RESEARCH ARTICLE

STUDY OF PHYSICO -CHEMICAL PROPERTIES OF SOIL IN SELECTED URBAN WASTE STORAGE SITES OF KERALA

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Manuscript Info

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Abstract

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Soil pollution is the contamination of soil by human and natural activities which may cause harmful effects on living organisms. Soil pollution mainly occurs due to industrial wastes, urban wastes, agricultural practices, radioactive pollutants etc. In the present study, the soil samples from three urban waste storage sites of Kerala- Vilappilsala, Brahmapuram and Njeliyanparambu were analyzed for physico-chemical properties (bulk density, texture, PH, electrical conductivity, available N, available P, available Ca and available Mg) and heavy metals (Cu, Zn, Cd, Hg, Cr and Pb). The soil bulk density was highest in site 3 and 4 (1.10g/cm^3) and lowest was in site 2 (1.08g/cm^3). Texture of the soil is clayey soil in site 3 and sandy clay loam in site 2 and site 4. pH range was high in site 4 (7.1) and lowest in site 3(4.3). Electrical conductivity was higher in site 4 (2.25 dsm-1) and lower was in site 3 (0.15 dsm-1). Results obtained showed that soils of the various locations are significantly different from one another in terms of physical and chemical properties. Zn was found to be higher than all the other elements. The concentration of the metal was higher than the control site as a result of anthropogenic activities.

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Introduction:-
Industrialization together with social and agricultural activities of humans have an effect on environmental pollution and the global ecosystem. This corruption of the ecosystem has a negative effect on human health and other living organisms. Growing industrialization and environmental pollution that stems from technology have started to affect human health (Yadgir et al., 2000). Nearly all human activities generate waste, and the way in which this is handled, stored, collected and disposed can pose risks to the environment and to public health (Zhu et al., 2008). Several fluxes of waste and cover materials from different sources end up at these dumpsites and due to the heterogeneity and complexity of wastes, these dumpsites contain a variety of contaminants which can pollute the soil (Sukop et al., 1979).

Maintaining soil health/quality is indispensable for sustaining the agricultural productivity at higher level. The yields were limited by the physical conditions of the soils rather than their nutrient status in certain situations (Russel, 1975). The sustainability of soil as a medium of plant growth depends on both its chemical and physical fertility (Hillel, 1980). Heavy metal contamination in the biosphere due to human activities has become an important process in the geochemical cycling of these metals. Pollution of heavy metals is a problem of concern due to their non-degradable conditions posing toxic problems to living organisms if they exceeded certain limits (Ruhling and

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Steinner, 1998). Environmental pollution with heavy metals due to intensive agricultural and other anthropogenic activities poses serious problems for secure usage of farming land (Wong et al., 2002). Heavy metal toxicity has an inhibitory effect on plant growth, enzymatic activity, stomatal functions, photosynthesis activity, microbial activity, accumulation of other nutrient elements and also damages the root system (Johansson et al., 1998). Other negative effects of heavy metals, especially as they are discharged through industrial effluents include negative effects on porosity and water holding capacity, CEC, mineral composition and seed germination (Ayolagha and Nleremchi, 2000). The objectives of the present study are to analyze the physical and chemical properties of soil in urban waste storage sites of Kerala as well as to evaluate the presence of toxic heavy metals in urban waste storage sites (Cu, Zn, Cd, Hg, Cr, Pb).

Materials and Methods:-
Study area:
The study site includes three major waste disposal sites of Kerala- Vilappilsala at Trivandrum, Brahmapuram at Kochi and Njeliyanparambu at Calicut. Kerala lies between northern latitude of $8^o.17'.30''$ N and $12^o.47'.40''$ N and east longitudes $74^o.27'.47''$ E and $77^o.37'.12''$ E. Kerala lies between the Arabian sea in the West and the Western Ghats (Sahyadris) in the East with an area of 38863 sq km. Vilappilsala- Vilappilsala village located about 15 km away from Thiruvananthapuram. The village was selected for the dumping of urban waste generated from Thiruvananthapuram. Brahmapuram- Brahmapuram waste plant is located at the Vadavucode- Puthencruz grama panchayat in the outskirts of Kochi city, contains all the degradable and non-biodegradable waste generated by the people inhabiting there. Njeliyanparambu- Njeliyanparambu is located 6km away from Kozhikode has gained prominence for being a dumping ground for Kozhikode city.

Preparation of soil samples:
The samples were collected from three sites polluted with domestic sewage and industrial effluent. The soil samples were stored in labeled polythene bags and brought to the laboratory for analyzing physico-chemical parameters and heavy metals. Bulk density was calculated following Blake and Hartge (1986). Soil pH was measured using 1:5 proportion of soil and water by glass electrodes (Jackson, 1958). Electrical conductivity was determined by conductometric method using a conductivity meter. Total nitrogen content in the soil sample was determined by micro-Kjeldahl's method (Jackson, 1958). Concentration of total phosphorus in the soil samples was determined by spectrophotometric method after acid digestion by Olsen's method (Olsen et al, 1954). Exchangeable potassium, calcium and magnesium of the soil were analyzed using the procedure of Jackson (1958). The soil organic carbon (OC) was determined by wet chemical oxidation method of Walkley and Black (1934).

Heavy metals analysis:
1 gm of the oven dried sample was weighed and placed in a 250 ml beaker to which 15 ml of aquaregia (35% HCl and 70 % high purity HNO_3 in 3:1 ratio) was added. The mixture was then digested at 70^0C till the solution became transparent. The resulting solution was filtered through whatman filter paper no. 42 into 50 ml volumetric flask and diluted to mark volume, using deionized water and the sample solution was analyzed for concentration of Copper(Cu), Zinc(Zn), Cadmium(Cd), Mercury(Hg), Chromium (Cr) and Lead (Pb) using an Atomic Absorption Spectrophotometer (Perkin-Elmer A Analyst 400) (APHA, 2005).

Results and Discussion:-
Physical and chemical characteristics of soil:
Table 1: and Fig-1 shows the physico-chemical properties of soil samples of study area.
Bulk Density:
The bulk density was highest at site-3 (1.13g cm^{-3}) while it was lowest (1.08g cm^{-3}) at site 1 with an average of 1.10 g cm^{-3}. Tripathi and Misra (2012) reported that the bulk density was highest at site 1 (3.11±0.40g cm-3) while it was lowest (1.47±0.48g cm-3) at site 2 in contaminated soils of municipal waste dump sites at Allahabad, India. In soil sample collected from anthropogenic sites in Abeokuta, Nigeria, Olayinka et al. (2017), reported a bulk density value ranging from 0.78-2.29 gcm-3. High bulk density at dumpsites can reduce the root length and limits the root penetration in dump soil (Rai et al., 2010).

Organic Carbon:
Soil carbon is the last major pool of the carbon cycle. The carbon that is fixed by plant is transferred to the soil via dead plant matter including dead roots, leaves and fruiting bodies (Lal, 2008). Organic carbon contents play a

crucial role in sustaining soil fertility, crop production and environmental quality due to their effect on soil physical, chemical and biological properties, such as soil water retention, nutrient cycling, gas flax and plant root growth (Saiju and Kalisz, 1990). In the present study, the organic carbon content in soil samples ranges from 2.63 % (S2) to 5.41% (S1) with an average of 3.46%. Maximum organic carbon content was noted in site 1 and minimum organic carbon was detected at site 2. Deshmukh and Aher (2017) observed the organic carbon in soil sample (0.8-12.2%) in the Municipal Solid Waste (MSW) disposal site near Sangamner city, Maharashtra. The value of percentage organic carbon range between 1.39-5.30% in the active dumpsite of soil samples in south western Nigeria (Badmus et al., 2014). The organic carbon in the soil may be due to biodegradable wastes in municipal solid waste. The decomposition of the soil microbes results in the nutrient rich content of the soil (Obute et al., 2010; Amos-Tautua et al., 2014).

Soil p^H:
Soil pH controls various chemical processes in soil. The pH of natural soil lies between 7 and 8.5 and its variation might be possible due to temperature, disposal of municipal waste, biological activity etc. (Oyedele et al., 2008). In the present study, the P^H of the dump sites ranged from 4.3 to 7.1. The lowest p^H value was recorded at site 2 ie. 4.3 which shows that the soil is highly acidic. This low PH at site S3 (4.3) may be due to the dumping of acid containing waste materials like batteries on the dumping site. The highest pH 7.1 was recorded at site 3. At the control site the soil p^H is alkaline.The pH of the contaminated soil by mining activity range from 4.63-8.04 (Baran et al., 2014). Krishna et al (2016) studied the effect of Municipal Solid Waste leachate on the soil quality reported that the pH of the contaminated soil is 7.45. The pH values of soil sample in the municipal solid waste dumpyard in Vellalore, Coimbatore district varied from 8.04-9.20 with a mean value of 8.53 (Uma et al., 2016). A study of contaminated soil physico-chemical properties of municipal waste dump sites at Allahabad, the pH of the soil ranged from 6.42±0.46 to 7.16±0.81 which is tending towards neutral or alkaline pH (Tripathi and Misra, 2012). The study was carried out in five solid waste dump sites in the city of Port Harcourt, Nigeria showed the pH of the soil ranged between moderately acidic 4.8±0.18 and slightly above neutral 7.66 ± 0.44 (Obianefo et al., 2017). The high pH values are due to the presence of soluble sodium along with HCO-3 ions, which precipitates calcium and magnesium carbonates during evaporation (Deshmukh, 2012).

Electrical conductivity (EC):
The EC value depends on the dilution of the soil suspension. The soil electrical conductivity (EC), associated with soil salinity (Santini et al, 2013), is measured as one of main soil characteristics in agricultural production and environmental protection. It is influenced by soil moisture content, salts, and amount and type of clays and other factors (Eigenberg et al, 2002). In the present study, the electrical conductivity at dumpsite 2 was lowest (0.15dSm^{-1}) while it was highest at site 3 (2.25dSm^{-1}). This shows that the movements of charged particles are more at site 3 which is a good indicator of the growth of plants. Previous studies reported that in Vellalore dumpyard, Coimbatore district of Tamilnadu, the electrical conductivity varied from 1.01 mS/cm – 1.0 mS/cm with a mean value of 1.01 mS/cm (Uma et al., 2016). According to Badmus (2014), the soil electrical conductivity value ranged from 5.03-6.08 mS/cm with a mean value of 6.08 mS/cm. Thus, electrical conductivity is a measure of ions present in the soil solution (Ku and Sangita, 2015).

Available Nitrogen:
The rich nutrient content of the soil is due to the activities of soil organisms in the decomposition of the wastes (Obute et al., 2010; Amos-Tautua et al., 2014). The available nitrogen in the soil varied from 0.93ppm (site 2) to 5.29 ppm (site 1) during the study period. The maximum value of available nitrogen at site 1 and minimum at site 2. Previous studies reported that the total nitrogen in the soil from selected solid waste dump site in Port Harcourt, River state, Nigeria, was 0.04±0.01–0.62±0.13% (Obianefo et al., 2017). The mean values of nitrogen were 0.94±0.09, 1.07±0.08, 0.82±0.03 and 0.63±0.11% from four different waste dump sites in Nigeria (Akinbile et al., 2016). Nitrogen controls the utilization of potassium, phosphorus and other constituents (Smith et al., 1996).

Available Phosphorous:
Phosphorus is known as the key nutrient to agriculture because lack of available phosphorus in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). In agricultural fields, phosphorus is added second to nitrogen, in frequency of use as fertilizer nutrient (Trohel and Thompson, 1993). The concentration of available phosphorous ranged from 6.50ppm (site 2) to 64.50ppm (site 1) during the study period. Previous studies showed that the five solid waste dump sites located in Port Harcourt of the Niger delta area of Nigeria showed phosphorous level (0.041±0.01 – 4.07±0.02 mg/kg) in dump sites especially in the wet season as compared to the

control (Obianefo et al., 2017). Assessment of physico chemical properties in surface soil of municipal open waste dumpsite in Yenagoa, Nigeria showed that the available phosphorous ranging from 35.00±1.01 to 84.20±1.02 mg/kg (Amos-Tautua et al., 2014). It is reported that high phosphate reduces the availability of cation metals to plants (Brady and Weil., 1999).

Available Potassium:
Potassium is the third most required element by the plants, which plays an important role for the biochemical and physiological processes that influence plant growth and development (Wang et al., 2013). Potassium content in soil is due to degradation of solid waste (Eddy et al, 2006). In the present study, the potassium content in soil samples varied from 32 ppm (site 2) to 1570ppm (site 1) during the study period. The highest value obtained with site 1 and the lowest at site 2. Potassium plays essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance and stress resistance (Marschner et al., 2012). Uma et al (2016) carried out the study of polluted soil during the summer and winter season in solid waste dumping in and around Coimbatore, Tamilnadu. The results indicated that the presence of potassium varied from 6-16mg/L with a mean value of 9.27 mg/L during summer season and 5-12 mg/L with the mean value of 8.08 mg/L during winter season. Ingavale et al (2012) studied the physico- chemical characteristics of soil of Bhogawati river bank in Kolhapur district during the monsoon and post monsoon period .The results showed that the potassium level (53.25 ppm) are quite high during the post monsoon period. Excess of potassium is not harmful for soil and crop productivity (Goswami and Sharma, 2008).

Available Ca and Mg:
Calcium content in the soil samples varied from 132.10ppm (site 2) to 5954ppm (site 1) during the study period. The highest value was noted at site 1 and the lowest at site 2. The Magnesium content in soil sample varied from 16.60ppm (site 2) to 179.43ppm (site 1). The highest value noticed at site 1 and lowest at site 2. Uma et al (2016) studied the physico-chemical characteristics of soil of the municipal solid waste dumpyard in and around Coimbatore, Tamilnadu. The results showed that during summer season the presence of calcium varied from 6.0-85mg/L with a mean value of 33 mg/L and magnesium varied from 60.96-100.24 mg/L with a mean value of 79.79 mg/L and during winter season the presence of calcium varied from 5-80 mg/L with a mean value of 29.5 and magnesium varied from 58.94-99.4mg/L with a mean value of 76.28mg/L. The high acidity reduces the availability of cation like calcium and magnesium (Goswami et al., 2012).

Texture:
 Texture of the soil is related to physical properties such as plasticity, permeability, ease of tillage, fertility, water holding capacity and soil productivity (Brady, 1996). In the present study the soils of the dump site in site 2 are clay-soil while other sites are sandy clay loam in nature. Amos-Tautua (2014) determined the soil quality around municipal open waste dumpsite in Yenagoa, Nigeria, had higher sand and lower clay and silt content. The soils of municipal waste dump sites, Allahabad had very low clay content (0.63±0.42 – 6.42±0.92%) and maximum sand content (44.59±1.42 – 53.78±1.46%) (Tripathi and Misra, 2012). Soils with separate high sand and low clay content have high pollutant leaching potentials (Nyles and Ray, 1999).

Heavy metals in soils:
The total metal concentrations of selected heavy metals such as Copper, Zinc, Cadmium, Mercury, Chromium and Lead at different study sites are given in Table -2, fig.-2.

Copper:
The copper content in soil samples varied from 2.5 mg/kg (site 2) to 70.1mg/kg (site 3) but are lower than the permissible limit of WHO (1993) (Table-3). The copper content in the soils of study sites are in the order S3 >S1>S2. Similar studies were reported by Tripathi and Misra (2012) in contaminated soils of municipal waste dump sites at Allahabad was 70.63±1.62 mg/kg and 90.70±1.84 of copper at site 1 and site 2 respectively. The increase in concentration of heavy metal in soil may be due to the influence of urban wastes dumped in the soil. According to Azeez et al (2011) the concentration of copper ranged from 2.83-72.36 mg/kg in the municipal solid waste deposition was investigated in Abeokuta, Nigeria.

Zinc:
Zinc occurs naturally in soil (about 70mg/kg in crustal rocks) (Davies and Jones., 1988). In the present study, the zinc content in soil samples varied from 3.7 mg/kg (site 2) to 116 mg/kg (site 3) and below the permissible limit of

WHO (1993) (Table-3). Zinc content of soils in the study sites are in the order S3>S1>S2. Earlier studies (Tripathi and Misra, 2012) in the municipal waste dump site, Allahabad, India supports the current findings that the zinc concentration will be 32.46±1.07mg/kg, 54.98±1.29mg/kg and 108.00±3.26mg/kg for site 1, site 2 and site 3 respectively. Amusan et al (2005) carried out work on the soils in municipal waste dump sites in Nigeria. The results showed that the zinc concentration of soils in waste dump sites are 63.2–102.11μg/g. It has been identified that zinc that is soluble in water which is found in soils can pollute ground water (Morgan et al, 2008).

Cadmium:
Cadmium is one of the ecotoxic metals, with highly undesirable effects on soil health, plant metabolism, humans and animal health (Kabata-Pendias, 2000). In the present study, the highest value of cadmium content in site 3 is 0.5 mg/kg while the lowest value is 0.4 mg/kg in site 1 and above the permissible limit recommended by WHO (1993) (Table-3). At site 2 and control site the cadmium concentrations were not detected. Total concentration of cadmium was <0.1 mg/kg in decomposed municipal solid waste (Tessier et al., 1979). The study conducted in the contaminated soils of municipal waste dump sites reported the cadmium concentration (35.50±0.89mg/kg) were present only in site 1 (Tripathi and Misra, 2012).

Mercury:
At site 2 the concentration of mercury was 0.07 mg/kg and is above the permissible limit by WHO (1993) (Table-3) while 0.1 mg/kg at site 3. At site 1 and control site the Hg concentrations were not detected. Previous study reported that the mercury content of the heavy metal contamination of dumpyard soils was 0.42 mg/kg at Laloor, Thrissur, Kerala (Divya and Sushama, 2017).

Chromium:
Major sources of Cr contamination include releases from electroplating processes and the disposal of Cr containing wastes (Smith et al., 1995).The Chromium content in the soil samples ranged from 3.2 mg/kg (site-2) to 21.7 mg/kg (site 3) during the study period and is above the permissible limit recommended by WHO (1993) (Table-3). Chromium content of soil in the study sites are in the order S3>S1>S2. Previous study reported that the chromium concentration (39.86±3.35mg/kg) were highest at site 1 in contaminated soils of municipal waste dump sites at Allahabad (Tripathi and Misra, 2012). According to Amos-Tautua et al (2014) the mean concentration of chromium in municipal open waste dump site, Yenagoa, Nigeria was 0.05±0.01and 0.06±0.01 mg/kg which is slightly higher when compared with the control (0.005±0.01 mg/kg).The sources of chromium in soil may be due to batteries, discarded plastic materials, empty paint containers and coloured polythene bags.

Lead:
Lead is a naturally occurring, bluish gray metal usually found as a mineral combined with other elements, such as sulphur (ie., PbS, $PbSO_4$), or oxygen ($PbCO_3$), and ranges from 10 to 30 $mgkg^{-1}$ in the earth's crust (USDHHS,1999). Typical mean Pb concentration for surface soils worldwide averages 32 mg/kg and ranges from 10 to 67 mg kg−1 (Pendias and Pendias, 2001). In the present study, the lead content in soil samples of study area varies from 4.7 mg/kg (site 2) to 19.4 mg/kg (site 3) and is below the permissible limit recommended by WHO (1993) (Table-3). Lead concentration of soil in study sites are in the order S3>S1>S2. Previous study reported that the highest lead concentration (108.85±3.99 mg/kg) was reported in site 1 followed by site 2 (86.80±1.63 mg/kg) and site 3 (71.47±3.34 mg/kg) in contaminated soils of municipal waste dump sites at Allahabad (Tripathi and Misra, 2012). It was reported that 82.84 mg/kg in the soils of dumping sites in Laloor, Thrissur, Kerala (Divya and Sushama, 2017). Lead is reported as a hazardous element due to its bioaccumulation potential (Raymond and Felix, 2011).

Table 1:- Physico-chemical properties of soil samples.

Parameters	Site-1	Site-2	Site-3	Site-4
Bulk density(g cm^{-3})	1.08	1.10	1.13	1.11
Organic carbon(%)	5.41	2.35	2.63	3.74
pH	7.0	4.3	7.1	7.8
Electrical conductivity(dSm^{-1})	1.70	0.15	2.25	0.27
Available N (ppm)	5.29	0.93	4.87	3.15
Available P(ppm)	64.50	6.50	30.0	37.0

Available K(ppm)	1570.0	32.0	537.50	392.50
Available Ca(ppm)	5954.0	132.10	2753.0	2118.0
Available Mg(ppm)	179.43	16.60	108.63	198.40
Texture	Sandy clay loam	Clay	Sandy clay loam	Sandy clay loam

S1-Vilappilsala; S2-Brahmapuram; S3-Njeliyanparambu; S4-Control

N:Nitrogen; P:Phosphorus; K:Potassium; Ca:Calcium; Mg:Magnesium

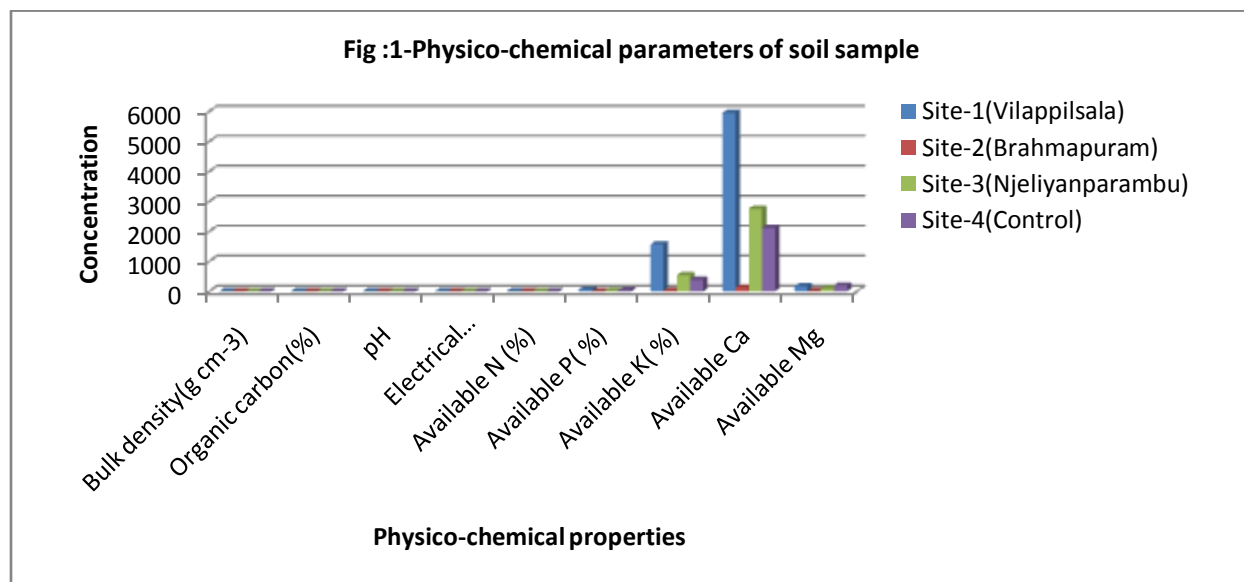**Table 2:-** Total metal concentrations(mg/kg) of selected heavy metals at study sites.

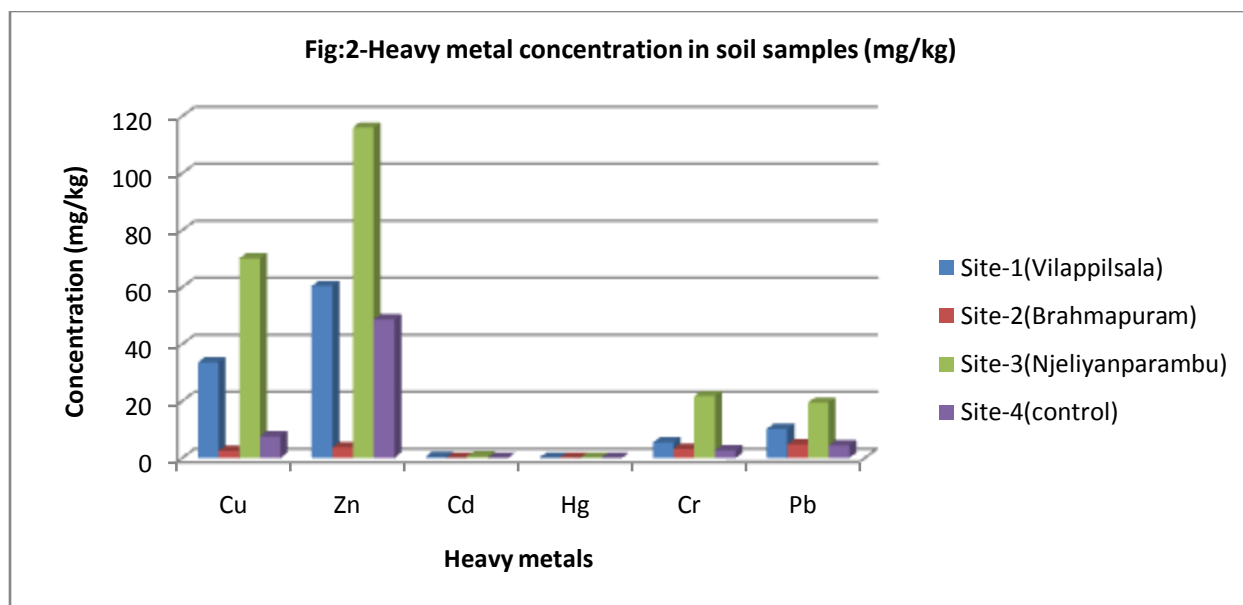| Heavy metals	Site-1	Site-2	Site-3	Site-4
Cu	33.5	2.5	70.1	7.6
Zn	60.3	3.7	116	48.6
Cd	0.4	ND	0.5	ND
Hg	ND	0.07	0.1	ND
Cr	5.4	3.2	21.7	2.6
Pb	10.2	4.7	19.4	4.4

S1-Vilappilsala; S2-Brahmapuram; S3-Njeliyanparambu; S4-Control

mg/kg- Milligram per kilogram; Cu: Copper, Zn: Zinc, Cd: Cadmium, Hg: Mercury, Cr: Chromium, Pb: Lead ;
ND-Not detectable

Table 3:- Permissible limits of heavy metals (WHO).

Heavy metal (mg/kg)	Permissible limit
Copper	150
Zinc	500
Cadmium	0.3
Mercury	0.05
Chromium	0.05
Lead	40

Fig :1-Physico-chemical parameters of soil sample

Fig:2-Heavy metal concentration in soil samples (mg/kg)

Conclusion:-

Dispersal of industrial and urban wastes causes contamination of the soil. It cause serious environmental concern and turns harmful to human beings and other living organisms. So the knowledge of the sources of contaminants is necessary for the selection of suitable remedial measures. Based on the above study, it has been concluded that the following trend of heavy metal in the selected soil samples is Zn>Cu>Pb>Cr>Cd>Hg in the soil samples. Zn was found to be higher than all the other elements. The concentration of heavy metals was found higher in site 3, compared to other sites. The study warrants cost effective remediation techniques to reduce the level of contaminants in the soil.

Acknowledgements:-

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