

# Physical and Numerical Modeling of One Dimensional Contaminant flow Considering Sorption

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**Abstract—** This paper consists of two parts. One is experimental study and second numerical modeling. Using one dimensional flow equation by taking a soil column using continuous contaminant source. The physical modeling is used to study the adsorption characteristics of the column and retardation of flow. Second part of the thesis consists of the numerical modeling using classical advective – dispersive contaminant transport equation considering sorption. Based on the results of the physical modeling it is observed that there is continuous variation of the contaminant flow velocity ( $V_c$ ) varies with time. Therefore the retardation factor ( $R$ ) varies with time. So generally the value of  $R$  is calculated by taking the ratio of velocity of flow ( $V_x$ ) to the contaminant flow velocity ( $V_c$ ). The contaminant flow velocity is the ratio of height of the sample to the time required for relative concentration  $C/C_0$  of 0.5. The main aim of the project is to study the sorption effect of the soil using different admixtures, in order to control the flow of the contaminant at deeper depths. Column tests are conducted on soil mixed with various additives individually. Various concentrations of contaminants are added to tap water, by using Water Analyzer (Systronics 371), their conductivity is measured. A standard conductivity (mS) Vs concentration (mg/L) graph has been made. Sorption of contaminant, retardation factors and partition coefficients has been estimated. From partition coefficient values the amount of additives required to reach attenuation state is obtained. By this, we can suggest contaminant for Cr(VI) contaminated site to effectively minimize the movement of contaminant. The adsorption potential of the soil mixed with different additives in various percentages for removal of Hexavalent Chromium was also studied from column tests on soils mixed with the admixtures. Based on the observations of the test data i.e., variation of the velocity of the contaminant flow with time, numerical model (Nirmala Peter, 2008) using classical advection dispersion equation with sorption is checked by inputting different retardation factors instead of a single retardation factor obtained from time required for a relative concentration of  $C/C_0$  equal to 0.5. This resulted in numerical curves fitting well with the experimental data.

**Keywords:** Sorption, Heavy metals, Soil analysis and Numerical modeling

## I. INTRODUCTION

Chromium (Cr) is one of the world's most strategic and critical materials having a wide range of uses in the metals and chemical industries Cr alloys enhance metal resistance to impact, corrosion, and oxidation. Chromium is used in stainless steel and non-iron alloy production for plating metals, development of pigments, leather processing, and production of catalysts, surface treatments, and in refractories. Chromium occurs in various oxidation states, of which chromium (VI) [Cr (VI)] is a suspected carcinogen and a potential soil, surface water, and groundwater contaminant. Cr (VI) may also occur in the natural environment, but human-caused Cr (VI) contamination has recently been the focus of much scientific discussion.

Hexavalent chromium (chromium VI) refers to chemical compounds that contain the element chromium in the +6 oxidation state. Virtually all chromium ore is processed via hexavalent chromium, specifically the salt, sodium dichromate. Approximately 136,000,000 kilograms of hexavalent chromium were produced in 1985. Other hexavalent chromium compounds are chromium trioxide and various salts of chromate and dichromate. Hexavalent chromium is used for the production of stainless steel, textile dyes, wood preservation, leather tanning, and as anti-corrosion and conversion coatings as well as a variety of niche uses. A chromium hexavalent (Cr VI) compound, often called hexavalent chromium, exists in several forms. Industrial uses of hexavalent chromium compounds include chromate pigments in dyes, paints, inks, and plastics; chromates added as anticorrosive agents to paints, primers, and other surface coatings; and chromic acid electroplated onto metal parts to provide a decorative or protective coating. Hexavalent chromium can also be formed when performing "hot work" such as welding on stainless steel or melting chromium metal. In these situations the chromium is not originally hexavalent, but the high temperatures involved in the process result in oxidation that converts the chromium to a hexavalent state.

## II. MATERIALS AND METHODS

The study was carried out on two different soils, S1 i.e., Red Soil (SC) and S2 Clay mixed with red soil in equal

proportions (CI) (the index properties of soil are presented in Table I).

TABLE I. INDEX PROPERTIES OF SOIL

S.No	Property of soil	S1(Only red soil)	S2(Red soil + clay)
1	Grain size distribution		
	Gravel (%)	4	3
	Coarse sand (%)	12	8
	Medium sand (%)	37	23
	Fine sand (%)	15	12
2	Silt & clay (%)	32	54
	IS classification	SC	CI
3	Atterberg's limits		
	Liquid limit (%)	35	46
	Plastic limit (%)	18	22
	Plasticity index (%)	17	24
4	Specific gravity	2.68	2.69

### III. EXPERIMENTAL PROCEDURE FOR COLUMN TESTS

The test is conducted to find sorption, retardation factor (R) and distribution coefficient ( $K_d$ ) of the soil sample. The below procedure is followed for a single column test and the same procedure is continued for the remaining column tests. The column test program is shown in Table II.

TABLE II COLUMN TEST PROGRAM

S.No	Test name	Additives added	Initial concentration of the contaminant (mg/L)
1	Column test - 1	S1 soil	1700
2	Column test - 2	S2 soil	800
3	Column test - 3	S2 soil	4200

#### A. Preparation of Soil Sample

An air dried soil sample is selected and weighed around 1000gm. A permeability mould with dimensions of diameter 10cm and height 12.7cm in which soil is compacted. Soil sample (Clayey sand) for the test is prepared by gentle compaction, by adding moisture content of 8% with respect to the weight of the soil, in three layers by taking the distance between consecutive layers to form one single soil specimen. During the preparation of soil specimen, the quantity of soil required for one layer is based on a pre-assigned value of bulk density i.e., assuming a bulk density value for a specified height and diameter of the column is weighed out for preparing each layer of the soil specimen. The layer is compacted by giving 15-20 blows with standard rammer weight of 2.5kg.

Compact the soil in layers up to the required height in the mould, by using scale top clearance of the mould is measured, the average bulk density and dry density of the soil specimen is calculated.

#### B. Saturation of the Soil Specimen

The compacted soil specimen is saturated by connecting a stand pipe of diameter 2cm, containing water to the opening, which is connected to the top of the mould through a flexible pipe. Keeping the mould tap closed, water is allowed to enter the mould from the top surface of the soil specimen. The entrapped air is gradually removed through the second opening provided to the mould. The air in the pores of the soil specimen will be gradually replaced by water. Open the tap at the bottom and allow the water to flow out for a few seconds to obtain a steady state of flow. When the quantity of inflow into the mould and the quantity of outflow from the base of the mould are equal, completion of saturation for the soil specimen is ensured.

#### C. Measurement of Permeability

A constant outflow is maintained at regular intervals of time, to determine the hydraulic conductivity of the soil specimen by constant head method. By maintaining the water level constant in pipe the water is collected at bottom of the mould, the quantity of water collected to the concern time is noted. Initially the tap is open fully to evaluate the permeability of the soil. A clamp is used to adjust the required velocity of flow, by which the permeability is also adjusted. From this permeability value adjusted velocity of flow (cm/s) is obtained.

#### D. Preparation of Contaminant Solution

Hexavalent chromium is weighed around 85gms (for column test 1), shifted to measuring jar and made it to dissolve completely. The tap water is measured in a tank around 50 litres and the solution which is prepared in the measuring jar is thoroughly mixed with the water in the tank to prepare the contaminant solution. Similar procedure is followed based on concentration of the contaminant for remaining tests.

#### E. Preparation of Conductivity Vs Concentration Graph

This graph is used to find the concentrations of solution (mg/L) to the obtained conductivity values from Table III. Initially hexavalent chromium of 5656mg is dissolved in one litre of tap water and its conductivity is measured, similarly the procedure is continued by dissolving various quantity of hexavalent chromium in one litre water. The graph is plotted by taking Conductivity (mS) on X-axis and Concentration (mg/L) on Y-axis shown in Fig.1. The values of conductivity are measured in milli Siemens (mS).

TABLE III. CONDUCTIVITY (mS) Vs CONCENTRATION (mg/L)

Conductivity (mS)	Concentration (mg/L)
5.93	5656
4.54	3535
3.3	2828
2.18	1414
1.59	707
1.05	353
0.93	176.5
0.91	88.25
0.84	44.125
0.75	22.06
0.71	11.03
0.123	0

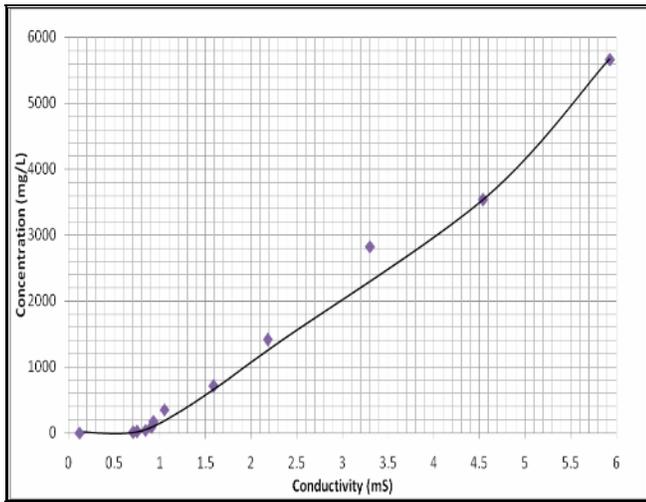


Fig 1: Conductivity (mS) Vs Concentration (mg/L) graph

**F. Introduction of the Contaminant and Collection of Representative Contaminant Samples**

A tank of Size 30 X 30 X 55cm of 50 liters capacity is used to contain the contaminant. At bottom of tank a small outlet is provided which is connected to permeability mould through a flexible pipe of diameter 10mm. The tank is placed at a height of 186cm from permeability mould. In set-up, before introducing the contaminant into the soil column, the tap at the base of the column was closed, and the connecting pipe from the overhead tank to the column was disconnected to drain put water from the tank. The water column above the surface of the soil column was also removed. The prepared contaminant with an initial concentration,  $C_0$ , is poured in the overhead tank which is connected to the permeability mould. Simultaneously open the tap at the base to allow free flow of the contaminant through the soil specimen. The tap is open throughout the period of experimentation. The contaminant samples at regular intervals are collect by opening the tap provided above the base of the mould. The tap is opened simultaneously to facilitate collection of 5-10 ml of the contaminant each time. The chemical concentrations of the samples are obtained from time to time, till the concentration

of the contaminant sample collected from the base tap is almost equal to, or a minimum of 0.84 times the initial concentration ( $C_0$ ). Determine the chemical concentration,  $C$ , of the samples from time to time, by the conductivity of the collected samples. Continue this procedure till the concentration of the contaminant collected from the base is almost equal to the initial concentration,  $C_0$ , or at least 0.84 times the initial concentration. The schematic view of the setup is shown in Fig.2.

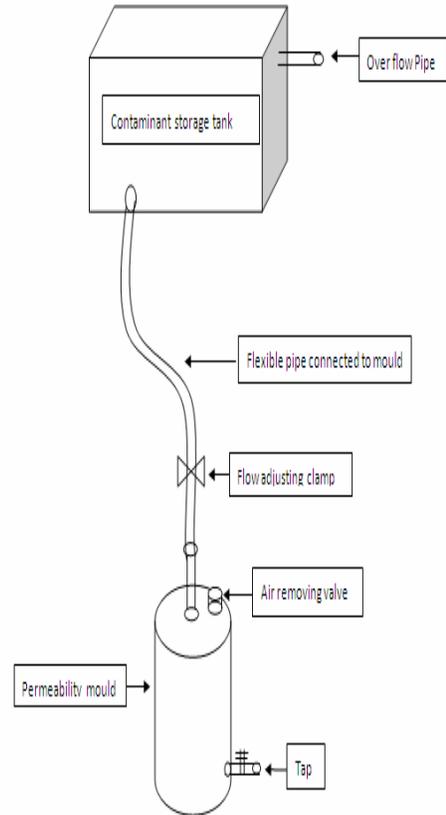


Fig 2: Schematic view of column test setup

**G. Determination of Contaminant Concentrations by WATER ANALYSER 371**

The sample (5-10ml) is collected from mould in a small jar an electrode is placed in the solution and conductivity is measured.

SYSTRONICS WATER ANALYSER 371 is a micro controller based instrument for measuring  $p^H$ , mV, Dissolved Oxygen (D.O.), Salinity, Conductivity, TDS, Temperature, Colorimetric and Turbidity in water sample one at a time. The WATER ANALYSER 371 provides both automatic and manual temperature compensation. Fig.3 shows the clear view of the equipment.



Fig 3: Systronics water analyser 371

IV. NUMERICAL MODELING

The modeling process involves the translation of conceptual model in to mathematical terms by a set of partial differential equations with an associated set of auxiliary boundary conditions.

Based on the assumptions made in the conceptual model, the governing equations are as follows:

A. Convective – Advective Equation (CDE) for reactive contaminant

$$D_x \frac{\partial^2 C}{\partial x^2} - v_x \frac{\partial C}{\partial x} = R \frac{\partial C}{\partial t} \tag{1}$$

$$\frac{D_x \partial^2 C}{R \partial x^2} - \frac{v_x \partial C}{R \partial x} = \frac{\partial C}{\partial t} \tag{2}$$

Where  $D_x$  = Hydrodynamic dispersion co-efficient,  
 $V_x$  = Velocity of contaminant through the porous medium and  
 $R$  = Retardation Coefficient or factor.

B. The initial and final boundary conditions are

$$C(x, 0) = 0 \text{ at } t=0$$

$$C(0, t) = C_0 \text{ for } t > 0$$

$$C(L_1, t) = C(L, t) \quad L_1 > L$$

Where  $L$  is the total depth or thickness of the stratum.

Normalizing equation (2) with  $X = x/L$ ,  $T = t/t_0$  and  $t_0 = L/V_x$

$$\partial X = \frac{1}{L} \partial x, \quad \partial T = \frac{1}{t_0} \partial t$$

$$\partial^2 X = (1/L^2) \partial^2 x, \quad \partial t = t_0 \partial T$$

$$\partial x^2 = (L^2) \partial^2 X, \quad \partial t = t_0 \Delta t$$

Substituting  $X$  and  $T$  in the equation 2, the equation reduces to following equation 3

$$\frac{D_x}{R} \frac{1}{L^2} \frac{\partial^2 C}{\partial X^2} - \frac{v_x}{R} \frac{1}{L} \frac{\partial C}{\partial X} = \frac{\partial C}{t_0 \partial T} \tag{3}$$

C. Finite difference method of solution to the governing equation

The finite difference method is the most popular method for solving problems of ground water flow and transport. The partial differential equations describing the flow and transport process include terms representing derivatives of continuous variables. These derivatives are approximated by discrete linear changes over small discrete intervals of space or time. If the intervals are sufficiently small, then all the linear increments will represents a good approximation of the true curvilinear surface. In the present work the problem described in Fig 4 was stimulated in a soil column with one-dimensional flow and dispersion. The total length of the column is divided in to a number of segments, each represented by its coordinates as  $(i-1, t)$  to  $(i+n, t)$  at any time period. The nodes are located at the centre of each segment. An equation is written for each nodal point. The goal of modeling is to predict the value of the unknown variable, here the concentration of the contaminant at the nodal points. Finite difference method approximates the first derivatives in the partial differential equations as difference quotients, that is, the differences between values of variables at adjacent nodes. In the present case, the variable is concentration of concentration;  $\partial C/\partial x$  at a point midway between the nodes under consideration is given by,

$$\frac{\partial C}{\partial x} = \frac{(C_{i+1,t} - C_{i-1,t})}{2 \Delta x} \tag{4}$$

Similarly a reasonable approximation for the second derivative is given by

$$\frac{\partial^2 C}{\partial x^2} = \frac{(C_{i+1,t} - 2.C_{i,t} + C_{i-1,t})}{(\Delta x)^2} \tag{5}$$

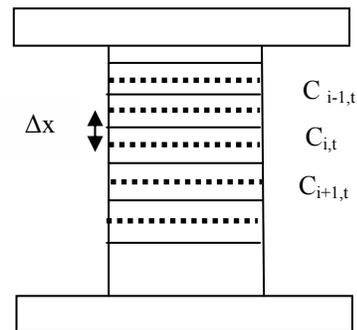


Fig 4: Elements for finite difference Analysis

Substituting equations (4), (5) in equation (3) the governing equation transforms

$$\frac{D_x}{L^2.R} \left[ \frac{C_{i+1,t} - 2C_{i,t} + C_{i-1,t}}{(\Delta X)^2} \right] - \frac{v_x}{R.L} \left[ \frac{C_{i+1,t} - C_{i-1,t}}{2\Delta X} \right] = \frac{[C_{i,t+\Delta t} - C_{i,t}]}{t_0 \Delta T}$$

$$\frac{D_x^* \Delta t}{v_x \cdot L \cdot R (\Delta X)^2} [C_{i+1,t} - 2C_{i,t} + C_{i-1,t}] - \frac{\Delta T}{2 \cdot \Delta X \cdot R} [C_{i+1,t} - C_{i-1,t}] = C_{i,t+\Delta t} - C_{i,t}$$

$$\mu_x = \frac{D_x^* \Delta t}{v_x \cdot L \cdot R \cdot (\Delta X)^2}, \beta_x = \frac{\Delta T}{2R \cdot \Delta X}$$

$$\mu_x [C_{i+1,t} - 2C_{i,t} + C_{i-1,t}] - \beta_x [C_{i+1,t} - C_{i-1,t}] = C_{i,t+\Delta t} - C_{i,t}$$

$$C_{i,t+\Delta t} = C_{i+1,t}[\mu_x - \beta_x] + C_{i-1,t}[\mu_x + \beta_x] + [1 - 2\mu_x]C_{i,t} \quad (6)$$

In this numerical modeling the value of  $\mu_x$ ,  $\beta_x$  are inputted by taking constant dispersion coefficient ( $D_x$ ) and velocity of flow of water and choosing appropriate  $\Delta x$  and  $\Delta t$  values in such a way that the model is stable. However different values of  $R$  with  $C/C_0$  and  $T$  are inputted for the model. Finally the breakthrough curves were compared as laboratory data with numerical curves shown in figure (5) (6) (7) by taking the different retardation factor values  $R$  for column test 1, 2 and 3 respectively.

The hydrodynamic dispersion coefficient that represents both dispersion and diffusion is generally represented as follows

$$D_x = \alpha \cdot v + D_d^*$$

Where  $D_x$  = Longitudinal dispersion coefficient  
 $\alpha$  = Dispersivity = 0.1 L.  
 $L$  = Length of the sample.  
 $v$  = Seepage velocity.

$D_d^*$  = Flow velocity through the porous media ( $3 \times 10^{-6} \text{ cm}^2/\text{s}$ ).

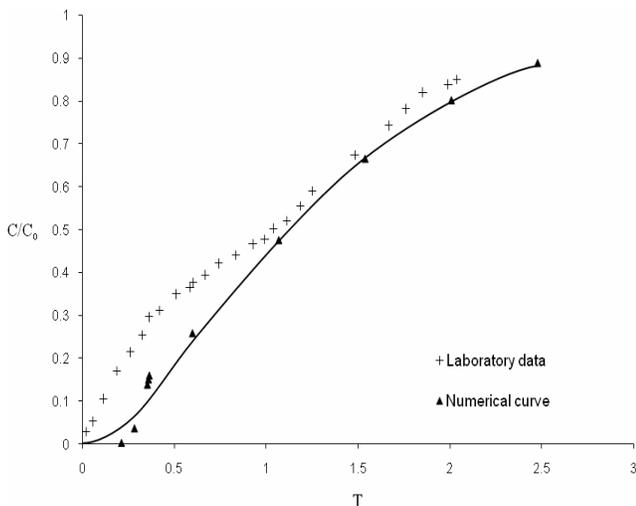


Fig 5 Relative concentration  $C/C_0$  with Normalized time (T) for laboratory and Numerical approaches for column test 1

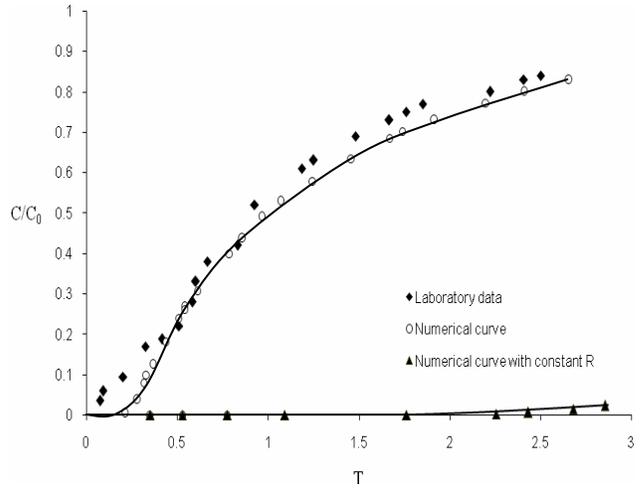


Fig 6 Relative concentration  $C/C_0$  with Normalized time (T) for laboratory and Numerical curve for column test 2

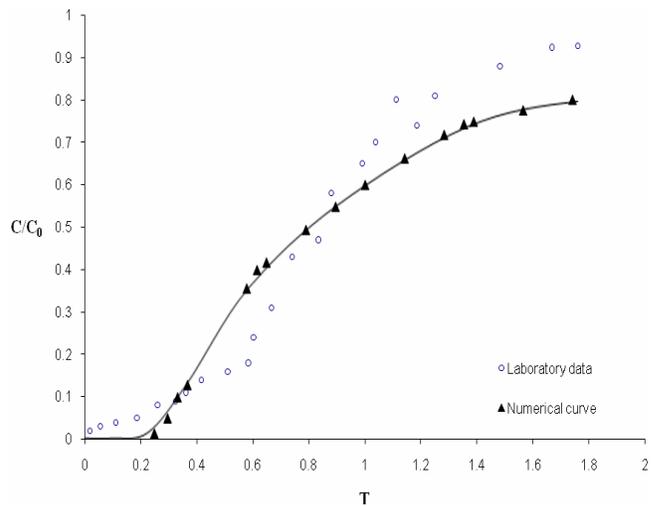


Fig 7 Relative concentration  $C/C_0$  with Normalized time (T) for laboratory data and Numerical curve for column test 3.

## V. CONCLUSIONS

The numerical curves fitted well with experimental data when retardation factors used are based on the variation of  $R$  with  $T$  and  $C/C_0$  rather than taking a single  $R$  value corresponding to  $t_{0.5}$  for the case where the concentration of the contaminant was low. However in case of high concentration the numerical curve deviated from the experimental data beyond a relative concentration  $C/C_0$  of 0.7. The contaminant flow velocity ( $V_0$ ) is related to relative concentration ( $C/C_0$ ) through power law variation, and that of retardation factor with relative concentration ( $C/C_0$ ) through polynomial variation. The contaminant flow velocity ( $V_0$ ) varies with normalized time ( $T$ ) through power law variation. The retardation factors vary linearly with normalized time ( $T$ ).

#### ACKNOWLEDGMENT

The authors express their gratitude to Mr Nagabhushanam and Mr Mallesh for their assistance during the experimental work in the laboratory. This work is a part of the Master of Technology program for the award of M.Tech (Geo-environmental Engineering) degree to first author.

#### REFERENCES

- [1] E C Nirmala peter (2008) “Physical and Numerical Modelling of One dimensional Contaminant transport with Scale - dependent Dispersion”.
- [2] A Lj Bojic, M Purenovic and D Bojic “Removal of chromium (VI) from water by micro-alloyed aluminium composite (MAIC) under flow conditions”. ISSN 0378-4738 = Water SA Vol. 30 No. 3 July 2004.
- [3] A.R. Rahmani, M.T. Samadi, R. Noroozi “Hexavalent Chromium Removal from Aqueous Solutions by Adsorption onto Synthetic Nano Size ZeroValent Iron (nZVI). Published in World Academy of Science, Engineering and Technology 74 2011.
- [4] Alaerts GI, Jitjarurunt V, Kelderman P. Use of coconut shell based activated carbon for chromium (VI) removal of Water. Sci. Technol. (1989) 21:171-179.
- [5] Ajamal, H., A. Mohammad and S. Anwar, Sorption studies of heavy metals on teak leaves using thin layer and column chromatographic technique. Pollution Research, 2001 20(3): 425-428.
- [6] Arun kumar Lagashetty and A Venkataraman Appa “Adsorption study of Pb<sub>2+</sub> Ions on Nanosized SnO<sub>2</sub>, Synthesized by self-propagating Combustion Reaction”. Bull. Master.Sci., Vol.27 No.6, December 2004, pp.491-495.
- [7] Baral, S. S.; Dasa, S. N.; Rath, P., Hexavalent chromium removal from aqueous solution by adsorption on treated sawdust., Biochem. Eng. J., (2006) 31 (3), 216–222.
- [8] Bishnoi, N. R.; Bajaj, M.; Sharma, N.; Gupta, A., Adsorption of Cr (VI) on activated rice husk carbon and activated alumina., Bioresource Technol., (2004). 91 (3), 305–307.
- [9] Balkaya N, Bektas T Chromium (VI) sorption from dilute aqueous solutions using wool. Desalination and water treatment. (2009). 3:43-52.
- [10] D. Kaplan and T. Gilmore, Zero-Valent Iron Removal Rates of Aqueous Cr (VI) Measured Under Flow Conditions. Water, Air, & Soil Pollution, 155, 2004, pp. 21-33.
- [11] Dinesh Mohan, Charles U. Pittman Jr. “Activated carbons and low cost adsorbents for remediation of tri- and Hexavalent chromium from water”. Published in Journal of Hazardous Materials B137 (2006) 762–811.
- [12] Hausman M R (1990) Mc grawhill Book Co; “Engineering Principles of Ground modification”.
- [13] Hari D. Sharma, Krishna R Reddy: Geo environmental Engineering site Remediation, Waste Contaminant, and Engineering Waste Management Technologies”, JOHN WILEY & SONS, INC.2004.
- [14] K. Selvi, S. Pattabhi and K. Kadirvelu, Removal of Cr (VI) from aqueous solution by adsorption onto activated carbon. Kidlington, ROYAUMEUNI: Elsevier 2001.
- [15] Kerry Rowe. R. Queens University, Kingston, Ontario, CANADA “Geotechnical and Geo Environmental Engineering Hand Book”. Kluwer Academic publishers Boston. 2001, pp.3 & 69-104.
- [16] M. Nameni; M. R. Alavi Moghadam; M. Arami “Adsorption of Hexavalent chromium from aqueous solutions by wheat bran”. Published in Int. J. Environ. Sci. Tech., 5 (2), 161-168, spring 2008.
- [17] M. Kobya, Removal of Cr (VI) from aqueous solutions by adsorption onto hazelnut shell activated carbon: kinetic and equilibrium studies. Bioresource Technology, 91, 2004, pp. 317-321.
- [18] Montanher SF, Olivira EA, Rollemberg MC Removal of metal ions from aqueous solutions by sorption onto rice bran, J. Hazard. Mater. (2005). 117: 207-211.

- [19] N. Ahalya, R.D. Kanamadi, and T.V. Ramachandra “Removal of hexavalent chromium using coffee husk”. Published in Int. J. Environment and Pollution, Vol. X, No. Y, XXXX.
- [20] N. Shao-feng, L.Yong, X. Xin-hua, and L. Zhang-hua, Removal of Hexavalent chromium from aqueous solution by iron Nanoparticle, Journal of Zhejiang University Science-B, 6(10), 2005, pp. 1022-1027.
- [21] Philip B. Bradient. Hanadi S. Rifai. Charles J. Newell. “Ground Water Contamination Transport and Remediation”. PTR Prentice Hall, Englewood Cliffs, New Jersey, 1994, pp119-151 & 228 -332.
- [22] Sarwoko Mangkoedihardjo, Rhenny Ratnawati and Neni Alfianti “Phytoremediation of Hexavalent Chromium Polluted Soil Using *Pterocarpus indicus* and *Jatropha curcas* L”. Published in World Applied Sciences Journal 4 (3): 338-342, 2008.
- [23] S. Tangjuank, N. Insuk, V. Udeye and J. Tontrakoon “Chromium (III) sorption from aqueous solutions using activated carbon prepared from cashew nut shells”. Published in International Journal of Physical Sciences Vol. 4 (8), pp. 412-417, August, 2009.
- [24] S. Gupta and B. V. Babu, “Removal of toxic metal Cr (VI) from aqueous solutions using sawdust as adsorbent: Equilibrium, kinetics and regeneration studies”. Chemical Engineering Journal, 150, 2009, pp. 352- 365.
- [25] Singanan, M., Abebaw, A. and V. Singanan, Studies on the removal of Hexavalent chromium from industrial wastewater by using biomaterials. Electronic Journal of Environmental, Agricultural and Food Chemistry, 2007, 6(11): 2557-2564.
- [26] Shiny, K.J., K.N. Remani, T.K. Jalaja and V.K.Sasidharan, Removal of chromium by two aquatic pteridophytes. Indian Journal of Environmental Health 2004, 46: 249-251.
- [27] Zahir Rawajfih and Najwa Nsour “Effect of organic and inorganic amendments on sorption of Cr (VI) and Cr (III) in soil”. © 2010 19<sup>th</sup> World Congress of Soil Science, Soil Solutions for a Changing World 1 – 6 August 2010, Brisbane, Australia.
- [28] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
- [29] I. S. Jacobs and C. P. Bean, “Fine particles, thin films and exchange anisotropy,” in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
- [30] K. Elissa, “Title of paper if known,” unpublished.
- [31] R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.
- [32] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, “Electron spectroscopy studies on magneto-optical media and plastic substrate interface,” IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetism Japan, p. 301, 1982].
- [33] M.Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

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