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Study of Soil Characteristics & Their Influence on Mobility of Copper

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Abstract: *Soil is a major reservoir for contaminants as it possesses an ability to bind various chemicals. Pollution with toxic heavy metals is a serious concern because once these heavy metals enter the soil they can persist for a long time. In present investigation, the basic soil characteristics of three different soil samples are studied to understand the transport of heavy metal Copper through vertical diffusion and their by plotting breakthrough curves at different depths. The results indicate that the diffusion of Copper at different depths of soil columns is time dependent and increases with the depth of soils. The results of the study are highly useful in designing of the abatement techniques adopted for removal of containments or impurities especially focusing on inorganic pollutants, managing effluent disposals producing from industries processing heavy metals, prediction of heavy metal movement in soils and finally their way to groundwater.*

Keywords: *Soil, Heavy metal, Ground water contamination, Mobility of heavy metals, Copper contamination.*

1. Introduction

Heavy metals are naturally occurring & abundantly found elements present in the Earth's crust. They are highly toxic because of the ability to bio-accumulate in the body tissues of living organisms.Thus, these heavy metals find a natural way to enter in the food chain.Heavy metals have unique property to associate with natural occurring substances by chemical bonding or sorbed on the surface of any particular natural substances which may tends to increase or decrease their mobility in the soil strata (Davies, 1991). Thus, the contamination of soil due to inorganic impurities especially due to heavy metals is of great interest as there is high possibility of further contamination of ground water due to the leaching of these heavy metals.

The pollution of soil due to heavy metals contamination is of great interest because these metals finally find a natural way to enter in the food chain and thus, deteriorate not only the soil or ground water quality but also cause adverse effect on the health of living beings which is totally irreversible. There are certain properties associated with these heavy metals as a result of which they are of great concern as they are non biodegradable in nature even after millions of years. Moreover, as already discussed they tends to accumulate in the soft body tissues of living organisms (Phipps, 1981). These heavy metals are already persisting in the soil environment through various non – anthropogenic sources and natural occurring phenomena's. But if the concentration of heavy metals increased beyond the permissible limit, they have lethal effects as they are carcinogenic in nature.

Copper element which is considered in the present study is required for plants, but only in trace concentrations. But if concentration exceeds the permissible limit it becomes toxic. It is generally discharge in the environment by the various electroplating industries, semi – conductor manufacturing units, metal finishing & electroplating industries, textile industry and small scale metal processing industries (Reimers, 1978).

1.1 Chemical contamination: Mobility of heavy metals through soil

Soil is a major sink of pollutants. The various inorganic substances emphasizing only on the heavy metals are of prime concern. Usually it is highly difficult to predict the mobility or transportation of heavy metals through soil strata as they tend to form soluble or insoluble compounds.The downward movement of heavy metals through soil strata is dependent over many factors especially the chemical and engineering properties of the soil like soil pH, texture, fixation behavior of the soil, in situ bulk density, moisture content of soil, dry density, and permability.

Copper form soluble precipitates in the unpolluted soils. As a result of which retention of copper is done, through adsorption mechanisms in which the precipitates can be extracted out by under appropriate conditions. The formation of stable chemical complexes of coppereither with inorganic or organic ligands tends to support the copper mobility respectively in the different soil types (Lorenz, 1999).

1.2 Soil Texture or Soil Particle Size

Soil texture or soil particle size is one of the most governing factor which tends to influence the

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transportation of heavy metals through the soil strata as it has been observed that the type of soils having fine texture are tends to immobilized the heavy metals to larger extent. In addition the fine textured soils have more cation exchange capacity which is a governing factor in heavy metal fixation (Wiklander, 1964).

1.3 Soil pH

Soil pH, also affect the mobility of heavy metals as it determines whether the particular heavy metal tends to oxidize or reduced under the given pH of the soil. pH determination of the soil is useful for study of absorption, precipitation, solubility and stability of the heavy metals in the specific type of soil.But at the same time, it has been found that the redox potential of the soil tends to change under the influence of biological conditions (Harter, 1983).

1.4 Fixation

Metals enterto soil or ground water by any meansundergoes fixation and adsorption processes, which directly affect the mobility of the metals through soil strata. Most of the heavy metals undergo precipitation reactions once form chemical compounds with various organic or inorganic substances found in the soil. This precipitation reaction is determines the chemical fixation capability of the particular heavy metal and thus, determine its behavior (Bowen, 1947).

2. Scope of study

The present study involve the mobility of heavy metal copper is considered under present study through the soil by analyzing the basic engineering properties of the given soil sample and their by establishing breakthrough curves at different depths in the soil. Percolation of Copper solution through soil column for different soils is carried out to plot the breakthrough curves.

2.1 Soil samples

Three soil samples are collected from different sites for the use in the given study. Two of them are collected from the river Patiala Ki Rao which is nearby to the city, Chandigarh. One sample is collected near River Bridge and the other is collected from 500m away from the bridge. The third sample is collected from the PEC University campus whose engineering properties of soil differ greatly from the Patiala Ki Rao river soil. All the three samples were taken from a depth of 2.5 feet. Patiala Ki Rao river flows with polluted water and industrial effluents during dry period. To have a natural unpolluted sample, the soil samples fromPatiala Ki Rao river are collected from the well upstream location of the point of confluence of industrial drains meeting the river.

2.2 Experimental determination of basic Engineering Properties of Soils

Soil properties like in situ bulk density, dry density, moisture content and grain sizedistribution (Cu & Cc) are determined. Permeability of soil samples determined by constant head method.

2.2.1 Experimental Setup of Column to study the mobility of copper solution

This test carried out to study the copper sorption capacity of soil and its mobility through different soils. A column of square cross section (15 x 15 cm) at 135 cm depth made of perplex glass to facilitate visual observations was used in column studies. The column had eight ports at centre to centre spacing of 25cm. At the lower end the column was provided with a valve for regulating the flow through the column. To bring to the natural in situ condition of soil in the local channel, the column was filled up with the soil sample to a depth of approximately 1.0meter at the dry density levels obtained in the lab. The lower valve was opened and submerged under the water in a tank of 0.5m x 0.5m x 0.3m size. For empting the tank an outflow valve was provided. The upper part of column was kept empty to a depth of approximately 15 cm above the soil surface to provide a constant head of water over the soil column.

2.2.2 Experimental Analysis: Copper Diffusion

Copper solution of 10ppm prepared in distilled water using copper sulphate $CuSO_4.6H_2O$. To stimulate the field conditions in industrial drains the soil column is applied with a constant head of 10 cm of copper solution above soil surface in the column. The solution feed into column constantly from the top from a storage tank in such way that the level of solution in the column remains constant. The three different types of samples collected from four sampling ports of the column lying at depth of 16cm, 41cm 66cm and 91cm from the soil surface. The samples from the four ports are collected at different time after the column fed with copper solution above the soil surface.

2.2.3 Breakthrough Curves

The breakthrough curves are plotted between the concentration ratio C/Co and time from the instant the solution fed into the column. For the plot of breakthrough curve breakthrough time $T_{1/2}$ is determined. $T_{1/2}$ is the time when the concentration ratio of 0.5 is attained in the outflow solution at any depth of soil strata in the column.

Table 1: *Uniformity Coefficient (C_u) and Coefficient of curvature (C_c) for three types of soils*

S. No.	Properties	Soil sample 1	Soil sample 2	Soil sample 3
1	D_{60}	150 μm	300 μm	150 μm
2	D_{30}	90 μm	180 μm	20 μm
3	D_{10}	70 μm	95 μm	5 μm
4	C_u	2.14	3.15	30
5	C_c	0.77	1.13	.53

The above results of sieve analysis show that soil sample 1 and 2 are poorly graded sandy soils (SP). The uniformity coefficient for both the samples being less than 6 further classifies them poorly graded. Hence, according to Indian Standard Classification of Soils the soil sample 1 and 2 are classified as SP (poorly graded sand).The soil sample 3 is a mixture of fine grained sand and silt. This type of soil in Indian Standard Classification is classified as silty sand. The value of uniformity coefficient for this soil being less than 6 further classifies this soil as poorly graded. This soil hence classified as SM.

2.2.4 In Situ Bulk Density, Moisture Content and Dry Density

The field in situ bulk density (γ_t) determined for all the three samples and found to be 1.48 gm/cm^3, 1.56 gm/cm^3 and 1.73 gm/cm^3. The moisture content determined by Oven Dry Method for all the three samples are found to be 1.2%, 2.1% and 6.8% respectively. The dry density (γ_d) for all three soil samples calculated to be 1.46 gm/cm^3, 1.52 gm/cm^{3}and1.62 gm/cm^{3}respectively.

The coefficient of permeability (K) for the different soil types are found to be 0.0011cm/sec, 0.0031cm/sec and 1.1 x 10 $^{-8}$cm/sec respectively which classifies that the soil sample 1 & 2 are pervious and soil sample 3 as semi – pervious.

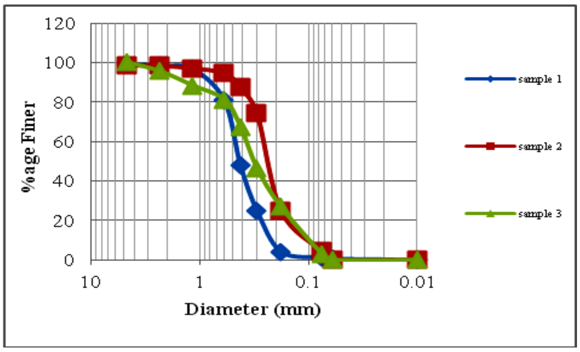

Figure 1: *Particle Size Distribution Curve for all the three Samples (soil sample1, soil sample 2 and soil sample 3)*

2.3 Mobility of Copper: Breakthrough Curves for Soil Samples

In order to plot breakthrough curves, initially 10mg/l of copper sulphate solution($CuSO_4$) is fed in the column to generate the natural conditions. Thus, the curves are plotted for residual concentration with respect to time at four different depths of 16 cm, 41 cm, 66 cm and 91 cm in the column test for soil sample 1, 2 & 3 respectively and are shown in figures 2, 3 and 4 respectively.

2.3.1 Breakthrough Curve for the Soil Sample 1

From the **Figure 2** the breakthrough time for the corresponding depths are found as below:
T $_{½}$ for the depth of 16 cm = 24 hrs
T $_{½}$ for the depth of 41 cm = 42 hrs
T $_{½}$ for the depth of 66 cm = 56 hrs
T $_{½}$ for the depth of 91 cm = 72 hrs

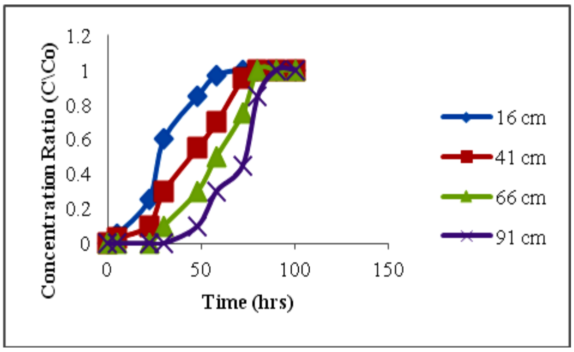

Figure 2: *Breakthrough curves at different depths of Soil sample 1*

2.3.2 Breakthrough Curve for the Soil Sample 2

From the Figure 3 the breakthrough time for the corresponding depths are found as below:
T $_{½}$ for the depth of 16 cm = 36 hrs
T $_{½}$ for the depth of 41 cm = 46 hrs
T $_{½}$ for the depth of 66 cm = 54 hrs
T $_{½}$ for the depth of 91 cm = 72 hrs

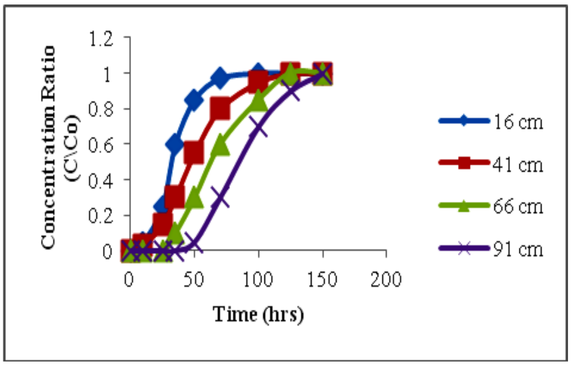

Figure 3: *Breakthrough curves at different depths of Soil sample 2*

2.3.3 Breakthrough Curve for the Soil Sample 3

From the **Figure 4** the breakthrough times for the corresponding depths are found as below:
T $_{½}$ for the depth of 16 cm = 7 days
T $_{½}$ for the depth of 41 cm = 9 days
T $_{½}$ for the depth of 66 cm = 12.5 days
T $_{½}$ for the depth of 91 cm = 17.5 days

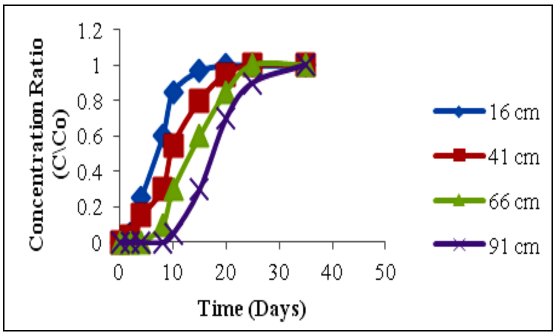

Figure 4: *Breakthrough curves at different depths of Soil sample 3*

3. Results and Discussion

Breakthrough curves obtained for outflow concentration of Copper at different depths of the soils follow the standard 'S' pattern which can be utilized for calculation of T ½ . This value plays an important role while designing the columns to remove the impurities and contaminants of heavy metals through the process of adsorption. Thus, calculation of T ½ value is essential to study the metal diffusion among the soils covering the other conditions also. T ½ values for different soils at different depths are shown in Table 2.

***Table 2:** $T_{1/2}$ of all the soil samples*

Type of soil	Depths in the column	T ½ Values
Sample 1	16cm, 41 cm, 66 cm, 91 cm	24 hrs, 42 hrs, 56 hrs, 72 hrs
Sample 2	16cm, 41 cm, 66 cm, 91 cm	36 hrs, 46 hrs, 54 hrs, 72hrs
Sample 3	16cm, 41 cm, 66 cm, 91 cm	7 days, 9 days, 12.5 days, 17.5 days

The saturation equilibrium of Copper at different depths of soil columns is time dependent and increases with the depth of soils. The time taken for the Copper solution to reach the saturation equilibrium is comparatively more in upper 16 cm depths, which indicates that copper retained in higher concentration in the top soils. The lower depths require comparatively lesser time to attain the saturation.

The time requires for the full saturation for Copper at different depths differ from one soil type to another. This is minimum in case of soil type 1, which is poorly graded sand with high coefficient of permeability and the saturation time is maximum for soil type 3 which is silty sand with finer grain size and is semi pervious with a low numerical value of coefficient of permeability in both elements study. Permeability is the most important factor which affects the percolation of water through the soils as well as the mobility of heavy metals through them. Mobility of copper in soils also affected by dry density and hence, in situ conditions of the soil.

4. Conclusions

The present study reveals that there has been safe and proper disposal of heavy metals so as they do not contaminate the environment as a whole. There has been implementation of the appropriate techniques to the industrial wastewater; contaminated sludge etc. for completes removal of the heavy metals before they are to be disposed off in the open environment.

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