was set without the addition of soil solution.

Available:

$$N\left({}^{Kg}/_{Ha}\right) = \left[(A-B)*N*0.014*2240000\right] \div \left[\text{Weight of Soil Samples } (g)\right]$$

N=Normality of H_2SO_4.

2.1.5. Determination of available phosphorous and potassium

Available phosphorous was determined calorimetrically and available potassium was determined by flame photometer.

2.1.6. Determination of trace metals

The trace metals such as Pb, Cr, Cd, Ni, Zn, Mn, Cu, and Fe were analyzed using atomic absorption spectrophotometer of model GBC 932.

3. RESULTS AND DISCUSSIONS

The analytical data of soil samples are presented in Tables 1-5, and its graphical representation is as shown in the Figures 2-6.

The discussion for trace elements is based on the permissible limits cited in Table 6.

Fertility rating for organic carbon: Low: <0.5%, medium: 0.5-0.75%, High: >0.75%.

3.1. pH

Soils of locations S_1, S_2, S_3, and S_4 showed neutral or slightly alkaline nature during both the seasons. However, S_5 location showed acidic nature during both the seasons. This may be due to the constant addition of chemicals to the soil coupled with high temperature and excessive rainfall, resulting severe acidity build up in the soil system and affecting the nutrient uptake of plants in the fields. Low pH leads to aluminum toxicity. Aluminum is found bound with clay particles and organic matter. When soil pH drops, Al becomes soluble, and the amount of Al in soil solution increases. Soil Al of concentration 2-5 ppm is toxic to the roots of sensitive plant species, and above 5ppm is toxic to tolerant species. The adverse effect of low pH can be overcome by liming the soil [14]. This helps to increase the pH, hence reduces the availability of Al to non-toxic level.

Table 1: The mean values of pH and organic carbon during wet and dry seasons.

Locations	pH		Organic carbon (%)	
	Wet season	Dry season	Wet season	Dry season
S_1	7.4	7.9	0.58	0.58
S_2	6.75	6.74	0.51	0.72
S_3	7.02	6.95	0.11	0.47
S_4	6.8	7.7	0.58	0.14
S_5	5.54	5.62	0.84	1.27

Table 2: The mean concentrations of macronutrients during wet season.

Locations	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
S_1	154	15	400
S_2	369	10	156
S_3	148	4	149
S_4	193	9	148
S_5	221	40	151

Table 3: The mean concentrations of macronutrients during dry season.

Locations	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
S_1	151	32	477
S_2	221	18	181
S_3	210	5	160
S_4	190	21	149
S_5	221	55	152

3.2. Organic Carbon

A high percentage of organic carbon was recorded in S_5 location during the seasons, (0.84% and 1.27%). The other four locations showed medium values.

Soil organic carbon (SOC) is the amount of carbon stored in the soil. It is a component of soil organic matter - plant and animal materials in the soil that are in various stages of decay. SOC is important for all three aspects of soil fertility namely chemical,

Table 4: The mean concentrations of trace metals during wet season.

Trace metals (ppm)	Locations				
	S_1	S_2	S_3	S_4	S_5
Pb	0.49	2.28	BDL	BDL	BDL
Cr	1.02	0.18	0.30	0.16	0.27
Cd	0.07	0.056	0.046	0.047	0.050
Ni	BDL	0.03	BDL	BDL	0.46
Zn	5.98	3.54	0.89	3.29	1.09
Mn	11.2	13.5	7.86	15.7	13.8
Cu	0.9	1.5	0. 2	0.6	0.7
Fe	5.03	6.78	4.2	5.07	5.75

Table 5: The mean concentrations of trace metals during dry season.

Trace metals (ppm)	Locations				
	S_1	S_2	S_3	S_4	S_5
Pb	0.70	2. 50	BDL	BDL	BDL
Cr	1.42	0.48	0.47	0.36	0.42
Cd	0.09	0.076	0.096	0.097	0.080
Ni	BDL	0.08	BDL	BDL	0.66
Zn	4.62	5.1	1.82	0.62	0.84
Mn	15.08	19.85	9.62	16.08	13.54
Cu	0.76	2.48	1.02	0.56	0.52
Fe	7.15	9.92	8.02	3.41	5.79

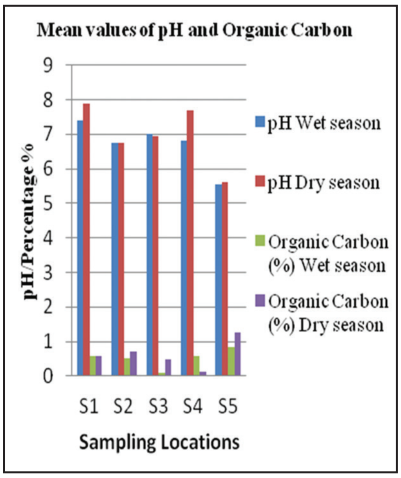

Figure 2: The variation of pH and organic carbon during wet and dry season.

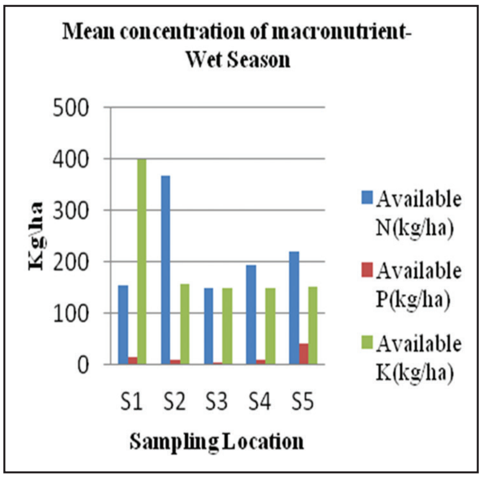

Figure 3: The mean concentration of macronutrient-wet season.

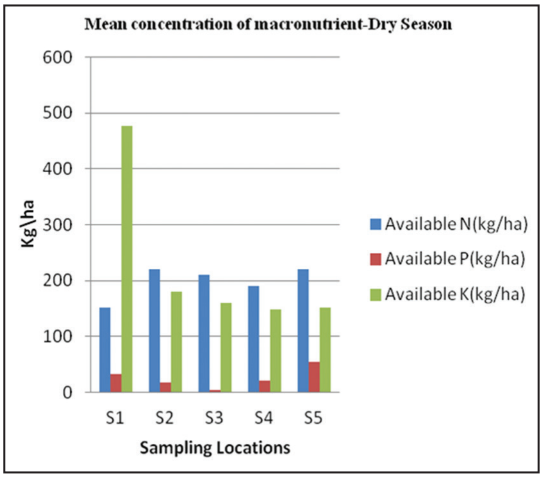

Figure 4: The mean concentration of macronutrient-dry season.

physical, and biological fertility. It releases nutrients for plant growth, promotes the structure, biological

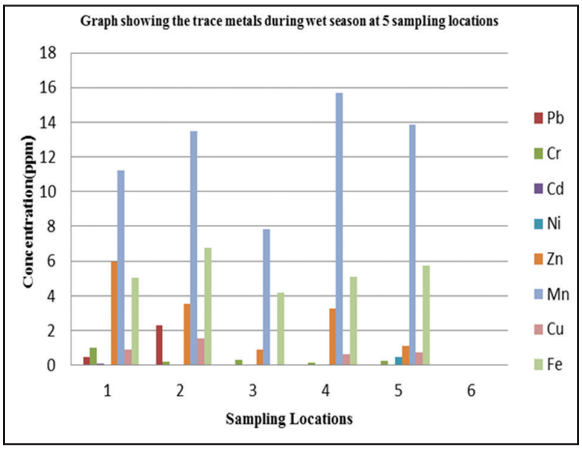

Figure 5: The trace metal during wet season.

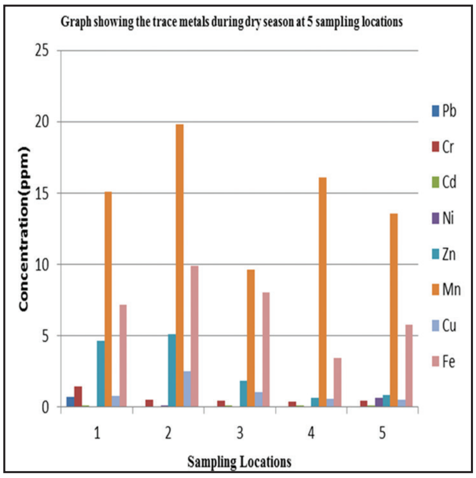

Figure 6: The trace metal during dry season.

and physical health of the soil, and is a buffer against harmful substances. SOC is a part of the natural carbon cycle. Plants and animals die and return to the soil where they are decomposed and recycled. Minerals are released into the soil and carbon dioxide is released into the atmosphere. The amount of SOC present in the soil vary hugely according to soil and landscape types, change in climate and farming methods. Temperature, rainfall, land management, soil nutrition, and soil type are the factors that influence SOC levels.

There are a wide range of management options and farming practices that can increase SOC level either by increasing the inputs or decreasing losses. Inputs can be increased by the direct addition of organic materials, composts, manure, and other recycled organic materials [15]. If more carbon is stored in soil as organic carbon, it will reduce the amount present in the atmosphere, and help reducing global warming. The process of storing carbon in soil is called "sequestration."

3.3. Available Nitrogen

Other than location S_5, all the other samples showed a deficiency of nitrogen. This low figure will affect the metabolic activity of the plants in the region curtailing the growth of it. Nitrogen deficiency symptoms in plants are stunted growth, shorter internodes, and small pale yellow leaves. Plants may become light green. To overcome this deficiency, it is necessary to add nitrogen-containing fertilizers to enrich the soil.

3.4. Available Phosphorous

Location S_5 showed a higher amount of phosphorous during both the seasons. Comparatively, the amount of phosphorous was low during the wet season. Normally, in cool climate deficiency of phosphorous is predominant. As this nutrient helps in energy storage and transport of energy in plants, it is more and more essential in the nutrient family. Its deficiency causes disturbance in the nitrogen metabolism of plants. This deficiency can be managed using animal manures, rock phosphate, and using inorganic synthetic triple superphosphate and ammonium phosphate to soil.

3.5. Available Potassium

Locations S_2, S_3, S_4, and S5 showed low levels of available potassium during both the seasons. However, location S_1 showed the very high level of available potassium during both the seasons.

Potassium is an essential plant nutrient and is required in large amounts for proper growth and reproduction of plants. Potassium is considered as the "quality nutrient." Plants absorb potassium in its ionic form, K+. In photosynthesis, potassium regulates the opening and closing of stomata, and therefore, regulates CO_2 uptake. Potassium triggers enzyme activation and is essential for the production of adenosine triphosphate. Potassium plays a major role in the regulation of water in plants (osmoregulation). Both uptake of water through plant roots and its loss through the stomata are affected by potassium. It is known to improve drought resistance. Protein and starch synthesis in plants require potassium as well. Potassium is essential at almost every step of the protein synthesis. In starch synthesis, the enzyme responsible for the process is activated by potassium. Potassium has a crucial role in the activation of many growth-related enzymes in plants.

Potassium deficiency causes cholrosis, slow or stunted growth, and poor resistance to temperature changes and to drought, defoliation. Potassium deficiency also causes poor resistance to pests, weak, and unhealthy roots, uneven ripening of fruits.

Potassium deficiency can be managed by adding potassium-specific fertilizer, often called potash, which consists of K_2CO_3. Rock potash may be a good solution because it has high potassium content but is released slowly to reduce overdose. Common forms of inorganic fertilizers include potassium nitrate, potassium sulfate, and monopotassium phosphate.

Too much potassium disrupts the uptake of other important nutrients, such as calcium, nitrogen, and magnesium, creating deficiencies that usually produce visible effects. High level of potassium can be minimized by selecting a blend that is low in potassium, or contains none at all, is a first step in assuring that it does not build up to unsuitable levels in the soil. Dilute and flush out large amounts of potassium by watering the soil any time it appears dry to a depth of one inch. Schedule any fertilizing within several weeks before planting so that the potassium does not have time to accumulate during the off-season. To minimize long-term potassium buildup, consider using aged or composted animal manure as a substitute for commercial fertilizers, as its components break down more slowly to keep up with plant demand.

3.6. Lead

Locations S_1 and S_2 showed significant concentrations of Pb during both the seasons (0.49, 2.28 ppm - wet season and 0.70, 2.50 ppm - dry season). Locations S_3, S_4, and S_5 showed below detection levels of Pb during both the seasons. The high concentration of Pb in locations S_1 and S_2 may be due to the deposition of automobile exhaust, garbage disposal, discarded batteries, and other lead-bearing materials. The addition of artificial fertilizers and pesticides causes an increase of lead levels in agricultural soils [16].

3.7. Chromium

During the wet season, the concentration of Cr was found to range from 0.30 to 1.024 ppm and 0.36-1.42 ppm during the dry season. All the locations showed a higher level of Cr during both the seasons. Specifically, location S_1 showed a higher level of Cr during both the seasons (1.024 ppm and 1.42 ppm). This may be due to the dumping of sewage sludge disposal in these agricultural lands [17].

3.8. Cadmium

The concentration of Cd ranged from 0.046 to 0.07 ppm during the wet season and 0.076-0.097 ppm during the dry season. This high metal concentration may be attributed to the combustion of fossil fuels that contain Cd as one of the constituents. This gets transported through air and contaminates soil. Cadmium can be easily taken up by the plants due to high solubility in the environment [16].

3.9. Nickel

It is observed that only location S_1 (0.03 ppm - wet season, 0.08 ppm - dry seasons) and location S_5 (0.46 ppm - wet season, 0.66 ppm - dry seasons) showed marked values of nickel. All the locations showed a below detection level. It is a known fact that plants are more sensitive to nickel toxicity than animals. From the above data, it is clear that the locations S_2 and S_5

have nickel toxicity. This may be due to the deposition of sewage sludge, disposal of car batteries, pigments, paints, poultry wastes, and combustion of fossil fuels. High concentrations of nickel will end up in the soil as sink when they are leached into the soil and can dissolve in soil water and rivers as a result of runoff during the wet season [16].

3.10. Zinc, Manganese, Copper, and Iron

During both the seasons, it was observed that the concentrations of Zn, Mn, Cu, and Fe were higher than the permissible limits. It was observed that during wet season the concentration of Zn ranged from 0.89 ppm to 5.98 ppm. This is much higher than the permissible limit. Zinc can be easily taken up by plants due to high solubility in the environment.

It was also observed that during both the seasons the concentration of Mn ranged from 0.62 ppm to 15.68 ppm which is also higher than the permissible limit.

The analytical data showed a low concentration of copper mostly in all locations. However, location S_2 showed a higher value (1.54 and 2.48 ppm). Copper is an important nutrient for many soil microbes. It controls, molds, and often alleviates perceived Zn deficiencies. It plays a vital role in root metabolism and helps to form proteins, amino acids and is a host of organic compounds. It acts as a catalyst or form part of the enzyme systems. To get rid of this deficiency, it is needed to add sufficient amount of copper sulfate to soil [17].

It is observed that in all locations the concentration of Fe was high during both the seasons. The value ranged from 3.41 to 9.92 ppm. The concentration was higher than the permissible limit. Fe is not classified as a toxic metal, but its concentration and chemical form can influence the speciation of Pb and hence its toxicity [15].

4. CONCLUSION

The present study reveals that location S_5 showed acidic nature and had a higher percentage of organic carbon and available potassium when compared to all other locations during both the seasons. Locations S_1 and S_2 showed significant concentrations of Pb during both the seasons. Specifically, location S_1 showed a higher level of Cr during both the seasons. The concentration of Cd was high during both the seasons. It is observed that only location S_1 and location S_5 showed marked values of nickel. During both the seasons, it was observed that the concentrations of Zn, Mn, Cu, and Fe were higher than the permissible limits. In general, higher mean trace metal concentrations were recorded in the soil during the dry season when compared to wet season, this is due to the run off effect that is capable of removing trace metals from the soil and effect of rainfall which may facilitate the leaching of the soil and contributes to the dilution of soil solution during wet season. The analytical results indicate that in both wet and dry seasons, most of the trace metals were above the natural trace metal concentrations of soil samples which is a course of concern as these metals can accumulate to pollute the environment.

Table 6: Permissible limits of trace metals.

Trace metals	Permissible limits (ppm)
Pb	0.1
Cr	0.05
Cd	0.05
Ni	0.02
Zn	1.2
Mn	2.0
Cu	1.5
Fe	3.7

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