EFFECTIVENESS OF FILTRATION IN CADMIUM REMOVAL IN A LOW COST DOMESTIC WATER PURIFICATION SYSTEM

S. D. Jayasena[1], Y.U.A. Bandara[1], W.D.C.R. Wanniarachchi[1], S.K. Gunawardana[1], W.R.P.I. Weerakkody[1], U.D.N.N. Udawattha[1], R. Mallawaarachchi[2], N. P. Miguntanna[2], J.Meegoda[3]

[1]Undergraduate student, Department of Civil and Infrastructure, Faculty of Engineering, South Asian Institute of Technology and Medicine (SAITM), Sri Lanka. Email: sanishka94@gmail.com
[2]Senior Lecturer, Department of Civil and Infrastructure, Faculty of Engineering, South Asian Institute of Technology and Medicine (SAITM), Sri Lanka.
[3]Professor in Civil Engineering and Director of Geotechnical Testing Lab, Department of Civil and Environmental Engineering, New Jersey Institute of Technology, Newark, United States of America

ABSTRACT

Chronic Kidney Disease due to unknown etiology (CKDu) has become a major health problem in rural Sri Lanka. Previously confined to North Central and Uva provinces, it is now prevalent in the Northwestern, Eastern, Southern and Central provinces, and parts of the Northern provinces. It was recognized that the main cause for CKDu is the accelerated amounts of Cadmium Cd^{2+} ions dissolved in water consumed by the population of these areas. The objective of this research is to investigate the effectiveness of a low cost filtration techniques in Cadmium removal and identify the optimum layer configuration of different filter materials such as Kaolinite and Bentonite in the removal process.

Keywords: Chronic Kedeny Disease, Cd Removal, Filtration

1. INTRODUCTION

Chronic Kidney Disease (CKD) has become a major public health problem in Sri Lanka at the moment and also in several other countries in the world. CKD is defined as kidney damage evidence by structural or functional abnormalities of the kidney with or without decreased Glomerular filtration rate (GFR) over a three months period. CKD is graded from 1 to 5 according to severity, based on National Kidney Disease Outcomes Quality Initiative (KDOQI) criteria.

The high cost involved in the management of end stage renal failure has led to a substantial burden on global health-care resources [1]. The management of disease is even more difficult in developing countries due to lack of resources and financial restrictions.

The mortality and morbidity due to CKD is increasing in Sri Lanka and this burden is even more pronounced in the North Central Province (NCP) of the country. A considerable number of CKDu patients have also been reported from Badulla and Kurunegala districts alarming the need of identifying correct etiology and important of effective and efficient remedial measures. The number of CKD patients in registries from MOH offices in CKDu endemic areas by 2010 is 20336. Now this number is likely to be around 25000 [2].

The NCP where the major burden of CKD is seen extends over 10530 km^2 in the dry zone of the country and the majority of people live in the region depend on farming for their livelihood. The disease mainly affects males from poor socio-economic backgrounds who are involved in paddy farming [1].

Recent studies have shown that elevated levels of Cadmium in water is a major reason for CKDu. Areas which where CKDu were mostly recorded, were the areas where Cadmium was present in dangerously high percentages in water [3].

Cadmium is a transition metal with an oxidation number of +2. It naturally occurs with zinc and lead in sulfide ores. Cadmium concentrations in unpolluted natural waters are usually below 1 µg/l [4]. A major source of Cadmium enters into water is the fertilizers. Furthermore, Cadmium tends to dissolve a lot efficiently in acidic waters.

This research project has been designed to investigate the effectiveness of a low cost filtration technique in Cadmium removal and identify the optimum layer configuration of different filter materials such as Kaolinite and Bentonite in the removal process.

2. METHODOLOGY

The research methodology primarily comprises of three stages. Firstly, the filter arrangement was

designed and fabricated. Secondly, Cd^{2+} solutions were prepared in various concentrations which simulate the levels of concentration of Cd^{2+} in water. Thirdly, testing of filtrate of the solution passing through the various layer configurations of different filter materials was started.

2.1 Design and fabrication of filter

The filter arrangement was directly based on the existing NJIT low cost filter arrangement model shown in Figure 1. However, few modifications were done according to the local conditions and availability of the materials.

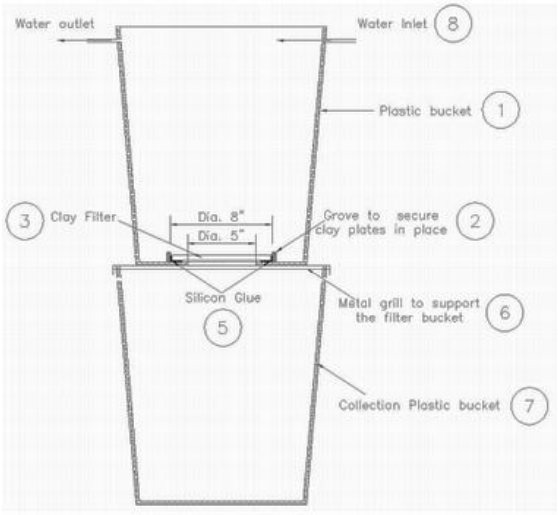

Figure 1: NJIT filter arrangement

Figure 1 shows the schematic diagram of the filter. The top of the filter, or the part where the impure water is filled was formed by a used filter bottle with a capacity of about 19 litres. This enables a considerable amount of water to be stored and also it provides enough space for the filtering layers. A 20 litre paint container was used as the collector bucket.

As shown in the Figure 1 the filter bed was formed by a clay cake which was also assumed to have the ability to remove Cadmium up to some extent. The clay cake was made porous by adding 10% of saw dust (by weight) and then burning in a kiln.

The filter materials chosen were Kaolinite and Bentonite. These clays were selected based on the assumption that they have the ability to absorb Cadmium in water. Furthermore, these clays are the types of clay which are available at a low price.

2.2 Preparation of Test Solution

A Cadmium (Cd^{2+}) ion solution of concentration 100 ppb (parts per billion) is used as the parent solution to prepare the solutions in different concentrations. This solution was prepared as follows.

The solution was prepared using Cadmium Chloride ($CdCl_2$) salt. In order to prepare a 100 ppb solution of Cd^{2+} ions, we need to measure 163 µg of $CdCl_2$. Since, this amount is very hard to measure, it was decided to prepare a high concentrated solution of Cadmium and dilute up to the desired level.

Therefore, this was done by dissolving 163 mg of $CdCl_2$ in 1L of water and then dissolving 20 ml of this solution in 20 L of water.

2.3 Testing

The identification of optimum filter design is based on number of tests. They are.

1. Permeability test
2. Material efficiency test
3. Layer height test
4. Layer configuration test

2.4 Permeability test

Constant Head permeability test is conducted to check the permeability of the clay cake which is used as the filter bed. The test is based on the Equation 1.

$$Q = \frac{kA\Delta P}{\mu \Delta L} \qquad (01)$$

Where,
Q = Discharge (volume/time)
k = Coefficient of Permeability
A = Area of the clay cake
ΔP = Pressure difference (height difference x density x 9.81)
µ = dynamic viscosity of the fluid
ΔL = thickness of the cake

1L of water is put in to the top bucket and the initial height of the water is measured, then the water is allowed to pass through the clay cake within a constant time and the final height and the volume passed through is measured. Using the above measurements the required parameters are calculated and finally the permeability of the cake is obtained in units of square meters using the Equation 1.

2.4.1 Material efficiency test

This test is done to identify the most efficient type of clay in the reduction of cadmium present in water. The test will be conducted by passing the Cd^{2+} solution through each type of clay individually and then testing the filtrate for Cd^{2+}.

The thickness of the layer that will be used is 20 mm.

2.4.2 Layer height test

This test is done to identify the thickness of the layers that provides the most efficient removal of Cd^{2+}. The test will be conducted for range of layers with different thicknesses in each clay type individually.

2.4.3 Layer configuration test

This test will be conducted to identify the best configuration of layers. Based on the outcomes of layer height test, a suitable height for each clay type will be first decided. Then they will be arranged in different configurations and the filtrate of the solution passing through different configurations will be tested.

The proposed configurations for the ongoing testing are as follows.

1. First configuration
   a. Kaolinite
   b. Bentonite

2. Second configuration
   a. Bentonite
   b. Kaolinite

3. RESULTS

By performing the above mentioned tests, it is expected to identify the optimum layer configuration which facilitates the efficient removal of dissolved cadmium up to an admissible level.

4. ACKNOWLEDGEMENT

The authors wish to thank Mr. Roshan Fernando, an external advisor of the SAITM Engineers without Boarders (EWB) Chapter for his support throughout this project. And also, Mr. Janitha Batagoda, post graduate researcher attached to NJIT-USA for providing us the necessary technical details of the NJIT Filter model. Finally, authors wish to extend their special thanks to the staff of University of Sri Jayawardenapura for providing us the laboratory testing facilities.

5. REFERENCE

[1] K.Wanigasuriya, "*Aetiological factors of Chronic Kidney Disease in the North Central Province of Sri Lanka*: A review of evidence to-date. Journal of the college of community physicians of Sri Lanka" Volume 17, No. 01: 2012.

[2] C. S. Weeraratna, "*CKDu research: Why the Health Ministry?*" The Island, January 2014.

[3] M.A.C.S. Jayasumana, P.A. Paranagama, M.D. Amarasinghe, K.M.R.C.Wijewardane, K.S.Dahanayake,S.I.Fonseka,K.D.L.M.P.Rajakaruna,A.M.P.Mahamithawa,U.D.Samarasinghe, V.K.Senanayake, "*Possible link of Chronic arsenic toxicity with Chronic Kidney Disease of unknown etiology in Sri Lanka*". Journal of Natural Sciences Research. Vol.3, No.1. 2013.

[4] L. Friberg, G.F. Nordberg, V.B. Vouk, Handbook of the toxicology of metals. Vol. II. Amsterdam, Elsevier, pp. 130–184, 1986.