

## Application of laterite soil in removing chloride ion from drinking water

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### ABSTRACT

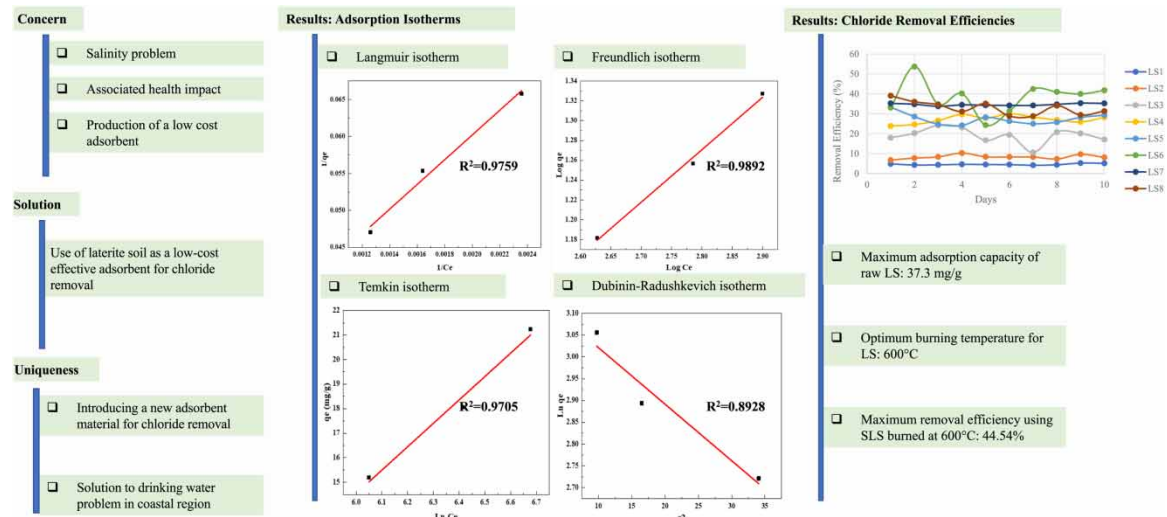
Increasing salinity is a crucial issue for the people of coastal regions in Bangladesh. To resolve this problem, efficient and low-cost materials can be used as adsorbents to remove salinity from water. Among those, laterite soil (LS) is one of the efficient adsorbents in water treatment. This study demonstrates a low-cost salinity removal technique using laterite soil as adsorbent. The effect of burning temperature on raw laterite and synthetic laterite has been analyzed. The performance of the adsorbents has been observed in terms of efficiency in salinity removal. Both batch and column adsorption have been carried out to evaluate the adsorption capacity of raw LS and burned LS, respectively. Raw laterite shows maximum adsorption capacity of 21.24 mg/g in batch adsorption at an initial concentration of 900 mg/L. The optimum burning temperature for thermally treated LS has been found as 600 °C. However, SLS (Synthetic Laterite Soil) burned at 600 °C gives greater chloride ion removal efficiency (44.54%) than LS (38.23%) in removing salinity from water.

**Key words:** adsorption, burning temperature, laterite soil, low-cost, salinity, surface modification

### HIGHLIGHTS

- Among three initial chloride concentrations, the adsorption capacity was found maximum for the most concentrated one.
- Thermally treated synthetic LS at 600 °C was found to have maximum removal efficiency of 44.54%.

### GRAPHICAL ABSTRACT



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## 1. INTRODUCTION

One in six people worldwide, 783 million in total, don't have access to improved drinking water sources (Grey *et al.* 2013). About 25% of the world does not have access to good quality and quantity of fresh water and more than 80 countries face severe water crisis (Abdallah *et al.* 2008). Access to safe drinking water is limited especially in third world countries such as Bangladesh. Bangladesh, a low-lying deltaic land, is particularly vulnerable to climate change and its associated hazards (Agrawala *et al.* 2003). The coastal areas of Bangladesh, with its near flat topography and location at the tip of the 'funnel-shaped' Bay of Bengal, are susceptible to several natural hazards: cyclones and tidal surges, salinity intrusion, riverbank erosion, shoreline recession, etc. Among them, salinity intrusion is nowadays a crucial problem in the coastal region (Baten *et al.* 2015). Drinking water from natural sources in coastal regions has become contaminated by varying degrees of salinity due to saltwater intrusion from rising sea levels, cyclone and storm surges, and upstream withdrawal of freshwater (Ayub *et al.* 2020). Salinity in drinking water is one of the major problems in the coastal region. According to World Health Organization (WHO), about one-fourth of the population has no access to safe drinking water, especially in the coastal region of Bangladesh (Akib Javed *et al.* 2020). The coastal region covers almost 29,000 km<sup>2</sup> (about 20% of the country) and about 53% of the coastal areas are affected by salinity (Haque 2006; Mustari & Karim 2014). About 15 million people are forced to drink saline water and 30 million people are unable to collect potable drinking water due to a lack of available safe water sources (Abedin *et al.* 2019).

The southwest coastal areas of Bangladesh are in a great threat to safe drinking water. Since 1948, river salinity in the southern districts of Patuakhali, Pirojpur, Barguna, Satkhira, Bagerhat, and Khulna has increased by 45% (Alam *et al.* 2017). Sodium ions (Na<sup>+</sup>) and chloride ions (Cl<sup>-</sup>) are mainly responsible for the salty taste of drinking water, mainly groundwater. Sodium ion concentration of Dacope Upazilla, situated under the Khulna district in Bangladesh's southwest coastal region, was found to be 939.856 mg/L and 521.210 mg/L in groundwater and surface water respectively (Benneyworth *et al.* 2016). According to the report of a joint expert consultation of the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) in 2002, the sodium intake should not be more than 2 g/day (<85 mmol/day) but the population of Dacope Upazilla is taking about 5–16 g/day (Shammi *et al.* 2019). The maximum allowable limit of chloride ion concentration is 250 mg/L. Beyond this level, chloride can imply negative impact human health (Azad *et al.* 2022). Salinity intrusion into drinking water and its associated health impact is one such critical issue that results in increased blood pressure (BP) or hypertension leading way to cardiovascular diseases (CVD). It is seen that women of Dacope have suffered from pre-eclampsia, gestational hypertension during pregnancy (Khan *et al.* 2011). Thus there is an urgent need to remove these fatal ions from water.

Several desalination techniques such as reverse osmosis, electrodialysis and electrodialysis reversal, ion exchange technology, and thermal technology have been developed around the world (Younos & Tulou 2005; Aliyu *et al.* 2018; Hyder *et al.* 2021). Although these techniques are efficient in salinity removal of drinking water, they are not suitable for rural people due to their complexity in nature. On the other hand, available technologies do not provide an effective solution in dealing salinity problem in drinking water (Garg & Joshi 2015). Some technologies such as the use of fitkari (24%) and pressure sand filters (18%) are used to treat salinity, but 51% of people do not use any home water treatment. Boiling of water is seen as very rare because it needs fuel and wealth (Benneyworth *et al.* 2016). None of them seems to be cost-effective with respect to their economic condition. Therefore, low-cost and sustainable techniques for salinity reduction from drinking water are an urgent need for the southern part of Bangladesh.

For metallic ion removal, different physico-chemical treatments have been adopted globally. In comparison with these techniques, adsorption process is cost-effective and user-friendly (Mohan & Pittman 2007). The adsorption technologies for low-skill communities are more appropriate due to their sludge-free operation nature. This solves the problem of sludge disposal and renders the system more viable especially by using low-cost adsorbents (Ali & Gupta 2006). Several recent publications utilized different inexpensive and locally abundantly available adsorbents (Joseph *et al.* 2019). Utilization of indigenous materials in treating saline water can be a good solution. Previous studies showed that low-cost indigenous materials such as laterite soil (LS) could be used as efficient adsorbents. LS is a highly weathered material, rich in secondary oxides of iron, aluminium, and manganese (AN *et al.* 2015). These types of soils are formed under warm temperatures and abundant rainfalls in tropical and subtropical climates such as Bangladesh, Sri Lanka, India, Thailand, etc (Maji *et al.* 2008). In

Bangladesh, LS is mainly available in Madhupur Tract or Red Soil Tract such as Narsingdi, Gazipur, Tangail, and in Chittagong district (Halim *et al.* 2008).

LS can be used as an effective adsorbent material due to its high surface area, spherical shape, and improved porosity (Maji *et al.* 2008; Dissanayake *et al.* 2021). The LS was used as a low-cost adsorbent for the efficient removal of arsenic in Jharkhand, India (Bhengra *et al.* 2019). Heavy metals such as As, Cd, Cu, Pb, Cr, and Zn have been removed by using LS (Aminah & Izaat 2011; Syama *et al.* 2015). Moreover, the hydrous iron and aluminum oxides in LS are mainly responsible for producing net positive surface charge, which shows the capacity to absorb anionic components like chloride ions (Ranasinghe *et al.* 2014). Studies also revealed that LS is temperature sensitive for adsorption of As and F (Halim *et al.* 2008; Gomoro *et al.* 2012). Thermally treated LS at 400 °C showed its efficiency in removing fluoride ions from drinking water. LS is very effective for ion adsorption because the pH of the raw water does not change after ion removal as well as its iron content does not leach (Maji *et al.* 2008). The surface of laterite is positively charged, which is effective in removal of anionic ions (Mitra *et al.* 2016).

Therefore, LS can be used as a low-cost effective salinity removal material to bring the salinity content of drinking water within the permissible limit. But based on literature review, there is no research has been conducted yet to investigate the performance of LS as adsorbent to remove chloride ions from water. In this study, LS has been introduced as an effective adsorbent for chloride removal from water. The effect of burning temperature on LS has been investigated and the optimum burning temperature for LS in removing chloride ion from saline water has been analyzed. Synthetically made laterite sample (SLS) by adding Fe<sub>2</sub>O<sub>3</sub> can improve its efficiency due to the elevated iron content. Therefore, this study explores the effect of modification of LS in producing effective adsorbents to develop workable desalination techniques for drinking water.

## 2. METHODS

### 2.1. Collection of LS

Bangladesh is one of the lateritic zones of the world (Huq & Shoaib 2013). There are various places which are enriched with laterite soil. Narsingdi district is one of them. According to the findings of previous studies obtained from literature review, the soil sample has been collected at a depth of three feet from the Belabo upazilla of Narsingdi (latitude 24 °02'32.0" N and longitude 90 °50'53.0" E). Then the soil sample has been tested for soil composition and analyzed by an X-ray fluorescence (XRF) machine (model: AXIOS MAX DY729). Fuse bead method was followed for testing of soil content.

### 2.2. Processing of LS

At first, the collected LS was naturally processed by air drying to remove moisture content. Then it was grinded to make finer and passed through standard ASTM sieve no. 40 (425 µm opening). Meshing was required to maintain uniform gradation.

### 2.3. Preparation of SLS

Usually, LS has an iron content of approximately 25%. But the collected soil sample has only 7% Fe<sub>2</sub>O<sub>3</sub> which is insufficient for adsorption of chloride content. To improve its adsorption capacity, synthetic iron oxide has been added to the raw laterite soil. For this reason, the laterite is then named as synthetic laterite soil (SLS). To make SLS containing 25% iron oxide, 120 g of iron oxide were mixed with 500 g of LS.

### 2.4. Preparation of thermally treated LS

For final setup of filtration process, eight molds of LS with duplicates were made ensuring 1 inch (2.54 cm) diameter and 1 inch (2.54 cm) thickness. Then the molds were burnt in a muffle furnace at the specified temperatures as shown in Table 1. The burning process at the desired temperatures was maintained for 2 hrs and cooled down for approximately one hour. By observing these samples, an optimum burning temperature was found. Then SLS was burnt at this optimum burning temperature.

**Table 1** | Burning temperatures of LS

Mold ID	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8
Burning temperature (°C)	250	350	450	500	550	600	650	700

## 2.5. Adsorption process

Adsorption is an effective method for the removal of different ions in water treatment (Ali & Gupta 2006). Maximum adsorption capacity and maximum removal of pollutants are two parameters in the adsorption process indicating the performance of used adsorbents. For the removal of salinity, the behavior of laterite as adsorbent has been studied in this work.

At first, the effect of initial chloride concentration on adsorption capacity of raw LS was found out by conducting batch adsorption with three different concentrations: 500 mg/L, 700 mg/L and 900 mg/L. After that, the final setup of filtration with column adsorption using thermally treated LS was established. It is necessary for checking the reusability and applicability of the adsorbents for practical purposes (Islam *et al.* 2019). After analyzing the values of chloride content of filtered water, the maximum adsorption efficiency was identified and the corresponding optimum burning temperature was observed. Then SLS was burnt at that optimum temperature and used as adsorbent to compare with the LS sample. The adsorption capacity of surface-modified SLS was also checked. After conducting all the experiments, the most efficient adsorbent to remove chloride content was identified.

## 2.6. Adsorption isotherms

In a solid-liquid system, the adsorption results in the removal of solute from the solution onto a solid surface until the remaining solute in the solution is in dynamic equilibrium with solute on the solid surface. At equilibrium, there is a finite distribution of the solute between the liquid and solid phases, which can be described by many isotherms and adsorption models (Nirmala Rani & Talikoti 2013). They can be used to fit the observed experimental data and determine the model parameters (Ramnani & Sabharwal 2006). The adsorption capacity ( $q_e$ ) and removal efficiency of the chloride ion at equilibrium were determined using Equations (1) and (2), respectively (Ayub *et al.* 2020).

$$q_e = \frac{C_i - C_e}{W} \times V \quad (1)$$

$$\text{Removal efficiency (\%)} = \frac{C_i - C_e}{C_i} \times 100 \quad (2)$$

where,  $q_e$  represents the adsorption capacity (mg/g)  $C_i$  and  $C_e$ , respectively, represent the initial and equilibrium concentrations (mg/L) of the adsorbate; V stands for solution volume (L); and W represents mass of the adsorbent (g). The following four adsorption models have been analyzed for the adsorption of chloride by raw LS as adsorbent.

### 2.6.1. The Langmuir model

It is the most commonly used adsorption model described by the following equation (Ayub *et al.* 2020).

$$q_e = \frac{q_{max} K_L C_e}{1 + K_L C_e} \quad (3)$$

where  $q_{max}$  represents the maximum adsorption capacity (mg/g) and  $K_L$  (L/mg) is Langmuir's isotherm constant which shows the binding affinity between chloride ions and adsorbents. The parameter  $q_{max}$  represents the maximum sorption capacity of the biosorbent when surface is fully occupied by metal ions. It also represents total number of binding sites (per unit weight) involved in metal sorption (Crist *et al.* 1988). The Langmuir's isotherm was transformed into its linear form (Equation (4)), to determine the adsorption parameters (Hyder *et al.* 2015).

$$\frac{1}{q_e} = \frac{1}{K_L q_{max}} \cdot \frac{1}{C_e} + \frac{1}{q_{max}} \quad (4)$$

The separation factor ( $R_L$ ) was calculated using Equation (5).

$$R_L = \frac{1}{1 + C_i \times K_L} \quad (5)$$

where,  $R_L$  is the dimensionless Langmuir constant which indicates the adsorption possibility. A lower  $R_L$  value reflects that adsorption is more favorable. In a deeper explanation,  $R_L$  value indicates the adsorption nature to be either unfavourable ( $R_L > 1$ ), linear ( $R_L = 1$ ), favourable ( $0 < R_L < 1$ ) or irreversible ( $R_L = 0$ ) (Foo & Hameed 2010). This empirical model assumes monolayer adsorption. This type of adsorption can only occur at a finite number of definite localized sites, that are identical and equivalent, with no lateral interaction and steric hindrance between the adsorbed molecules, even on adjacent sites (Vijayaraghavan *et al.* 2006).

### 2.6.2. The Freundlich model

Freundlich isotherm assumes that the uptakes of metal ions occur on a heterogeneous surface by multilayer adsorption and that the amount of solute adsorbed increases infinitely with the increase in the concentration (Ramnani & Sabharwal 2006). The Freundlich isotherm is described by the Equation (6) (Ayub *et al.* 2020).

$$q_e = K_f C_e^{\frac{1}{n}} \quad (6)$$

Here,  $K_f$  is Freundlich's constant related to sorption capacity of adsorbent (LS), and  $1/n$  is the adsorption intensity. The value of  $1/n$  demonstrates the adsorption process either favorable ( $0.1 < 1/n < 0.5$ ) or unfavorable ( $1/n < 2$ ). In this study, the linearized form of the Freundlich equation (Equation (7)) was used to fit the observed experimental data (Begum *et al.* 2016).

$$\text{Log} q_e = \text{Log} K_f + \frac{1}{n} \text{Log} C_e \quad (7)$$

This empirical model can be applied to multilayer adsorption, with non-uniform distribution of adsorption heat and affinities over the heterogeneous surface (Adamson & Gast 1967). In contrast to Langmuir model, the Freundlich model does not assume saturation of metal sorption. For fitting the model to experimental data, the Freundlich model generally gives a better fit for a higher equilibrium concentration of metal in solution. However, the Langmuir and Freundlich isotherm models are said to suffer from two major drawbacks. Firstly, the model parameters obtained are usually appropriate for a particular set of conditions and cannot be used as a prediction model for another. Secondly, these models are unable to provide a fundamental understanding of ion adsorption (Kasprzyk-Hordern 2004).

### 2.6.3. The Temkin isotherm model

This model assumes that adsorption is characterized by a uniform distribution of binding energies, up to some maximum binding energy (Johnson & Arnold 1995). The isotherm contains a factor that explicitly taking into account of adsorbent-adsorbate interactions (Temkin 1940). By ignoring the extremely low and large value of concentrations, the model assumes that heat of adsorption (function of temperature) of all molecules in the layer would decrease linearly rather than logarithmic with coverage (Aharoni & Ungarish 1977). The model is given by the following equation (Temkin 1940).

$$q_e = \frac{RT}{b_T} \ln A_T + \left( \frac{RT}{b_T} \right) \ln C_e \quad (8)$$

Here,  $A_T$  is Temkin isotherm equilibrium binding constant (L/g),  $b_T$  stands for Temkin isotherm constant,  $R$  is the universal gas constant, and  $T$  is for temperature.

### 2.6.4. The Dubinin-Radushkevich (D-R) model

The D-R model is more general than the Langmuir model because it does not require homogenous adsorption sites. It is mathematically described by Equation (9) (Ramnani & Sabharwal 2006).

$$\ln q_e = \ln q_m + K \epsilon^2 \quad (9)$$

Here,  $q_e$  is the amount of solute adsorbed per unit mass,  $q_m$  is the sorption capacity of adsorbent per unit mass,  $K$  is the D-R adsorption constant and  $\varepsilon$  is Polanyi potential described by the following function (Equation (10)).

$$\varepsilon = RT \ln \left( 1 + \frac{1}{C_e} \right) \quad (10)$$

where,  $R$  is the gas constant,  $T$  is absolute temperature and  $C_e$  is the equilibrium concentration of solute in the solution. The value of  $K$  gives valuable information regarding the mean energy of adsorption, which is related to  $K$  by following equation (Oguz 2005).

$$\text{Mean energy, } E = (-2K)^{-\frac{1}{2}} \quad (11)$$

D-R model has often successfully fitted high solute activities and the intermediate range of concentrations data well (Foo & Hameed 2010). The approach was usually applied to distinguish the physical and chemical adsorption of metal ions (Dubinin 1960), with its mean free energy,  $E$  per molecule of adsorbate, for removing a molecule from its location in the sorption space to the infinity (Hobson 1969).

### 3. RESULTS AND DISCUSSION

The adsorption capacity of LS depends greatly on its physical and chemical properties which has been investigated in this study. Tables 2 and 3 represent the physical properties and chemical composition of LS, respectively. From the test result, the percentage of iron oxide has been found 8.85%, but for simplification, 7% iron oxide content was considered in this study.

**Table 2** | Physical properties of LS

Sample	Soil type	Specific gravity	Bulk density	Dry density	Liquid limit	Plastic limit	Plasticity index	Water content
LS	Silty clay	2.5	1.88 g/cm <sup>3</sup>	1.47 g/cm <sup>3</sup>	45.15%	20.13%	25.02	19.8%

**Table 3** | Chemical composition of LS

Sample	SiO <sub>2</sub> (%)	Al <sub>2</sub> O <sub>3</sub> (%)	Fe <sub>2</sub> O <sub>3</sub> (%)	CaO (%)	MgO (%)	SO <sub>3</sub> (%)	Others (%)
LS	60.0	16.99	8.85	0.09	0.36	0.02	13.69

#### 3.1. Effect of initial concentration

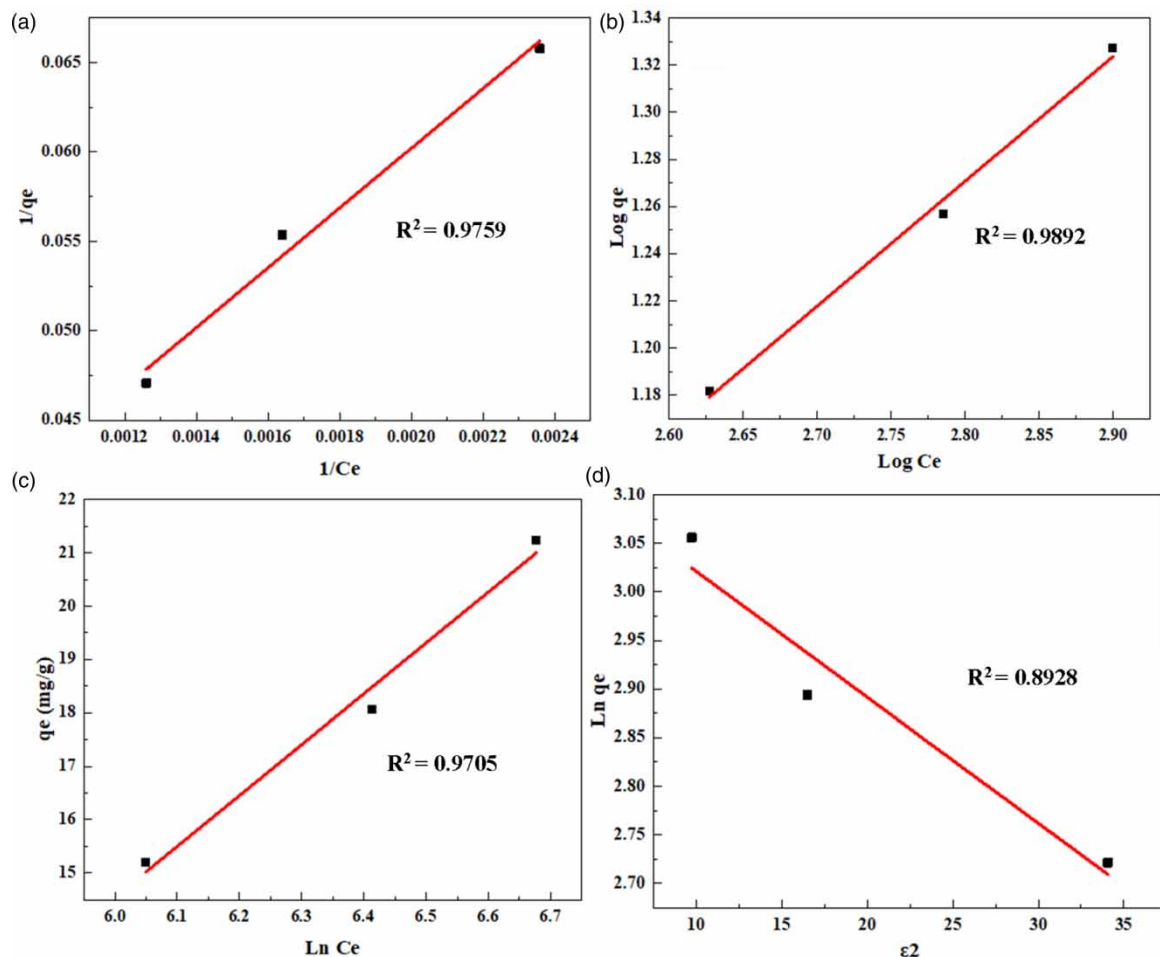
The raw LS was analyzed as adsorbent with three different chloride concentrations, 500 mg/L, 700 mg/L and 900 mg/L. Table 4 exhibits the adsorption capacity and removal efficiencies of raw LS at the specified concentrations. From Table 4, it has been observed that LS acts most efficiently in 900 mg/l in terms of adsorption capacity since the raw LS shows the maximum adsorption capacity of 21.24 mg/g for this concentration. So, 900 mg/l was selected for the final setup.

**Table 4** | Adsorption of Cl<sup>-</sup> using raw LS

Exp no.	Initial concentration, $C_i$ (mg/L)	Final concentration, $C_e$ (mg/L)	Adsorption capacity, $q_e$ (mg/g)	Removal efficiency (%)
1	500	424	15.2	15.2
2	700	609.7	18.06	12.9
3	900	793.8	21.24	11.8

### 3.2. Adsorption model

The experimental data has been incorporated in Langmuir, Freundlich, Temkin, and Dubinin-Radushkevich (D-R) isotherm models and the plot of respective isotherms are presented in Figure 1. The model parameters have been calculated and are tabulated in Table 5. As can be seen from Figure 1, the experimental data fit well in the Langmuir, Freundlich, and Temkin equations as straight line plots are obtained. However, the observed intercepts are negative for Freundlich, and Temkin models. But the Langmuir and D-R isotherm models show positive intercept values along with straight line plots (Figure 1(a) and 1(d)).



**Figure 1** | (a) Langmuir isotherm, (b) Freundlich isotherm, (c) Temkin isotherm, and (d) Dubinin-Radushkevich (D-R) isotherm for the adsorption of Cl<sup>-</sup> on raw LS.

The Langmuir's isotherm represents the monolayer adsorption of saline ion onto the LS surface having a finite number of adsorption sites (Sierra-Trejo *et al.* 2020). The fitness of the Langmuir model interprets chemisorption within the monolayer on the adsorbent (Begum *et al.* 2020). Between Langmuir and D-R isotherm, Langmuir was the best fitted with higher linear regression coefficient ( $R^2=0.9759$ ) than that of D-R model ( $R^2=0.8928$ ). A similar result was also found from the study of Hyder *et al.* (2015) for the adsorption of Cr(VI) onto bone char. Table 5 shows that maximum adsorption capacity of raw LS was observed to be 37.3 mg/g. Also, the value of  $R_L$  is less than one ( $R_L=0.4709$ ) which favors the adsorption of saline ions on LS surface (Ayub *et al.* 2020). On the other hand, the plot  $\epsilon^2$  against  $\ln(q_e)$  is linear and shows very good fitting indicating that the D-R adsorption model is also applicable for the adsorption of Cl<sup>-</sup> on raw LS. Using the value of D-R constant  $K$ , the mean adsorption energy for Cl<sup>-</sup> was calculated as 6.21 kJ/mol. The value of adsorption energy,  $E$ , indicates the mechanism of adsorption occurred. If this value falls within the range of 8–16 kJ/mol, the adsorption is ion exchange type. On the other hand, if the value of  $E$  is  $\leq 8$  kJ/mol, then the adsorption is physical occurred due to weak van

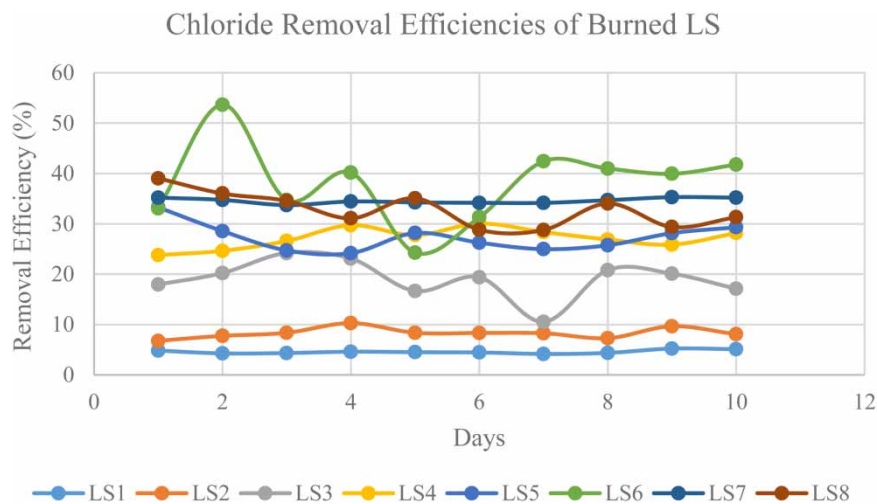
**Table 5** | Isotherm parameters for chloride ion removal by raw LS

Type of isotherm	Parameters	Values
Langmuir	$q_{\max}$ (mg/g)	37.3
	$K_L$	0.0016
	$R_L$	0.4709
Freundlich	$1/n$	0.53
	$K_f$	0.6121
Temkin	$B_T$ (J/mol)	9.525
	$A_T$ (L/mg)	0.0114
Dubinin-Radushkevich (D-R)	$q_m$ (mg/g)	23.35
	$K$	-0.013
	$E$	6.21

der Waals force (Maji *et al.* 2008). In this study, the value of  $E$  obtained was 6.21 kJ/mol, which indicates that the adsorption is physical in nature.

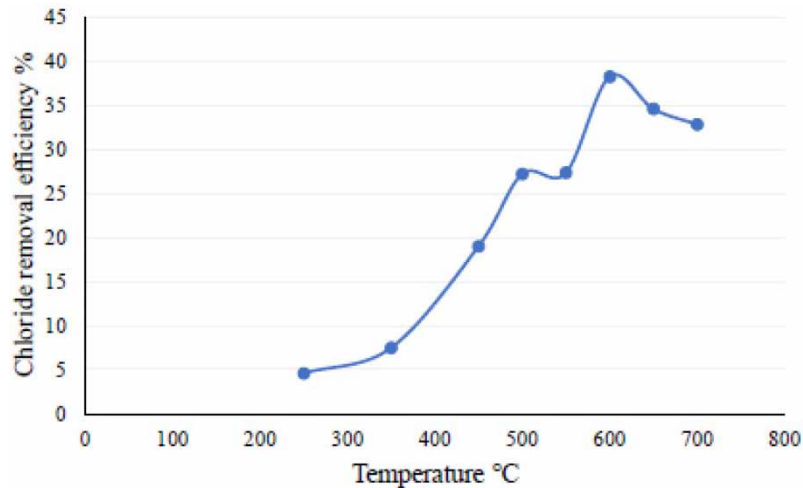
### 3.3. Effect of temperature on LS in removing chloride content

To find out the effect of burning temperature on LS for preparing filter media, LS was burnt at eight different temperatures (250 °C, 350 °C, 450 °C, 500 °C, 550 °C, 600 °C, 650 °C, 700 °C). By observing the effect of temperatures on the samples, the optimum burning temperature was found. Figure 2 exhibits the adsorption efficiency of LS1, LS2, LS3, LS4, LS5, LS6, LS7, LS8 samples for ten days of filtration. The saline water with an initial chloride concentration of 900 mg/L was passed through the respective filter media having 1 inch (2.54 cm) thickness. Then the average values of removal efficiencies are plotted against different temperatures in Figure 3.

**Figure 2** | Chloride removal efficiency (%) of burned LS in column adsorption.

According to the removal efficiencies shown in Figure 2, it can be concluded that LS6 shows maximum adsorption capacity of about 38.233%. From Figure 3, it is observed that from 250 °C to 500 °C burning temperature, the chloride removal efficiency of LS samples increases gradually with the increase of temperature. Then the percentage of chloride content is almost identical from 500 °C to 550 °C. It again increase gradually and reaches its maximum value (38.23%) at 600 °C for 1 inch thickness and further decreases its chloride removal efficiency corresponding to increase in temperature. Similar result has been obtained in removing fluoride ion using thermally treated laterite soils (Gomoro *et al.* 2012).





**Figure 3** | Chloride removal efficiency (%) of LS samples at different temperatures.

### 3.4. Effect of temperature on SLS in removing chloride content

SLS was burnt at the optimum temperature of 600 °C to compare with LS sample. Table 6 exhibits the adsorption efficiency of SLS with 1 inch thickness for the same initial chloride concentration (900 mg/L).

According to Table 6, the average value of removal efficiency of chloride content for ten days is 44.54% using thermally treated SLS at 600 °C. This value is greater than that of LS sample (38.23%). As iron oxide plays a vital role for adsorption in LS soil, SLS containing 25% iron oxide shows better performance on chloride adsorption than LS6 containing only 7% iron oxide.

**Table 6** | Chloride removal efficiency of SLS

Days	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Avg
Removal efficiency (%) of SLS	46.6	44.3	43.0	43.76	41.93	45.2	46.29	42.8	44.3	47.25	44.54

## 4. CONCLUSIONS

The contamination of natural water due to salinity is an environmental problem that has been frequently discussed by several sectors of society. Therefore, it is essential to devise an effective and feasible technology to remove the saline ions from water. LS is an extremely versatile material with a high surface area, thus an effective adsorbent. Low capital cost, being suitable for both batch and continuous processes, and applicability at very low concentrations are the major distinctive advantages of LS adsorption process.

The effect of raw materials and thermal treatment of LS on adsorption capacity has been analyzed and the following major findings can be concluded.

- Three initial concentrations of 500 mg/L, 700 mg/L and 900 mg/L were considered and the effective concentration was 900 mg/L.
- The optimum burning temperature for thermally treated LS in removing chloride ion content from saline water was obtained to be 600 °C. LS burned at 600 °C (LS6) showed the maximum chloride removal efficiency (38.23%) among all LS samples.
- Moreover, SLS burned at 600 °C gives greater chloride ion removal efficiency (44.54%) than LS6.
- From the overall findings, SLS, thermally treated at 600 °C was observed as the most efficient adsorbent in removing chloride ions from water.

## FUNDING AGENCY

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## DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

## CONFLICT OF INTEREST

The authors declare there is no conflict.

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