# Profiting from Cooked Tea Leaves Waste in Eco-Friendly Method

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*Authors' contributions*

*This work is carried out in collaboration between both authors. Both Authors designed the study, wrote the protocol and wrote the first draft of the manuscript. Both authors read and approved the final manuscript.*

| *Method Article* |
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## ABSTRACT

**Aims:** The aim of this study is to investigate the applicability of cooked tea leaves waste (CTLW) to the removal of phosphorus pollutant from water using different design parameters by adsorption process.
**Study Design:** Environmental engineering.
**Place and Duration of Study:** This study was carried out in the department of environmental engineering, College of engineering, between March 2013 and November 2013
**Methodology:** The experimental adsorption unit composed from fixed bed column was conducted in order to test phosphorus removal from simulated synthetic aqueous solutions (SSAS). Effects of bed heights of the adsorbent media (cooked tea leaves waste), flow rates of (SSAS), solution pH, feed temperature and initial concentration values of (SSAS) on the phosphorus removal efficiency were investigated.
**Results:** The highest percentage removal of phosphorus from (SSAS) was 97.68%. Statistical model was achieved to find a mathematical equation connecting all parameters governing the percentage removal of phosphorus. The samples of (CTLW) remaining were applied as fertilizer for tomato harvest. The results show that the tomato was bloomed and gave greater weight crop.
**Conclusion:** The percentage removal of phosphorus was very sensitive to the variation of solution pH, initial concentration of (SSAS), feed temperature, feed flow rate and adsorption bed height. Finally, the use of (CTLW) is consider as eco-friendly method

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because in the first stage it can be used to remove of phosphorus from the water and in the second stage it can be used as a cheap fertilizer.

## 1. INTRODUCTION

In the concept of sustainability development, surface and groundwater must be preserved for future generation. Phosphorus is one of the pollutants which is capable to traverse the surface and ground water. The most important sources of phosphorus are the wastewaters containing detergents and concentrated agricultural activities including soil fertilization, feedlots, dairies, and poultry farms. Those nutrients (nitrogen and phosphorus) are one of the leading causes of water quality problems in rivers, lakes, and estuaries, resulting in eutrophication, increased fish mortality and outbreaks of microbes [1]. At the current rate of exploitation, the high quality portion of the resource of mined rock phosphate will be largely depleted in less than 100 years, if another source of high-quality phosphate is not identified. This will place a burden on agricultural production, because lower grade phosphates will have to be used, significantly increasing production costs [1,2]. Phosphates recovered from wastewater plants might be a viable source of industrial raw material for manufacture of phosphate fertilizers. Currently, such phosphorus is regarded more as a contaminant than a resource [2]. This perspective has started to change in recent years [2]. The most common approach for removing phosphate from wastewater is precipitation with metallic salts because phosphate makes a precipitate with calcium, magnesium, or iron ions [3]. However, in the case of a lower concentration of phosphate, the removal of phosphate is difficult and more sludge is produced [3]. Studies of phosphorus immobilization by adsorption have been attracting more and more research interest in recent years for the saving of phosphate resources and the recycling of phosphate. Some researchers focus on activated alumina, iron-based compounds, layered double hydroxides, hydrotalcite, yttrium carbonate, and polymeric ligand exchanger while others put more attention on natural materials and their modifications, such as boehmite and goethite [4], and even solid wastes, such as fly ash, blast furnace slag alum sludge and cooked tea leaves waste [5-7]. The aim of the present work is to study the possibility of using cooked tea leaves waste (CTLW) for removing of phosphorus from simulated synthetic aqueous solutions (SSAS), and benefit from the cooked tea leaves waste residue in eco-friendly method.

## 2. EXPERIMENTAL DETAILS

### 2.1 Materials

#### 2.1.1 Cooked tea leaves waste (adsorbent media)

Cooked tea leaves waste (CTLW) was collected from local market in Baghdad city. The CTLW was washed three times with excess double distilled water and boiled to remove dust, impurities and other fine dirt particles that may be attached to the CTLW. The washed CTLW was then dried at 60°C for 24 hours.

### 2.1.2 Stock solutions

In order to avoid interference with other elements in wastewater, the experiments in this study were carried out using simulated synthetic aqueous solution (SSAS) of different phosphorus concentrations. A 1000 mg/l stock solution of phosphorus was prepared by dissolving 4.5 gram of Mono-potassium phosphate ($KH_2PO_4$) in one liter of double distilled water. All solutions used in the experiments were prepared by diluting the stock solution with double distilled water to the desired concentrations for the experimental work of this investigation. The phosphorus concentrations were measured using spectrophotometer thermo – genesys 10 UV, USA.
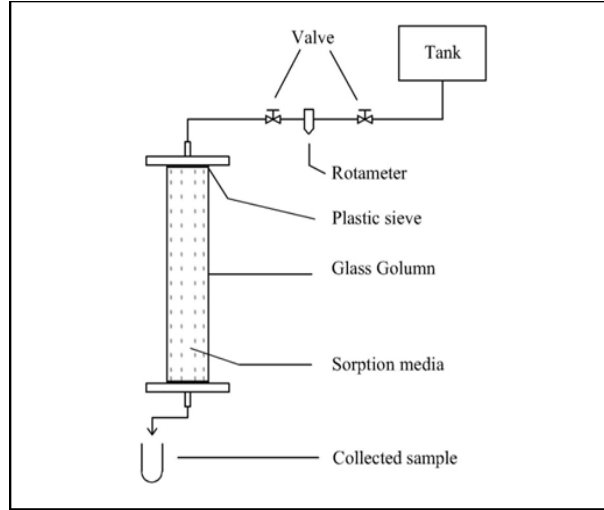
## 2.2 Sorption Unit

The experimental adsorption unit composed from fixed bed column was conducted in order to test phosphorus removal from SSAS with the various bed heights of the adsorbent media of CTLW using different flow rates of SSAS of phosphorus at various pH. The pH value was adjusted using 0.1 N NaOH and 0.1 N HCl solutions. A schematic representation of the sorption unit is shown in Fig. 1 where the flow direction is downward by gravity. The sorption unit consists of two glass container of SSAS of phosphorus, one for inlet and another for outlet each of (1 liter) capacity. Glass column has 2.54 cm diameter and 150 cm height. The sorption column packed with adsorbent media to a height of (10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 cm) supported from the top and the bottom by glass hollow cylinder layer, each cylinder have (0.5 cm diameter, 0.1 cm thickness and 1 cm long). Before starting the run, the packed bed sorption column was rinsed by double distilled water down flow through the column. The CTLW is packed in the column to the desired depth, and it was fed by mixing the media of CTLW with distilled water in order to avoid the formation of air bubbles inside the media. After the packed bed sorption column was accommodation and putting the required amount of adsorbent media, the adsorption process started by allowing the simulated synthetic aqueous solutions (SSAS) of required concentration and pH down flow through the sorption column from inlet container by gravity at a precise flow rate in experiment which is adjusted by the valve Fig. 1. To determine the best operational conditions, the experiments were carried out at a temperature between (5-55°C), various pH values which are (1-8) and initial feed concentrations of SSAS of different phosphorus which are between (1-100) mg/l each one alone and at different flow rates which are between (5-100) ml/min for phosphorus initial feed concentration. Outlet samples for each experiment were collected at every 10 minutes from the bottom of packed column and the unadsorbed concentration of phosphorus in SSAS was analyzed by spectrophotometer.

## 3. RESULTS AND DISCUSSION

The ability of cooked tea leaves waste (CTLW) to remove phosphorus from simulated synthetic aqueous solutions (SSAS) is a function of many parameters such as initial concentration of SSAS, pH of SSAS, bed height of adsorbent media CTLW (l), flow rates of SSAS (F), temperature of SSAS ($T_f$) and time of treatment (t). Therefore, it was important to study the effect each parameters separately to describe the rate and pattern of phosphorus removal. In this context, the percentage removal of phosphorus decreases with increasing initial concentration ($C_o$) of SSAS Fig. 2. This can be explained to the fact that the initial concentration of phosphorus has a restricted effect on phosphorus removal capacity. Simultaneously, the adsorbent media has a limited number of active sites which would have become saturated at a certain concentration. This leads to an increase in the number of

phosphorus molecules competing for the available functions groups on the surface of adsorbent material [8]. The highest percentage removal of phosphorus was 97.86 % at initial phosphorus concentration of 1 mg/l.



**Fig. 1. Experimental adsorption unit**
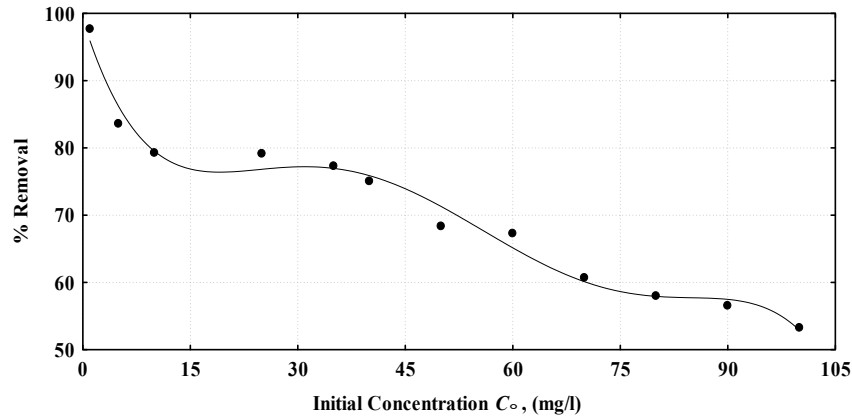


**Fig. 2. Effect of initial concentration ($C_\circ$) on the percent removal of phosphorus @ $T_f$ =55°C, I = 1 m, pH=8, t=60 min and F=5 ml/min**
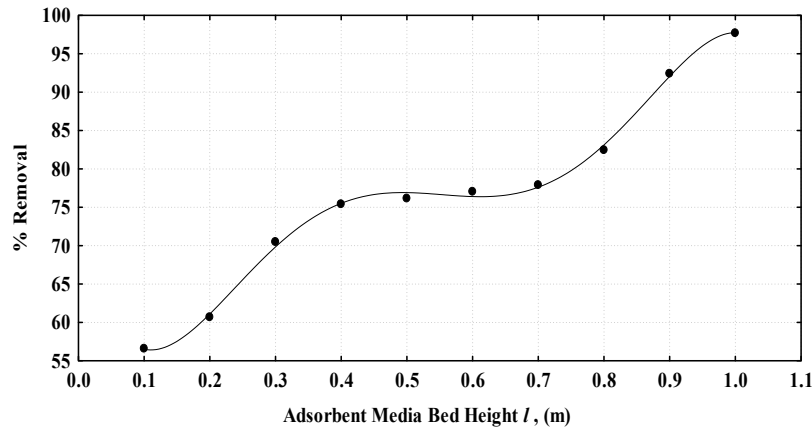
The percentage removal of phosphorus increases at any increase in the pH of SSAS of phosphorus Fig. 3. This increase can be attributed to the protonation of CTLW surface. The protonation of CTLW surface caused by the species of phosphorus in aqueous solution exists in the form of H3PO4, H2PO4−, HPO42−and PO43−, which form a buffer solution in the aqueous solution. When phosphate ions are adsorbed on the CTLW, the H+ is released from the solution, especially when the pH of the solution is low. As pH increases, there is competition between hydroxide ion ($OH^-$) and phosphate ions in the aqueous solution, the former being the dominant species. The net positive surface potential of sorbent media decreases, resulting in a reduction the electrostatic attraction between the (sorbent) phosphate ions species and the (sorbate) adsorbent material surface (CTLW), with a

consequent reduced sorption capacity which ultimately leads to decrease in percentage adsorption of metals ion. In the other hand, the adsorption of phosphorus ion can be explained by ion-exchange mechanism of sorption in which the important role is played by functional groups that have cation exchange properties. When pH of SSAS decreases, hydrogen ion increases in the solution. At the pH increases, the ligand functional groups in adsorbent media (CTLW) would be exposed, increasing the negative charge density on the adsorbent material surface, increasing the attraction of phosphate ions with positive charge and allowing the sorption onto adsorbent material surface [8].
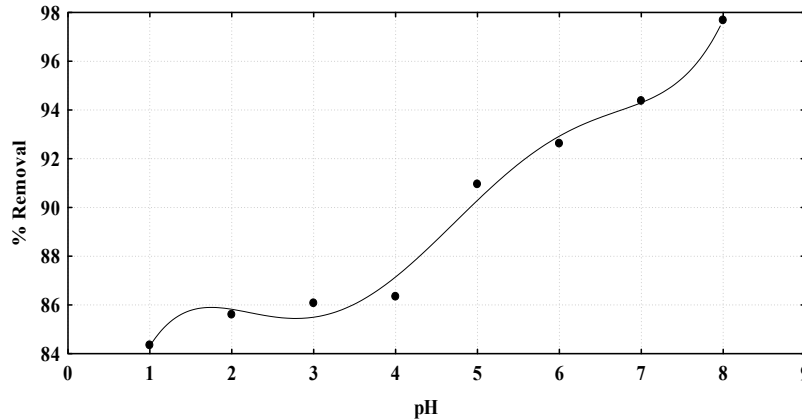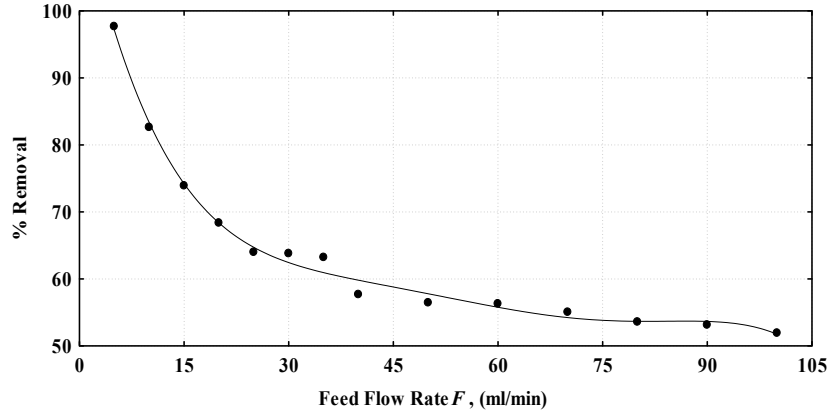


**Fig. 3. Effect of pH on the percent removal of phosphorus @ $C_o$= 1 mg/l, $T_f$ =55°C, l = 1 m, t=60 min and F=5 ml/min**

The effect of the adsorbent media bed height on the phosphorus removal is presented in Fig. 4. It can be shown that increasing of adsorbent media bed height leads to an increase in the percentage removal of phosphorus. The increase of bed height (l) means increase in the amount of adsorbent media of CTLW, thus increase in the surface area of adsorbent material and in the number of active sites of the adsorbent material surface, consequently increase in the phosphorus removal capacity on CTLW. This lead to an increase in the ability of adsorbent media to adsorb greater amount of phosphorus from SSAS at different initial concentrations and ultimately the percent removal of phosphorus increases.



**Fig. 4. Effect of adsorbent media bed height (l) on the percent removal phosphorus @ $C_o$= 1 mg/l, pH=8, $T_f$ =55°C, t=60 min and F=5 ml/min**

The results illustrated that when the flow rate of SSAS of phosphorus increases, the percentage removal of phosphorus decreases Fig. 5. This may be due to the velocity of solution in the column packed with the adsorbent media of CTLW which increases with an increase of flow rate. Therefore, the SSAS of phosphorus resides in the column for a shorter time, thus the adsorbent media uptake low amount of phosphorus from SSAS of phosphorus for high flow rate, consequently decrease in the percentage removal of phosphorus.



**Fig. 5. Effect of aqueous solution flow rate (F) on the percent removal of phosphorus @ $C_{\circ}$ = 1 mg/l, pH=8, $T_f$ =55°C, l = 1 m and t=60 min**

The results demonstrated that when the temperature increases, the percentage removal of phosphorus increases Fig. 6.The effect of temperature is fairly common and increasing the mobility of the acidic ion [1,8]. Furthermore, increasing temperatures may produce a swelling effect within the internal structure of the adsorbent media enabling phosphorus ions to penetrate further. It was indicated that phosphorus adsorption capacity increased when feed temperature increases from 5 to 55°C. This effect may be due to the fact that at higher temperature an increase in active sites occurs due to bond rupture.
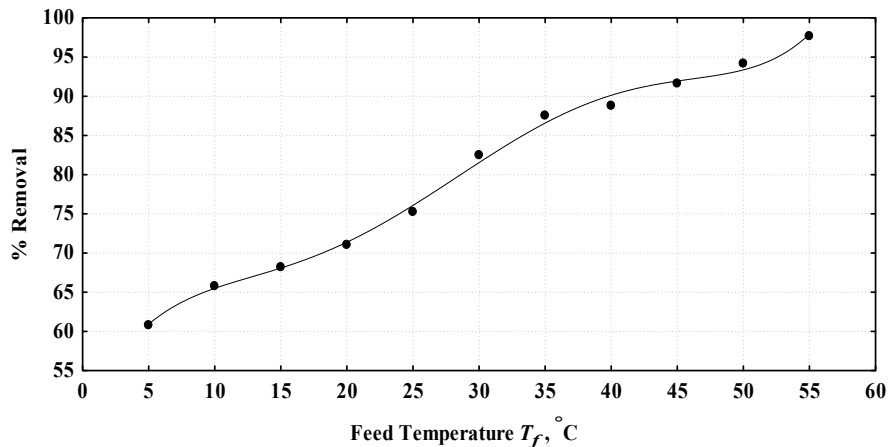


**Fig. 6. Effect of feed temperature ($T_f$) on the percent removal of phosphorus @ $C_{\circ}$= 1 mg/l, pH=8, l = 1 m, t=60 min. and F=5 ml/min.**

It can be seen from Fig. 7, the percentage removal of phosphorus increases with an increase in the treatment time of SSAS of phosphorus. When the treatment time of SSAS of

phosphorus increase and the velocity of SSAS in the column packed with the adsorbent material was remaining constant, the solution spends longer time and the adsorbent material uptake more amount of phosphorus from SSAS, therefore the percentage removal of phosphorus from SSAS increases [1,8].
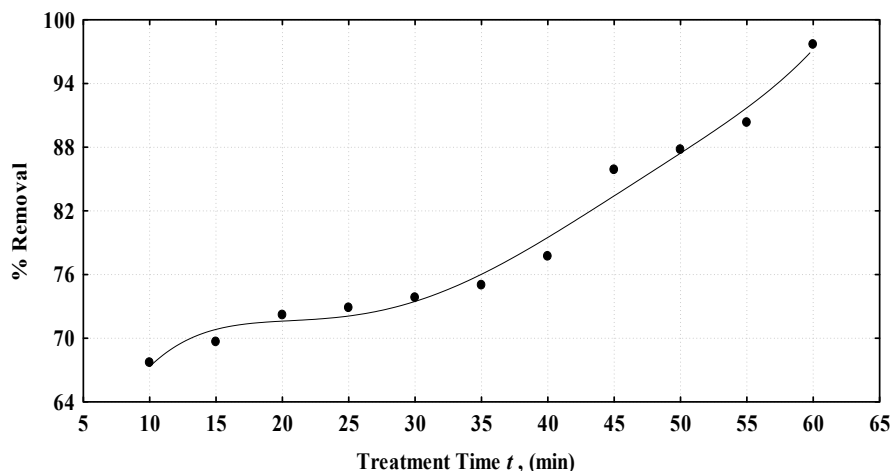


**Fig. 7. Effect of treatment time (t) on the percent removal of phosphorus @ C$_\circ$= 1 mg/l, T$_f$ =55°C, pH=8, l = 1m, and F=5 ml/min.**

## 4. STATISTICAL MODEL

A statistical model was carried out on the experimental results obtained from this study. Regression Analysis and π Theorem was adopted to maintain a relation between the percent removal of phosphorus and the feed temperature, solution flow rate, pressure, pH of feed solution, initial concentration of phosphorus, adsorbent media CTLW bed height, treatment time and column diameter. These relations are shown in equation (1) below, which has a correlation coefficient (R$^2$) equal to 0.9938.

$$\%R = 1.64 \times 10^{-6} \left(\frac{\rho_{sol}}{C_o}\right)^{0.2594} \times \left(\frac{l}{d}\right)^{0.2371} \times \left(\frac{T_f\, C_{Psol}\, t}{\eta}\right)^{0.1887} \times \left(\frac{K_{sol}\, T_f}{\mu}\right)^{0.1472} \times \left(pH\right)^{0.0145} \qquad (1)$$

Where;

$\%R$  : Percentage removal of phenol from SSAS

$\rho_{sol}$  : Density of SSAS (kg/m$^3$)
$C_o$   : Initial concentration of phenol (kg/m$^3$)
 L   : Adsorbent material bed height (m)
D   : Initial diameter of sorption column (m)
$T_f$   : Feed temperature (K)
$C_{Psol}$ : Heat capacity of SSAS (kJ/kg.K)
T    : Treatment time (s)
$\eta$   : Kinematic viscosity (m2/s)
$K_{sol}$  : Thermal conductivity of SSAS (W/m.K)
$\gamma$    : Surface tension ((N/m)
U   : Velocity of SSAS (m/s)

## 5. UTILIZATION OF IRAQI COOKED TEA LEAVES WASTE AFTER USES

Large amount of cooked tea leaves waste lingered after use in the removal of phosphorus from SSAS as explained above. This amount of CTLW can be used as a fertilizer for tomato crop as follows: CTLW waste was segregated and classified according to the degree of contain phosphorus and utilization from these remaining samples as a raw material in synthesis of a fertilizer for tomato crop. The samples give different ratios of phosphorus to CTLW. The ratios were between (0.01 to 0.1 wt %) for phosphorus. CTLW lingered with different ratios was firstly crashed to make powder, dissolved the powder in water completely and then irrigated tomato crop by this solution. Results show that the Tomato crop bloomed and gave higher weight crop (17.235 wt %) than tomato irrigated with fresh water.

## 6. CONCLUSIONS

It can be concluded that CTLW is capable to remove phosphorus from SSAS using fixed bed adsorption unit. Therefore, it could be recommended for removal of phosphorus from wastewater instead of other material because it is valid, cheaper, economical, simplicity for using, and has a high ability to adsorb phosphorus, and finally can be used in another benefit uses. Results show that the percentage removal of phosphorus increases with a decrease of flow rate of SSAS and initial concentration of phosphorus. On the other hand, any increase in the solution pH, treatment time, temperature and the height of adsorbent material CTLW leads to an increase in the percentage removal. It can be prepared a good fertilizer for tomato crop from the residual samples of CTLW that adsorb phosphorus from SSAS. Therefore, the polluted waste can be removed in economic and eco-friendly method.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1.  Tang YK, Tong ZF, Wei GT, Li ZM, Liang DW. Removal of Phosphate from Aqueous Solution with Modified Bentonite. J Process Engineering. 2006;6(2):312−319.
2.  Debashan LE, Bashan Y. Recent Advances in Removing Phosphorus from Wastewater and Its Future Use as Fertilizer (1997−2003). J Water Resources.
3.  2004;38:4222−4246.
4.  Puckett LJ. Identifying the Major Sources of Nutrient Water Pollution. J environmental science control. 1995;29(9):408−414.
5.  Li L, Stan forth R. Distinguishing Adsorption and Surface Precipitation of Phosphate on Goethite ($\alpha$−FeOOH). J Colloid Interface Sci. 2000;5:12−21.
6.  Cheung KC, Venkitachalam TH. Improving Phosphate Removal of Sand Infiltration System Using Alkaline Fly Ash. J Chemosphere. 2000;41:243−249.
7.  Johansson L, Gustafsson JP. Phosphate Removal Using Blast Furnace Slags and Opoka-mechanisms. J Water Resources. 2000;34(1):259−265.
8.  Huang SH, Chiswell B. Phosphate Removal from Wastewater Using Spent Alum Sludge. J Water Science Technology. 2000;42:295−300.

9.      Abbas M N. Phosphorus Removal from Wastewater Using Rice Husk and Utilization from the Waste Residue, under publishing.

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