Performance of Soil Aquifer Treatment (SAT) with Egg Shells Adsorbent to remove Zinc

Divya S.J., Nagarajappa D.P, Manjunath N.T, Sham Sundar K.M.

***Abstract*— In the present work, removal efficiency of egg shells powder was used to enhance the removal efficiency of Soil Aquifer System (SAT) for the removal of Zinc. The bench scale studies were carried out using 4 different concentrations of zinc in water (5, 10, 15, 20 mg/l) and varying adsorbent heights (25%,50%,75%) in 1.0m soil depth. Soil properties were determined and silty sand soil was used. The efficiency of SAT to remove Zn without Egg shells resulted in 40%. The adjunction of Egg shells in SAT resulted in increased removal efficiency. Whereas the efficiency was observed maximum at 50% height of adsorbent resulting in 85.5%. Comparison studies show that SAT in conjunction with Egg shells showed better performance than without adsorbent one.**

***Index Terms*— Egg shells powder, Soil Aquifer Treatment, Synthetic water, Zinc.**

I. INTRODUCTION

Water is essential to all forms of life and water of acceptable quality is essential for agriculture, industrial, domestic and commercial uses. All these activities are also responsible for polluting the water. The constant blending of heavy metals from industrial effluents by activities like mining, metal processing, electro plating, etc., to water stream induces various unfavourable effects on human health and the environment. Toxic metals tend to bio accumulate by entering into the food chain [1]. Elimination of toxic heavy metals from industrial wastewater has been done by several conventional methods like electro precipitation, membrane separation, evaporation, ion exchange, etc., which are expensive and inefficient for low concentrations of heavy metals. Novel technologies in treatment of industrial wastewater for reuse have been elaborated. Soil Aquifer Treatment (SAT) is one of the techniques with high infiltration system. Numerous studies have established positive and effective results for treatment of wastewater by SAT [2].

SAT is a geo-purification system that utilizes physical, chemical and biological processes during infiltration of wastewater effluent through soil strata to improve water quality. The quality of the water of a recharged aquifer is a function of the quality of the recharge water; the recharge method used, the physical characteristics of the vadose zone and the aquifer layers, the water residence time, the amount of blending with other sources[2]. A high degree of upgrading can be achieved where soil and groundwater conditions are favorable, by allowing sewage effluent to infiltrate into the soil and move down to the groundwater. The unsaturated zone then acts as a natural filter and can remove essentially all suspended solids, biodegradable materials, bacteria, viruses and other microorganisms. Significant reductions in nitrogen, phosphorus, and heavy metals concentrations can also be achieved. This gives an advantage to artificial recharge with wastewater over the direct application method. This process is known as soil-aquifer treatment(SAT)[5]. A simple representation of SAT is shown in fig 1.

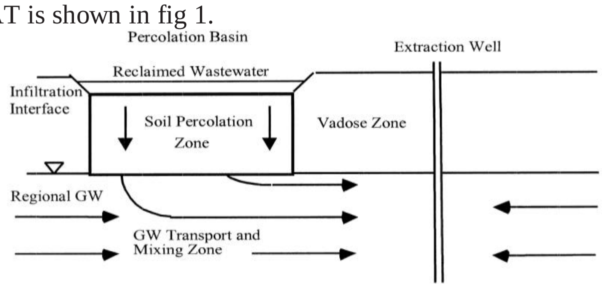

Fig 1. Schematic of Soil Aquifer Treatment(SAT) system.[8]

Zinc is a toxic heavy metal dismissed into the environment by the industrial activities, anthropogenic actions etc., Heavy metals are non-biodegradable unlike other organic pollutants. Zinc are widely used in metal industries like mining, metal cleaning, plating baths, pulp and paper mills, fertilizers, refineries, etc., which produce high levels of zinc in effluents [3][7].

Zinc is a vital element important for human health like to prevent premature skin aging and muscles. But too much of Zinc ingestion about 225 mg can cause eminent health issues like stomach cramps, vomiting, nausea, skin irritations, etc.,[4]

The removal efficiency of low cost adsorbents can be tested in aqueous solutions and then study in large scale. One of such easily available and inexpensive adsorbent is waste egg shells. Egg shells contain metal attracting hydroxyl groups which gives it good adsorption capacity. The vast amount of egg shells adjudges for the feasibility of choosing it as adsorbent for the study.

This study infuses SAT with egg shells to remove Zinc as it is always preferred to aim at working with low cost process.

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II. Related work

The literature studies reveals that Soil Aquifer Treatment (SAT) is an the emerging managed aquifer recharge technology, which in combination with other available wastewater treatment technologies could produce effluent of acceptable quality for indirect potable reuse. The present study combines the use of adsorbent and SAT system to improve the treatment of removal of metals. Some related works are briefly described as follows.

Pilot studies were conducted by Chunye Lin et al.[5] to study the metal retention in SAT system. They studied the adsorption of some metals over multisorbents and soil. They inferred 32% of soil accumulated copper metal. While Zinc partitioned as 51.6% of soil accumulated metal. Partitioning was measured by distribution coefficient and sequential dissolution. Short term and long term adsorption studies were done. Results inferred that similar SAT soils may decrease affinity towards trace metals with long term effluent recharge affecting the ability of SAT to prevent metal penetration into the recharged aquifer.

Xiaomin Li et al. [4] studied the biosorption behaviours of zinc and other metal on to chemically modified orange peels. The maximum adsorption capacity of Zinc was found to be 1.2*mol/kg* which was increased by 60% compared to raw orange peels.

Animesh Agarwal and Puneet Kumar Gupta[6] made batch scale experiments on the removal of copper and iron by egg shell powder from aqueous solution. They reported 85% to 95% iron removal from 5 and 10mg/l iron solution and 80 to 95% in the same solution. Whereas it came out in their study that adsorption efficiency was decreased about 7% to 3% of iron and copper to mixed metal solution. It means that they found adsorption efficiency decreased for presence of more metals.

The following objectives were addressed by our study. The objectives of this project are to compare the efficiency of the selected soil to remove Zn with and without adsorbent in SAT system. Besides, the present study also aimed at behaviour of soil with different adsorbent height.

III. Materials and Methodology

A. Adsorbent Preparation

Egg shells were collected locally, dried and pulverized. Egg shell powder was prepared as per procedure given by Animesh et al., [6]. The samples were then washed 10-12 times with tap water and then with distilled water several times to remove dirt particles and dried for three hours in an oven at 40^oC and then allowed to cool, crushed and then finally sieved to prepare fine powder of 90 – 210 μ particle size.

B. Preparation of Zinc Solution (Synthetic water)

Analytical grade reagents were used for preparing the synthetic water. Zinc solution was prepared by diluting merck grade stock solution with deionised water to a desired concentration. Concentrated solution of Zinc Sulphate was prepared and the solution was then diluted to different known concentrations viz. 5, 10, 15 and 20mg/l for testing performance of SAT system. It was prepared and filled in 20 litres influent tank.

C. Preparation of Soil

Silty sand was characterized by the geotechnical properties obtained by the experiments. The dry density of soil was found to be 1.64 g/cm^3 and it was maintained by mixing water and compaction. Experiments were carried for single depth of soil 1m and 3 heights of adsorbent. A layer of 10 cm adsorbent was introduced in the soil column at 25% 50% and 75 % in different trials and experimented. A Nearly neutral *pH* 7.2 was observed in the soil.

D. Experimentation

Column studies were conducted in PVC columns of 5 inch diameter and 1.5m length. Silty sand was used for SAT and filled upto 1m depth. When conducting experiment with adsorbent, 3 adsorbent heights were tried at 25%, 50% and 75% of 1m soil depth. Synthetic water to be tested for removal efficiency was passed through the overhead tank and a ponding depth of 30cm was maintained above the soil mass. The effluent sample was collected from the bottom of the column and the metal concentrations were tested using Atomic Absorption Spectrophotometer (AAS). For each predetermined condition of experimentation, the soil was filled afresh in the column. Effluent samples in duplicate were prepared and analyzed for Zinc concentration using AAS.

IV. Results and Analysis

A. Performance of Silty Sandy soil without Egg shells.

Table I Shows the performance of silty sand soil of depth 1.0m without adsorbents. Table I also indicates that silty sand performed almost similar to all the influent concentrations.

Table I: Performamce of SAT without Adsorbent to remove Zinc in 1.0m column depth

Sl no	Influent Concentration, *mg/l*	Effluent Concentration, *mg/l*	Removal Efficiency %
1	5	3.06	38.8
2	10	5.79	42.1
3	15	8.87	40.8
4	20	12.58	37.1

The silty soil was efficient to remove Zinc from influent to some extent. The maximum removal was recorded as 42.1% for 10mg/l initial concentration and least at 20mg/l as 37.1%. The average overall efficiency can be taken as 40%.

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B. Performance of Silty Sandy soil with Egg shells at 25% height from bottom.

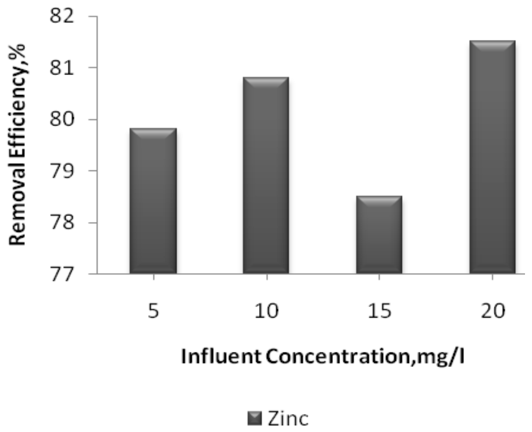

Fig 2.Performance of SAT with eggshells at 25% height from bottom of column

Removal efficiencies of zinc by SAT at 5,10,15,20 mg/l of influent concentration for 25% adsorbent height from the bottom of the column are shown in fig 2. The maximum efficiency at 25% height was observed for 20mg/l as 81.5%. The other efficiencies were 79.8%, 80.8% and 78.5% at 5,10 and 15 mg/l respectively.

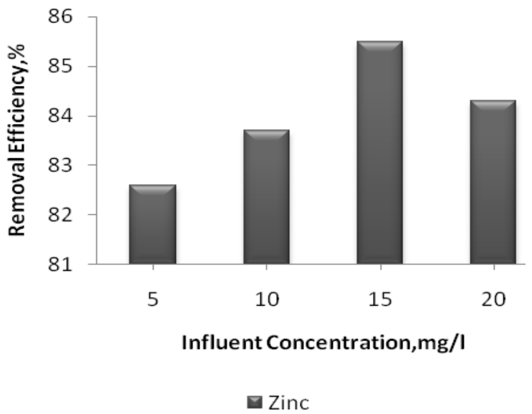

Fig 3.Performance of SAT with eggshells at 50% height from bottom of column

Removal efficiencies of zinc at 5,10,15,20 mg/l of influent concentration for 50% adsorbent height from the bottom of the column are shown in fig 3. The maximum efficiency at 50% height was observed for 15mg/l as 85.5%. The other efficiencies were 82.6%, 83.7% and 85.7.5% at 5,10 and 20 mg/l respectively.

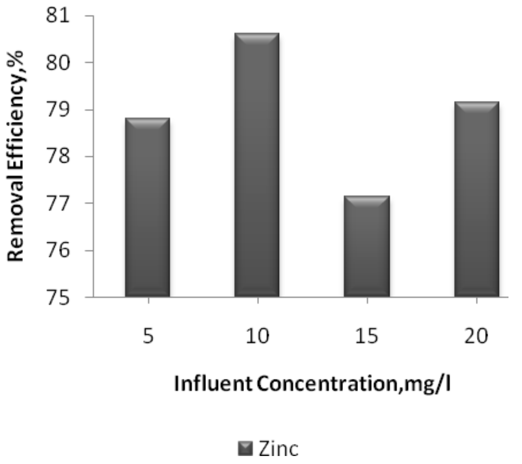

Fig 4.Performance of SAT with eggshells at 75% height from bottom of column

Removal efficiencies of zinc at 5,10,15,20 mg/l of influent concentration for 75% adsorbent height from the bottom of the column are shown in fig 4. The maximum efficiency at 75% height was observed for 10mg/l as 80.6%. The other efficiencies were 78.8%, 77.13 and 79.15% at 5, 15 and 20mg/l respectively.

C. Comparison of SAT with Egg shells and without egg shells.

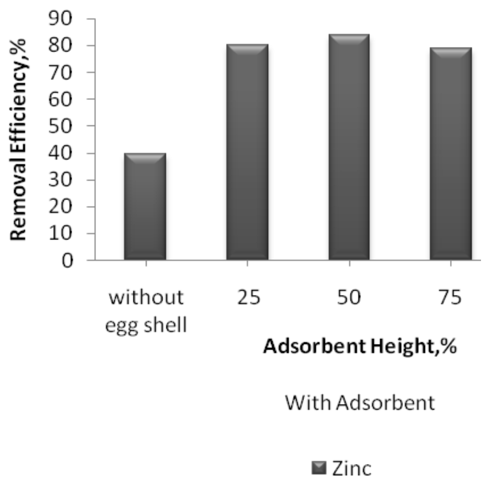

Fig 5.Comparison of Performance of SAT with eggshells and without adsorbent

The average removal efficiency was considered for each height as it was almost constant. The average efficiency at 25% height was 80.15, at 50% height was 84.05% and at 75% adsorbent height from bottom was 78.92% as shown in fig 5. It is commendable that the efficiency was nearly doubled compared to just soil SAT system in each height. The overall average efficiency was calculated taking average values at different influent concentrations. Compared to SAT without egg shells which had average removal efficiency of 40%, egg shells enhance the efficiency very effectively.

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V. CONCLUSION

The experimental studies reveal that silty sandy soil enhanced its removal efficiency of Zinc by the integration of egg shells as adsorbent in between the soil column. Almost constant removal efficiency was found for different influent concentrations. Albeit removal efficiency was achieved maximum in the adsorbent placement height 50% of 1.0m soil mass, overall efficiency was 81%. Silty sandy soil can be merged with egg shells and used to treat Zinc contaminated effluents more effectively. The maximum removal efficiency of this SAT system for Zinc was 85.5% at 50% height of adsorbent placed. The Zinc concentrations reached admissible values after treating. The results can be utilized for further increased concentration studies. This system can be utilized for industrial effluents containing zinc and reclaimed water can be used for indirect uses.

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